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Electricity access in Mozambique: A critical policy analysis of investment, service reliability and social sustainability

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ABSTRACT

Mozambique is a resource-rich energy hub, yet rural community access to electricity remains low, and urban centres suffer poor service quality. Aging transmission infrastructure, consumer growth, erratic generation, and extreme weather events exacerbate power cuts and oscillations that disrupt household activities and damage appliances. Through qualitative critical policy analysis of household (n = 120) and public/private stakeholder (n = 87) interviews in the four largest cities of Mozambique (Maputo, Matola, Beira and Nampula) we assess diverse perspectives on reliability, affordability, and investment/revenue-raising to meet SDG7 to provide clean, modern energy services for all. We find that although electricity tariffs commonly exceed household budgets, they remain politicised and are not cost-reflective – putting the national utility *Electricidade de Moçambique* E.P. (EDM) into growing debt and imminent insolvency, hindering its ability to ensure reliable, quality and affordable services. We recommend unbundling the electricity sector to enable EDM and the energy regulator (*Autoridade Reguladora de Energia* – ARENE) to be managed independently, and reducing state-induced inefficiencies that limit their ability to make transparent and fair decisions on tariffs, their institutional capacity and performance, and the development of the power sector.

1. Introduction

Electricity access is a cornerstone of global socio-economic development, poverty reduction and human wellbeing [1]. Electricity provides multiple benefits, from improved manufacturing capability, telecommunications and business development opportunities, to domestic lighting and refrigeration that directly improve employment, income, social networking opportunities, healthcare, and night-time education opportunities [2]. Recognition of the socio-economic development value of energy service improvements has led to a range of policy initiatives, notably the Sustainable Energy for All (SE4All) platform aimed at providing 'modern energy services' targeted at underserved and geographically remote rural communities where grid connections are limited or non-existent. Such interventions are vital for many rural communities, however, for urban and peri-urban residents connected to centralised grid networks other challenges electricity access remain – particularly relating to consistent service reliability, affordability and quality [3,4]. These factors remain major barriers for economic growth and development for many parts of sub-Saharan Africa (SSA) [5].

For many SSA countries, the cost of electricity service provision and its relationship to public expenditure and revenue-raising remain key development concerns. Yet, electricity tariffs are often not cost-reflective – they do not cover the full cost of infrastructure investment plans, maintenance costs, technology upgrades and power purchases. However, tariffs in SSA countries commonly rank among the highest in the world[1], imposing substantial constraints on socio-economic development and quality of life [7]. An estimated 57% of African households

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[1] e.g. the electricity price for residential users in Rwanda (0.259 USD/kWh), Mali (0.239 USD/kWh), and Burkina Faso (0.229) costs more than the average global electricity price (0.140 USD/kWh), and more than in USA (0.149 USD/kWh), Netherlands (0.185 USD/kWh) and France (0.219 USD/kWh) [6].

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and businesses experience electricity reliability issues such as frequent, unpredictable power outages lasting for hours or days [4,7]. Some SSA countries with the largest electricity access deficit, such as Kenya, Uganda and Mozambique, experience at least one power outage per week [8].

Electricity reliability and affordability barriers will likely persist, or worsen, under conditions of rapid population growth, urbanization, growth in production and manufacturing, leading to changing patterns of electricity demand [4]. Efforts by states and energy planners to increase electricity connections needed to achieve the UN Sustainable Development Goal 7 (SDG7) to "ensure access to affordable, reliable, sustainable and modern energy for all," may paradoxically exacerbate these barriers [3]. For many households with limited or no access to electricity, domestic energy needs are often met by candles or kerosene lamps for lighting, and fuelwood or charcoal for cooking [9]. The latter is associated with deforestation and biodiversity loss. Moreover, smoke produced by black-carbon fuels contributes to negative health outcomes due to poor indoor air quality, including cancer, respiratory and pulmonary diseases [10,11]. Actions towards SGD7 therefore have the potential to meet other environmental security, health and social equity goals for the poorest communities.

Harnessing the benefits of electrification requires commercial and domestic energy security, defined here as the supply of energy that is sufficient to meet personal needs, and is of good quality, i.e., reliable, affordable and at a stable price [12], whilst also stimulating low-carbon investment and decarbonisation efforts. Despite significant progress towards meeting SDG7, Africa accounts for up to 70% of the 789 million people globally without access to electricity [13]. While progress towards SDG 7 is often measured by counting grid connections as a proportion of total population, such an approach overlooks the quality, reliability and impacts of service provided [3,4]. Use of these binary measures renders the analysis incomplete. Emphasising quantitative measures of electricity access policy success obfuscates the socio-economic impacts of unreliable and costly electricity on households, and the role of appropriate policy and regulatory measures in ensuring operational efficiency and the economic sustainability of utilities.

In this empirical study of energy policy in Mozambique, we ask: how do stakeholders experience and respond to the ongoing challenge of electricity access, reliability, affordability, and investment/revenue-raising? Through qualitative analysis of the policy landscape, we address a research gap that links diverse experiences of energy networks with a broader assessment of energy sector reform. At the national scale, Mozambique is a critical case study of SSA state energy development – it is rich in renewable (hydro, solar, geothermal and tidal) and non-renewable (gas and coal) energy resources with potential to generate 187 GW of electricity. Mozambique has higher electricity generation potential relative to other southern African countries [14,15], with potential to become a regional energy hub, providing opportunities for investment and rapid socio-economic development [14,15]. However, though the domestic electricity sector has been subject to extensive institutional and regulatory reform over the past two decades, Mozambique's exploitation of energy resources for domestic use remains limited and unevenly distributed [14]. Equally, reliable and sustainable energy access (particularly in rural areas) remains relatively low compared to neighbouring countries (lower than South Africa, Tanzania, Zimbabwe and Zambia) [13], while urban centres suffer poor service quality. Indeed, Mozambique ranks 114th out of 137 countries for the quality of electricity supply [16]. Moreover, Mozambique is financially incapable of developing new electricity infrastructure. Excessive financial risk factors (including rent-seeking, weak institutional capability and governance failures) associated with developing electricity infrastructure make investment unattractive to private sector actors, further inhibiting the supply of affordable and reliable electricity [5]. Together, these factors have contributed to the ongoing revision of the national regulatory framework [16], which has been challenged by growing political uncertainty and unpredictable environmental conditions in recent years. Our research therefore speaks to a broader energy justice concern: that institutional support and capacity building are needed in order to deliver a fairer, more transparent and financially viable electricity system that supports the diverse needs of Mozambicans across rural, urban and peri-urban communities, under conditions of environmental stress, violent insurgency and political unrest.

2. Socio-technical challenges of electricity access in Mozambique

Contemporary energy policy in Mozambique is shaped by its political history, and socio-technical systems of energy provision that emerged at the end of Portuguese colonial rule in 1975. Mozambique's post-colonial development suffered a paucity of civil engineering, infrastructure and utilities expertise following the rapid departure of thousands of Portuguese settlers [17]. Following independence, Mozambique suffered a devastating civil war (1977–1992) between the Frelimo-led (Mozambique Liberation Front) state and the apartheid South Africa-backed Renamo (Mozambique National Resistance) rebels. The 1980s saw economic paralysis, an overall decline in population and life expectancy, and rural-to-urban migration driven by conflict. Such conflict resulted in the destruction of vital infrastructure, including railways, telecommunication lines and transmission grids. The end of the war, however, marked the onset of a period of national economic growth and recovery, though this started from a very low baseline. Growth tapered-off in the early 2000s, despite investments in several extractive mega-projects, while the lack of inclusivity in the country's development path became clearer [18,19]. In parallel, the discovery of some of the world's largest gas reserves in the offshore Rovuma basin offered the prospect of economic transformation, reducing dependence on foreign aid, while institutional indicators across a broad range of measures deteriorated [18–20]. The extensive extractive sector's contribution to the wider economy has, however, remained low and elusive, particularly as most investments have not achieved the production or profitability point [19]. What the extractive sector has done is increase opportunities for rent-seeking among powerful business and state elites [21]. This has negatively influenced the country's overall productivity, as the economy has become less diverse and resilient over time, with economic policy strategy shifting with changes in the dominant source of foreign investments [19].

Mozambique has seen growing economic and social crisis. At the national economy scale, in 2016 a major hidden debt scandal emerged, as high-level government officials procured secret loans of over US$2 billion (equivalent to about 13% of GDP) to fund several non-existent business ventures [22]. The ensuing public debt crisis has limited government capacity to provide funds for social development programs amid austerity, inflation, and withdrawal of donor support. Thus, although Mozambique's industrial and commercial firms are expected to drive electricity demand growth [23], the long-term effects of the debt scandal on the country's credit rating and economic downturn has delayed many investments and reduced support to state budgets from key donors, including UK Aid and Sweden's SIDA [24].

Mozambique's industrial base remains dependent upon the export of natural resources and import of secondary goods [25]. Most citizen livelihoods involve informal, rural economic activities–predominantly small-scale subsistence agriculture [19]. The donor community exerts a heavy influence upon state economic development, with continued reliance on donors and external finance for state budget support. These conditions have contributed to low levels of state capacity, resulting in slow decision-making around assessment and approval of infrastructure projects, deficient public service delivery and stark inequalities in access to vital services, including healthcare and education. Approval processes involve a high level of associated costs through rent-seeking behaviour and deficient capacity to adequately prepare tenders, evaluate proposals, and manage documentation [5]. Moreover, infrastructure provision is poorly integrated with land management policy – with

processes of urbanization (and consequently electrification) often occurring through unregulated 'bottom-up' citizen-led processes of urban governance [20], meaning that stronger on-the-ground analysis of urban infrastructure use and service conditions is warranted.

Compounding such challenges are increasingly unpredictable climate conditions, political unrest and violence. Mozambique's populous coastal municipalities suffered electricity grid disruption in the central region following tropical cyclones in 2019 and 2021, due to flooding and high winds. The growing frequency of these cyclones and related environmental disasters will likely aggravate the challenges of electricity provision in Mozambique, particularly in coastal zones. Societal concerns over corruption under the current administration have allowed the Democratic Movement of Mozambique (MDM) to emerge as an opposition power centre in the central and northern regions. Resurgent violence between Frelimo and a splinter group of Renamo (former rebels and now the main opposition party) has also plagued the central region. Skirmishes (principally 2013–2016), emerged in part due to an incomplete decentralization process. Demands for provincial autonomy were unmet by the ruling Frelimo party, thus exacerbating political fragmentation [26]. More recent conflict has emerged from nascent Islamic State-linked insurgency Ahlu Sunnah Wa-Jama (ASWJ) in gas-rich Cabo Delgado province in the far north. The humanitarian crisis caused by violence is disastrous. At the time of writing there are 2800 reported casualties, of which half are civilians, and 700,000 displaced people [27]. Vulnerabilities within infrastructure systems across the northern province are thus further weakened by violent conflict and mass internal displacement, stimulating a complex welfare crisis.

Against this broader socio-political and economic background of debt, environmental change and political conflict, Mozambique has relatively low levels of electricity access, with approximately 20 million (approximately 65%) inhabitants lacking a reliable source of electricity [13,28]. For the 70% of the population living in rural communities, access rates remain around 6% [15]. With a projected population growth of 28% by 2030 [28], the Government of Mozambique (GoM) has set ambitious targets of achieving 50% access to electricity in 2023 and universal access by 2030 through (mostly) on-grid and (to a lesser extent) off-grid connections [15]. Progress towards this target is subject to multiple socio-political and economic constraints. First, are the aging transmission and distribution networks, shaped by the colonial and post-independence political economy, including the dependence on and geographic proximity to regionally-dominant South Africa. Ongoing power export agreements between colonial-era Portugal and South Africa, involving the siting of power transmission lines to facilitate these export flows [29], limit access capability for domestic use. Second are the unfavourable market conditions for new generation and transmission projects that are viewed as high risk by many investors [23]. Third are the dispersed settlement patterns of rural communities, often linked by low-density road networks. Low population density and high dispersal represent additional costs to the national public electricity utility, *Electricidade de Moçambique E.P.* (EDM), for providing 'last mile' access. Moreover, rural energy users experience high electricity prices relative to income levels [11]. Together these socio-political and economic constraints are discussed below.

2.1. EDM's operational challenges

Mozambique's energy landscape includes a diverse array of energy generation sources and market interactions between private suppliers, state-owned utilities and regional export markets. The national system operator EDM was established after independence in 1977, as a vertically-integrated, state-owned company, and its remit includes transmission, distribution, commercialization, and some power generation [15]. Due to its limited generation capacity, EDM buys 88% of its total electricity needs from Cahora Bassa Hydroelectric dam (*Hidroelectrica de Cahora Bassa* – hereafter HCB), also a state-owned company, and other Independent Power Producers (IPPs) [15]. EDM also trades electricity within the Southern African Power Pool (SAPP) [15]. EDM made important gains in extending access since the late 1990s-early 2000s period, when the GoM initiated its grid extension program, supported by donors, following the civil war and economic and political liberalization [14]. However, EDM's investment in electricity systems is subject to ongoing financial constraints [24] (discussed below) and is limited by the broader national political and economic instability, including increases in an already high level of inequality, growing social polarization and a resurgence of regional and ethnic identity claims [26]. Collectively, these political, economic and institutional factors create an atmosphere of uncertainty and endemic crisis, discouraging investment in much-needed energy infrastructure, and exacerbating energy poverty [5].

EDM faces two primary operational challenges, namely revenue-raising and balancing the needs of large-scale energy users with domestic users at peak load [30]. The latter is due in part to aging energy infrastructural assets and low generation capacity, causing frequent brownouts, and breakdowns [24,31]. In 2019, EDM registered 7498 power interruptions with an average duration of 73 min [32]. Mozambique has one of the highest electricity tariffs in Southern Africa (US$ 10.58 cent/kWh) (see Fig. 1), a situation harmful to the 'small pocket' (*bolso pequeno*) of many residential users. National poverty remains high, with 46.3% of the population living on less than US$1.90 a day [19] to sustain a family of around 5 members [33], amid rising living costs and worsening living conditions [19]. Moreover, the informal nature of poorer people's livelihoods means that their income is often unstable and uncertain. Energy poverty emerges when low-income countries experience high electricity costs, or when subsistence consumption absorbs over 10% of households' budgets [34]. Yet although already unaffordable to many consumers, EDM's tariffs are not fully reflective of operational and investment costs, hindering its ability to withstand operational cost shocks, ensure reliable and quality services, and to mobilize funds for the infrastructure expansion needed to fulfil its commercial and social mandates to provide electricity for all [15,24]. In this respect, EDM shows similarities to many other SSA utilities listed in Fig. 1.

Energy companies, policymakers and public authorities commonly overlook the relationship between household social practices and energy consumption [3,4]. Yet, electricity networks are *socio-technical systems* involving complex interactions between humans, social norms and values, macro-economic conditions and broad-based political structures [36]. Electricity access in Mozambique, as in many other least developed countries and economies in transition, must therefore be understood as a complex and multi-scalar problem, in which an array of exogenous and endogenous factors exacerbates existing energy poverty and injustices (see, e.g. [37]).

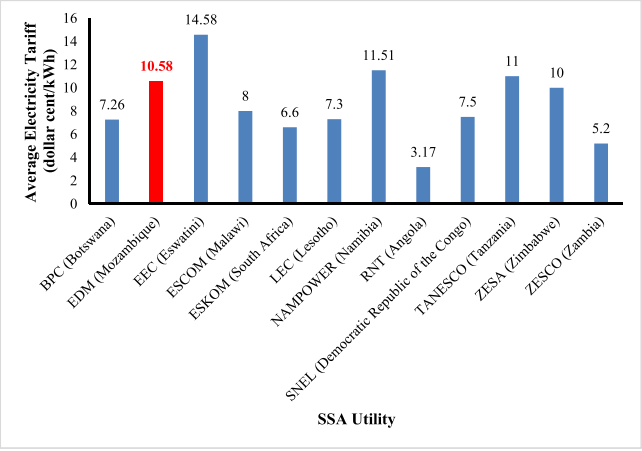

Fig. 1. Average regional electricity tariff (dollar cent/kWh) (Source: [35]).

The GoM is increasingly designing more flexible policies and market-oriented reforms to address EDM's performance challenges and overall power sector development. Similar to many SSA countries, power sector reform in Mozambique remains incomplete and under state dominance [37,38]. The reform process has been slow, and the sector continues to have a vertically-integrated structure, allowing some private sector participation for electricity generation [37,38], and lacking a strong and transparent regulator [23] - a reflection of the political-economy of the energy sector governance. There are, however, good examples of vertically-unbundled structures, such as Uganda, Kenya and Ghana [37,38].

The challenges of sustainable energy access are multifaceted and complex, and better understanding of it requires empirical analysis of the underlying policy and institutional frameworks in which decisions are made. Our aim is to enhance this understanding through qualitative inquiry, focusing upon the relationship between stated policy goals towards universal electrification advanced by key political and industry actors, and the challenges faced by Mozambican society, including imbalances in power relationships, inculcated by such strategies [39]. This is examined through viewpoints from a range of stakeholder- participants on the *socio-technical* nature of electricity access, security and reliability across four major cities in Mozambique, and how competing interests can be accommodated to generate policy solutions across such stakeholder networks. Within this context, we focus upon the challenges of efficient energy service provision through examining EDM's efforts to achieve the twin goals of revenue raising and fulfilling its social mandate. Then, we examine what impacts these efforts have upon domestic electricity reliability and affordability, low carbon development, and investment planning.

3. Background to the study sites

Field research was conducted between November 2019 and March 2020 in four major Mozambican cities (Fig. 2): 1) the capital, Maputo, which accounts for 3.72% of the population (1.12 million), 2) Matola 5.35% (1.61 million), 3) Nampula 2.47% (743,125) and 4) Beira 1.97% (592,090) [28,33]. Maputo and Matola are located in the southern region (Maputo Province), Nampula in the northern region (Nampula Province), and Beira in the central region (Sofala Province). Maputo, the national capital, has a 98% electrification rate (324,377 domestic customers) [32,40] – the highest in the country, reflecting its dominance through concentration of resources and investment [15,41]. Matola is a rapidly growing satellite city [42] that recently superseded Maputo in population size, creating new challenges surrounding energy and infrastructure provision amid urban expansion. With an 80% electrification rate (338,007 domestic customers) [40], Matola hosts the country's largest industrial parks, including Beluluane Industrial Park, a free-trade zone with 40 major companies such as the Mozambique Aluminium Smelter (MOZAL) and the Matola Gas Company, among the largest firms in Africa (Interview, EDM-Matola, December 2019). Due to high electricity demand – accounting for roughly three-quarters of total electricity consumption in Mozambique [43] – Mozal receives electricity imported from Eskom through the Mozambique Transmission Company (MOTRACO), a joint venture between EDM, Eskom, and EEC (Eswatini Electricity Company), founded in 1998 [44]. Both Matola and Maputo are located less than 100 km from the power sources (gas-fired power plants).

Nampula is the economic hub of the northern region, situated in close proximity to emerging resource extraction zones (e.g., Moma heavy sands project, operated by the Irish company Kenmare). It is also home to the Maratane refugee camp[2], and is accessed by an

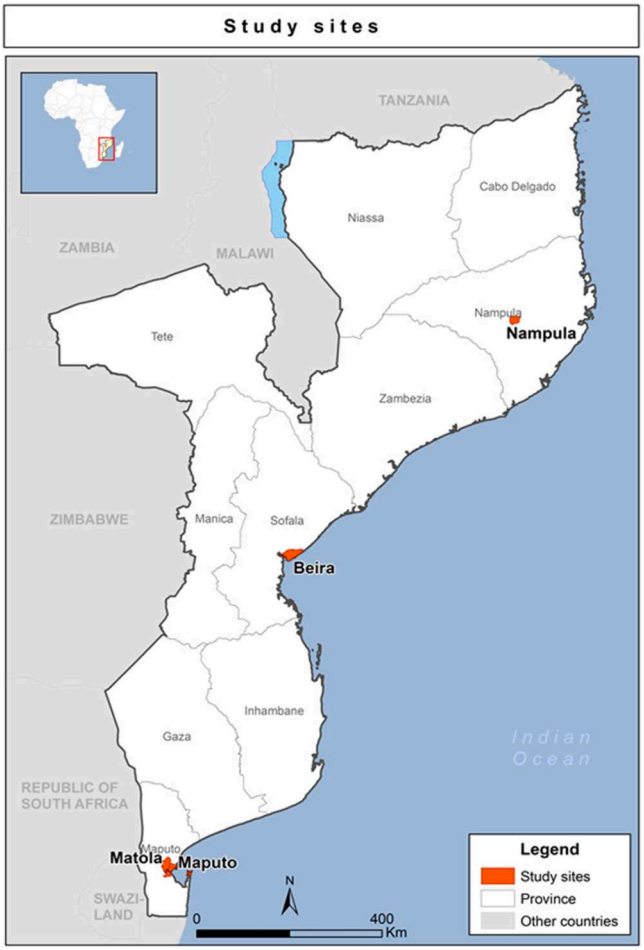

Fig. 2. Location of the four study sites in Mozambique.

interprovincial railway service to Cuamba district in Niassa province, known as the Nacala corridor. Nampula has an 89% electrification rate (172,310 residential users) [46], and its electricity is generated by HCB (731kms from Nampula city). However, since 2016, it has also benefited from a floating power plant (Karpowership) docked at the Nacala port (148 km from Nampula city), owned by the Turkish firm Karadeniz Holding [47]. Karpowership intended to export electricity to Zambia's utility (ZESCO), generating foreign exchange for GoM despite acute supply gaps in northern Mozambique. Due to non-payment from ZESCO, however, EDM has reversed the flow of power to supply northern Mozambique, providing much-needed back-up supplies of 125 MW, agreed until 2028 [47].

Beira has the second largest port in Mozambique, historically playing a strategic role for landlocked Zimbabwe and Malawi's access to seaports and international markets. It also anchors an important road and railway transit link, known as the Beira corridor, linking the port to interior regions of Mozambique and neighbouring states. Beira city is located 200 km from the power generation source, the Chicamba dam, built in the late 1950s, and has an 88% electrification rate (206,667 domestic users) [48]. Electricity users in the study sites experience frequent black-outs and power outages due to a lack of system resilience [30], yielding significant costs for consumers and the wider economy due to lost productivity. Table 1 shows that, from 2017 to 2019, the number of power interruptions has increased in each city while the duration has decreased (with the exception of Beira).

Despite a substantial increase in power interruptions, Nampula city has the lowest overall number and duration of interruptions. Matola and Maputo have registered the highest number of power interruptions due to the high numbers and spatial concentration of customers relative to

[2] The camp was opened in 2011 and hosts 9483 refugees and asylum-seekers, mostly from the Great Lakes and East and Horn of Africa, escaping war, persecution, mourning and suffering [45].

Table 1
Power interruptions registered in Maputo, Matola, Beira and Nampula city from 2017 to 2019 (Source: [32,48,49]).

Interruptions in distribution lines	City											
	Maputo			Matola			Beira			Nampula		
	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019
Total Interruptions	1150	1420	2019	1767	1844	2176	370	676	445	140	188	367
Total Duration (h)	1138.5	1090.7	1232.1	1655.5	1381.7	1636.9	388.7	435.3	305.6	171.3	200.5	324.4
Average duration (min)	99	77	61	94	75	75	105	64	69	122	106	88

generation capacity (see Fig. 3), despite having benefitted from the Power Efficiency and Reliability Improvement Project (PERIP) (running from 2018 to 2021) [50].

Beira has registered more power interruptions than Nampula, although less than in the previous year. Beira currently supplies its users through only one of two existing transmission lines. The city's substations are frequently overloaded, (Fig. 4), hindering system reliability and resilience. The other line remains non-operational (still to be repaired) due to destruction from tropical cyclone Idai, which struck in March 2019 near Beira causing widespread damage to housing, businesses and basic infrastructure. During post-Idai reconstruction, through support from the UN, the EU, the World Bank, African Development Bank and government assistance [52], EDM rebuilt most of Beira's vital infrastructure, including 800 km of medium-voltage lines; 600 km of low-voltage lines, and 47 transformers [32].

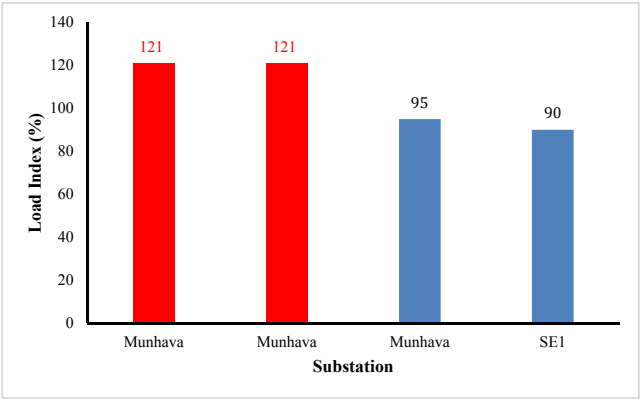

Fig. 4. Load index of critical substations in Beira city (Source: [48]).

4. Methodology

We conduct a critical policy analysis by drawing upon 207 semi-structured interviews (120 household-level interviewees and 87 public, private and donor-level stakeholders). Table 2 shows a breakdown of interviewed households and stakeholders' representatives per city. In each city, we randomly recruited representatives of households in six neighbourhoods (three peri-urban and three urban areas). Interviews were also conducted with EDM officials at both the directorial/managerial and technical/operational level through purposive sampling based upon job position as a selection criterion. A snowball sampling method was then used to recruit further interviewees both internal and external to the organisation including IPPs, other business and NGO stakeholders. Qualitative interview data is supplemented with field observations in each city, review of official documents, reports and policy briefs from relevant institutions in the energy sector, along with media sources (including TV, print and online newspapers and social media) to contextualise the broader policy landscape in which electricity system governance emerges.

Interviews were conducted in Portuguese, translated, transcribed, and then combined with secondary data. The complete dataset was coded using thematic analysis (TA) common to qualitative interpretation of policies, stakeholder experiences, perceptions and understandings [53]. It is based upon the identification and assessment of patterns of meaning (themes) within participant utterances with specific reference to the contested social power relationships emerging through electrification policy strategy. The TA of interviewee utterances is contextualised in relation to the broader electricity system statistics, print and other media discourses emerging from the coding process. All utterances are anonymised, and basic geographic and organisational details are stated to give context to the statements, in accordance with the research ethics compliance for this project.

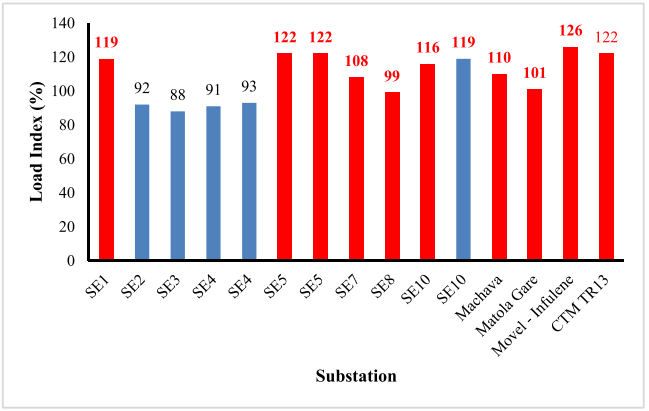

Fig. 3. Load index of critical substations (first graph) and distribution lines (second graph) in Maputo and Matola cities (Source: [51]).

5. Findings

Although EDM's social mandate encompasses the notion of socio-economic development and wellbeing through electricity provision [15], it underplays the role of justice and equity in the tariff structure and the company's overall responsibilities that come with the services provided. This section explores the current tensions surrounding the security (reliability and affordability) of electricity supply in the study

Table 2
List of interviews conducted, with households, organizations and locations.

Category of participants		Institution	City				Total
			Maputo	Matola	Beira	Nampula	
Household level			36	36	24	24	120
Institutional level	Public sector	Ministry of Mineral Resources and Energy	1	–	1	1	3
		EDM	26	11	13	10	60
		FUNAE	2	1	1	1	5
		Energy Regulatory Authority (ARENE)	1	–	–	–	1
		Municipality	–	–	3	1	4
	Private sector	HCB	1	–	–	–	1
		Gigawatts	1	–	–	–	1
		FENIX international	1	–	–	–	1
		Solarworks	–	1	–	2	3
		Autogas	1	–	–	–	1
		Mozambique Renewable Energy Association (AMER)	1	–	–	–	1
		Electrotecnica	–	–	1	–	1
		Veshrand Lda	–	–	1	–	1
		Maguezi	–	–	1	–	1
		HTA Consultores	–	–	–	1	1
		Ilumino Tecnico do Norte (ITN)	–	–	–	1	1
	Non-Governmental Organization	USAID	1	–	–	–	1
Total			72	49	45	41	207

sites, and in Mozambique more widely, and stakeholder-led solutions to these issues.

5.1. Reliable electricity supply challenges

Ensuring reliable flows of electricity is essential for the functioning of the national economy [2]. Within Mozambique, however, electricity reliability and consistency of grid-connected electricity, for urban residents in particular, is one of EDM's main challenges [54]. For instance, industrial customers such as from Matola's industrial parks receive better service provision in terms of quality, monitoring and assistance, compared with residential users, as one of EDM employees in Matola explained:

> "*Despite only representing 1% of customers, the industrial customers are special, they deserve very different attention in terms of the quality of energy, monitoring and service provision because from the point of view of consumption and billing they account for almost 50%. We must get there on time, there must not be failures, not even in metering*".

Many factors contribute to EDM's challenges to supply reliable electricity. The inefficient and aging infrastructures, including transmission lines and substations that predate Mozambique's independence, contribute to power outages across Mozambique whilst reducing the capacity of existing lines and substations [14,30]. Power interruptions are aggravated by extreme weather events (e.g., high temperatures, flooding, water shortages, heavy rainfall and strong winds), electricity supply shortages, and insufficient technical staff to cope with operations and maintenance [30]. EDM has 3327 employees compared with some 2 million (and growing) electricity users [40]. The latter often results in residents being left for several hours or days without electricity during supply interruptions. As one EDM official in Maputo explained:

> "*Although the international standard to respond to customers' issues is 1 h, due to difficulties, the EDM's standard is about 3 h, but in practice we take on average 4–5 h, and there are times when we stay around 2 days without being able to solve the problem*".

Household participants also reported cases in which EDM technicians demand financial reward from customers for power restoration service, especially if carried out outside work hours (also see [54]). Such illicit activities are endemic in Mozambique, and are practiced by EDM staff, and by criminals posing as EDM technicians to defraud consumers. EDM designed a campaign to raise customer awareness to not pay for fault repair and to report illicit activity [55]. It is common to see incidents of fraud being discovered, and perpetrators denounced and arrested on local television programming. Small-scale everyday corruption is widespread in Mozambique, but as in many developing countries, it receives insufficient attention from policymakers and development practitioners, despite its significant and immediate implications for poverty alleviation [56].

Apart from historical and environmental constraints, grid maintenance, repair, upgrading and expansion is further limited by EDM's financial insolvency [30]. Moreover, EDM sells electricity at a loss and so accumulates debts (upwards of US$1 billion) with suppliers (e.g., IPPs and contractors) [15], some of which include spin-off companies from EDM (e.g., Maguezi and TES-TOP), often linked to former high-level EDM officials. Further non-technical operational costs (including electricity theft) add to EDM's financial losses of around 30% (over US$100 million) of the total budget and reduce revenue for infrastructure investment, as an EDM official told us. In 2019, Maputo and Matola registered 32% electricity losses from distribution lines, while Beira and Nampula registered 29% and 28%, respectively [48,51].

Furthermore, high summer temperatures, along with the geographic distance between generation and use, inadequate grid connections, and overloaded infrastructures that lack reinforcement, and maintenance to support the growing urban demand, free public lighting provision, unpaid electricity bills, electricity theft and inaccurate metering [40,57] all contribute to inefficient transmission and operational losses. Customer debts and non-payment of electricity bills have accumulated, particularly from non-residential users, including state institutions, such as the Ministries of Health and Defence [32]. In 2018, US$ 42 million were missing from unpaid bills from state agencies [58] and US$ 70 million in electricity supplied to Zambia in 2015 and 2016 [47]. As in many other Mozambican public institutions, EDM's management has become politicized, and central governmental authorities often intervene in the company's operations, such as restricting its ability to disconnect non-paying institutions from the grid [54,59] and to apply penalties for non-payment. Of note is the Electricity Law 21/97 (from 1997), which includes provisions for non-payment penalties, ensuring fairness in applied tariffs, maintaining quality of electricity supply and compensations for damages to assets of customers and the utility [60]. Yet in practice, chronic non-payment creates a vicious cycle, harming EDM's financial outlook [58]. As demonstrated by an EDM employee in Beira:

> "*We have to improve the quality of electricity supply and reduce commercial losses (energy theft), the company cannot live with losses. If we*

supply electricity, we have to get the money from the electricity supplied and consumed."

Given the complex and multi-scalar factors that affect EDM's performance and viability, it has growing dependence on external finance for expansion, maintenance and rehabilitation of its infrastructure, including government and donor support (e.g., World Bank, EU, Norway and Sweden) [30]. While customer interviewees tend to blame EDM for the poor quality of electricity provided, EDM representatives see the problem as (at least partly) that of consumers. The challenges are mutually-reinforcing: EDM cannot keep up with growing electricity demand, which is exacerbated by installation of illegal power connections or unplanned infrastructures (e.g., multi-storey buildings to replace small houses) by some users, which overload power transformers and weaken the power load and quality for all consumers connected to the same network. Some users also bypass meters (sometimes with the help of certain EDM staff in exchange of compensation), adding illegal connections, vandalizing material assets or stealing electric cables, further devaluing the company's fixed assets, creating a tragedy of the commons in which overall supply quality is diminished through unregulated additional connection and illegal use.

EDM recognizes the contribution of the lack of regular maintenance, obsolete distribution lines and overloaded transmission lines to system instability on electricity quality. The latter is, in some cases, a result of government pressure to increase access despite EDM's lack of funds to upgrade or build new infrastructure. Since 2018, EDM is charged with fulfilling the national plan to connect to the grid 300,000 to 450,000 new customers annually[3] [15], roughly 4–6 times more than 2016, and 2–3 more than 2017 [40]. The high rate of new grid connections places strain on existing infrastructures, forcing the substations and transmission lines to exceed their capacity. An EDM official in Maputo recounts:

"*We have small power transformers of 50 kilo amperes with capacity to connect 200 customers to the grid, but because of the high customers' pressure to have access to electricity and because EDM does not have money, thus, we end up overloading the infrastructure*".

According to IEA [8], investment in electricity infrastructure in SSA has been made by states, with substantial contributions from international donors. Yet, levels of investment are currently insufficient to address shortfalls, requiring a two-and-a-half times increase by 2040 for a sustainable performance of utilities. Nevertheless, as the aforementioned factors contributing to electricity reliability remain still to be addressed, many households continue to face disruptions to their social practices, their everyday lives and their economic assets and activities.

5.2. Impacts of electricity (un)reliability

Though we avoid making national-level demographically representative claims given the nature of the interview sample, it is worth noting that the majority (around 60%) of households interviewed in peri-urban areas of Maputo and Matola cities were dissatisfied with the quality of electricity service provision – specifically frequent power oscillations and outages. These occur mainly between 6 and 11 pm – peak time when most people arrive home from work. In some houses that are connected to new transmission lines, the electricity voltage is insufficient to power lighting and domestic appliances, as explained by one customer interviewed in KaMpfumo urban district-Maputo, who is also an EDM employee:

"I have a three-phase connection, but I never have the recommended voltage (220 V). Because of that, I always have to keep a rag on the kitchen floor to soak the water from the fridge since it is always defrosting. This all happens because the expansion of electricity was not accompanied by improvement in quality. However, if I open my agenda, I will see instructions to provide quality electricity to our customers."

The data on voltage oscillations and damaged appliances or equipment of customers is missing from EDM reports, as these only cover damages to the company's equipment. Notably, EDM-Nampula has registered a substantial reduction in customer complaints of voltage-related issues. This delegation benefited from a 2016 System Voltage Compensation that helped to improve voltage stability. Interviewees in Maputo, Matola and Beira also say that electricity supplied has high intensity or oscillation, destroying lightbulbs and domestic appliances. Yet, EDM does not take responsibility for the damages nor compensate customers - another example of the lack of enforcement of the Electricity Law 21/97. Nonetheless, EDM applies penalties of up to 9296 Meticais (approximately US$145) to customers for damaging metering equipment [61]. Some customers therefore see the installation of more power transformers (PTs) as a solution to the frequently overloaded PTs that may break down or explode during peak times. In 2018, EDM [49] registered 6495 faulty transformers, of which 1017 were located in Maputo City, 1065 were in Matola, 1752 in the central region and 1445 in the north. Also, in 2019 EDM registered 111 accidents, an increase of 80% from 2018, of which 37 were fatal[4] [40].

Prolonged power outages[5] have a growing negative impact upon citizens' wellbeing (cf. [62]). As noted in research on urban households in Ethiopia [63], outages cause food spoilage, damage to appliances, have paralysed basic services (e.g., water, transport and telecommunications), caused economic losses for small-scale entrepreneurs, and setbacks for social and educational activities (e.g., night-time studies and entertainment). Outages also create situational opportunities for night-time criminality. Like many households in SSA unable to afford back-up power generation (e.g. Tanzania, Kenya and Senegal) [8], very few Mozambicans can afford generators. Solar panels are still uncommon in urban and peri-urban areas, as promotion of PV almost exclusively targets rural communities lacking grid connections [24,64]. Solar PV is often seen by beneficiaries as a temporary solution (Interview, FUNAE-Beira, February 2020). Without alternatives to light up their domestic spaces, citizens are left with candles or kerosene lamps and live in uncertainty regarding electricity restoration.

5.3. The role of cost-reflective tariffs

EDM has maintained subsidized and non-cost reflective tariffs unchanged between 2010 and 2015 [58]. An EDM interviewee reported that the company uses a 15-year-old tariff structure with inputs quoted in South African Rand and with an outdated HCB electricity price, even though HCB adjusts its prices yearly in line with South African inflation. The reason for this static tariff rate is inherently political. Raising electricity tariffs is costly at the ballot box as it is tantamount to increased state taxation. EDM subsidizes tariffs, but this means it perpetually lacks financial viability, commercial sustainability and the solvency it needs to support (and expand) its fixed assets [24]. The promise of electricity access remains electorally significant to Frelimo's voter share [58,65], and electricity reliability affects competitiveness in municipal and presidential elections, bolstering state legitimacy for Frelimo and its consent to rule [58]. Accordingly, there is a paradox within the politicization of electricity access between tariff rates and service quality that remains unresolved.

Several interviewees within EDM supported the incremental

[3] Around 10% of the new connections will be in Beira and Nampula, 2% in Matola and 1% in Maputo [40].

[4] 27 of these fatal accidents were of electrical origin, due to the lack of safety of the electrical infrastructure, among other reasons [40].

[5] EDM defines prolonged power outages as above three hours for response (Interview, EDM-Maputo, December 2019).

introduction of cost-reflective tariffs to alleviate this problem. Since 2015, EDM has successively increased tariffs annually, enabling it to cover the high costs of power purchase from IPPs, grid maintenance, upgrade and expansion to better meet surging demand and increase electricity access [15]. While the 'social tariff', for the poorest residents remains fixed, most residential consumers, who constitute around 92% of EDM's total customer-base and generate about 44% of revenue [40], have faced an average tariff increase of 118.6% (Fig. 5).

Tariff increases occur amid high levels of electricity export to South Africa through HCB, which despite technically producing enough energy to meet current domestic demand, continues to sell 65% of its existing capacity. A further 31.7% is sold to EDM, constituting only 52% (3651 MW) of EDM's total electricity needs [40]. Since EDM only has the capacity to produce 12% (873 MW) of its total needs, it must buy 35% (2491 MW) from IPPs and import 1% (74 MW) at higher prices (3 to 4 times) than HCB [58]. Table 3 shows EDM buys electricity from HCB at a rate of 0.036 USD, from the IPP Gigawatts for 0.11 USD and from Eskom for 0.30 USD (nearly 10 times more than HCB's price) [15,58].

Analysts estimate that from 2014 to 2017, EDM spent 21 billion Meticais (around US$338.7 million) purchasing electricity from the IPPs [58]. EDM is still running a deficit on electricity sales, purchasing between USD 0.09–0.10 per kWh, and selling at an average of USD 0.076 per kWh, while being further constrained by the devalued Metical and operating costs increases [40]. Despite the high purchase price, one EDM representative argued that IPP prices are exceptional (without import penalty cost of 0.30 USD per kWh), applied for countries that produce gas. The representative also considered the prices fair to allow IPPs to recover their high investment outlays in gas-fired power plants, which are relatively new technologies in this context, but costlier than hydroelectricity. Others have suggested that the high purchase prices stem from EDM's weakened negotiation power, since the IPPs have influential political actors from Frelimo as beneficiaries, thus the politicisation of energy supply indirectly influences the prices for domestic consumers [58]. According to critics, the long-term power purchases agreements (PPAs) with IPPs have made EDM the central player in safeguarding the economic viability of IPPs, and have also become a mechanism for the transfer of rents from the public to Frelimo-affiliated elites, who use investment in natural gas resources to accumulate assets for themselves and the party under the pretence of national development [21,69]. This has resonance with other cases in Africa, such as in Rwanda, where political elites have deployed the idea of modern technologies for socio-economic development to justify their choices of infrastructure and its implementation [70]. This rent-seeking behaviour by Frelimo-affiliated elites, which emerged following economic liberalization in the 1990s, hinders the relationship between economic development and national investment, a phenomenon referred to in the Mozambican context as 'economic porosity' [18].

Table 3
Electricity tariffs applied by energy suppliers in Mozambique (Source: adapted from [15,58]).

Energy supplier	Location of the power plant	Company Headquarters	Applied Tariff (USD/kWh)
HCB	Songo, Tete, Mozambique (Central region)	Mozambique	0.036
CTRG	Ressano Garcia locality,	Mozambique	0.85
Gigawatts	Moamba district, Maputo	Mozambique	0.11
Aggreko	province, Mozambique (Southern region)	Scotland	0.122–0.148
Mocuba Solar Plant	Mocuba district, Zambezia province, Mozambique (Central region)	Mozambique	0.13
Karpowership	Nacala city and district (offshore), Nampula province, Mozambique (Northern region)	Turkey	0.14
ESKOM	South Africa	South Africa	0.3

Though tariff rates are crucial to a utility's financial health, they also influence access and demand from users. Most domestic users have 'small pockets', with such tariffs straining their household budgets. Currently, the average minimum monthly salary in Mozambique is 4258 MZN/month (about $59 US), representing a 6.5% increase in relation to the previous salary adjustment of 2017 [71], while the tariffs increased by 30% in this period [72]. However, most residential users have prepaid electricity meters, widely installed by EDM in 2004, and their average monthly consumption ranges from 200 to 300 kWh, (a household monthly cost of roughly 1688–2532 MZN). This translates to 39.6 – 59.4% of average salary on electricity consumption. This is a significant problem of energy poverty, and highlights disparities between the experiences of Mozambicans and the populations of neighbouring countries. Notably, the 2019 *Africa Energy Outlook* showed that households in Mozambique spend twice as much to power a few basic appliances (four lightbulbs, a fan, a mobile phone charger and a television) than households in Ghana, Senegal and South Africa [8]. Thus, they are forced to find diverse strategies to manage electricity consumption according to resources available, such as sharing electricity connections between

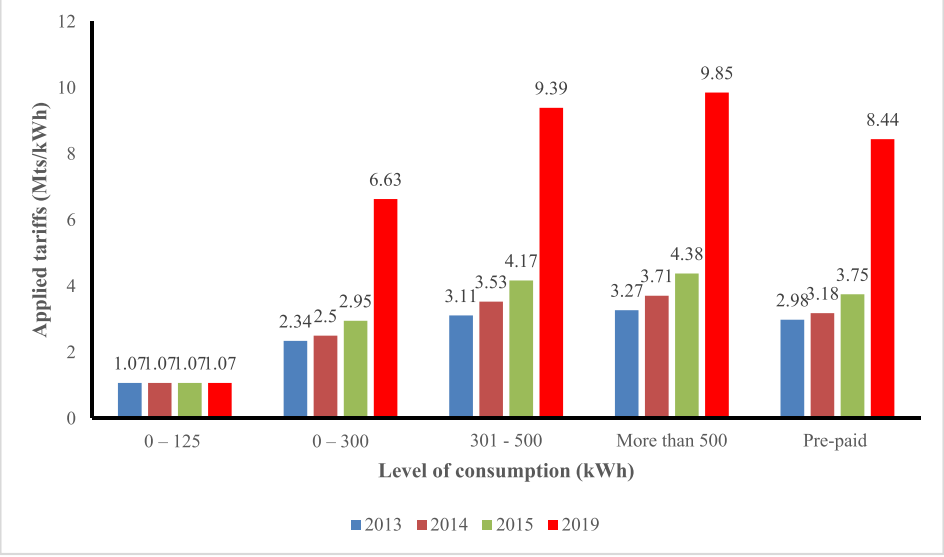

Fig. 5. Tariff increase from 2013 to 2018 by level of consumption (source: adapted from [61,66–68]).

households, fractioning electricity purchase and rationing electricity use by reverting to fans, rather than air-conditioning, for space cooling and thermal comfort, and to charcoal or gas for cooking, as explained by one household in Maputo: "*we cook on charcoal, we only use the electric stove to reheat food because electricity is very expensive.*"

Aside from high tariffs, some households interviewed claim that new (split) electricity meters installed to replace the traditional single-part prepaid meters, use more electricity, even for residents who live in small houses. They consider this an undesirable situation requiring the revision or change of the new meters[6]. Several EDM employees disputed these claims, explaining that the split meters allow EDM to track customers' consumption and help to reduce electricity theft, since the measuring components are installed on electricity poles and are alarmed to avoid fraud. In research on Ethiopia, Tesfamichael et al. [63] argues that households' limited understanding about the tariff increase and their own energy consumption contributes to their reduced trust and confidence in the utility. Nonetheless, EDM plans to successively increase tariffs by an average of 12.3% to 2042 to reach the cost-recovery level, with annual adjustments in line with the consumer price index and supply costs (see Fig. 6) [72].

In short, EDM advocates cost-reflective tariffs to support its financial viability and future solvency, and to meet its operational objectives, including investing in the maintenance and upgrade of its infrastructures. These measures agree with some of the World Bank's standard requirements for power-sector reform and restructuring [37]. Nevertheless, electricity users have different perspectives on potential solutions for service provision challenges and gaps, which we discuss below.

5.4. Stakeholder-led solutions

A critical policy analysis requires a clear understanding of the problem and potential solutions from all affected stakeholders [39]. Household interviewees provided a range of potential policy solutions to ensure electricity reliability and affordability. First, interviewees advocated for a national-scale energy regulatory authority with authorisation and capacity to monitor EDM's performance, pricing and ensure compensation to consumers for the damages created by blackouts and poor-quality services. Other commentators within Mozambique have also argued that the existing Energy Regulatory Authority (ARENE – *Autoridade Reguladora de Energia*) could strengthen its regulatory powers over the energy sector [58]. An official in ARENE told us that even though the agency was created in 2017 to replace the National Electricity Council (*Conselho Nacional de Electricidade* - CNELEC), it is being restructured, and the chair of the board of directors was appointed in late 2019. As tariffs rise, albeit incrementally, and energy insecurity continues for many users, there is a widely held view among interviewees that energy sector reform is now urgent.

Second, there is considerable support for electricity market liberalization to end EDM's monopoly and increase competitiveness within electricity markets. Proponents argue that customer choice would allow greater accountability to service providers and stimulate innovation and new socio-technical configurations, e.g. mini-grids. While the Law nº 21/97 opened a market for electricity production, transportation, distribution and commercialization for public and private investors [60], in practice, private actors have only invested in generation for supply to EDM, while EDM controls transportation, distribution and sale. Thus, the electricity generation and supply system remains vertically-integrated–a limitation that stems from preferences at high levels of the central government, according to the Gigawatts employee interviewed. The 1969 Portugal–South Africa power export agreement also gave HCB exclusive rights to perform the same activities as EDM. However, its markets are oriented towards South Africa's energy security needs, at one of the lowest prices in the world [29]. Nevertheless, the draft electricity law is expected to specify state and private companies' obligations and rights, including more clarity about IPPs' right to sell electricity within the SAPP, including South Africa.

Monopoly is a frequent characteristic of electricity systems configured as centralised grid infrastructure, as it allows utilities to efficiently aggregate consumers' load to connect to diverse power generation sources and to manage the myriad details of reliable local supply [73]. Monopoly of centralised grids also reduces mass investment required for the installation and duplication of large-scale grid infrastructure and maintenance across diverse geographic regions. The megaproject nature of centralised grids creates financial risk for private providers, and so either public ownership or public guarantee facilitates private investment; this becomes increasingly difficult under conditions of growing domestic financial uncertainty (cf: [5]). Monopoly presents a key barrier to system flexibility and diversity through islanded or micro-grid approaches, fed by renewables in areas of high investment cost and isolated demand. Such approaches would improve the overall system stability (by reducing load on aging assets), whilst lowering costs and enhancing access. Though micro-renewable generation is prioritised for rural areas where last-mile access has proved too costly for EDM, this approach could be applied in rapidly expanding urban and peri-urban regions that are currently poorly-served by existing energy services and infrastructures.

Another concern raised by interviewees focused on low purchasing power, rather than price itself, echoing previous studies (e.g., [11,24]). In this view, grid expansion in peri-urban and urban areas must be accompanied by inclusive growth, such as state and donor investment in projects to generate well-paying jobs, perhaps through the installation of new urban renewable energy projects, aiming to reduce energy poverty. Residents could then more easily absorb cost-reflective tariffs within household budgets. In reality, access to well-paying jobs would require multiple long-term steps, institutional reforms and structural changes, including improving educational access, providing training and skills development, scaling-up existing initiatives and investing in job-creating, labour-and knowledge intensive industries, rather than capital-intensive industries such as mining and resource extraction. Furthermore, the timely payment of electricity debts by government agencies[7] would increase EDM's revenue collection and improve its financial outlook, reducing the need to transfer debt-servicing onto residential users [58]. Lessons can be learned here from the state-owned Tanzanian National Utility which entered a management contract with a South African company (NETGroup Solutions). The utility doubled its revenue collection in 2004 by enforcing payments of unpaid bills or else imposing disconnections, including for public institutions [74]. However, this arrangement was controversial, as it failed to ensure the utility's technical turn-around in new electricity generation, transmission and distribution infrastructure, and electrification rates and reliability. This was ultimately deemed unacceptable by the Tanzanian Government, which decided not to extend the contract after completion in December 2006 [74]. We conclude therefore that the management of both tariff collection and expenditure requires mechanisms and practices to ensure good governance in order to be effective.

6. Discussion and conclusions

In this critical qualitative analysis of Mozambique's electricity system, we explore the issues of electricity access, reliability and affordability, through stakeholder reflections on energy policy in

[6] This is some people's misperception as the rollout of the meters happened a similar time to the tariff increase. Also, initially there were some faulty meters that had difficulties or rejected credit top ups, but assuming that it was loaded, thus making people to lose money.

[7] Government agencies are part of the general customers that are currently contributing with 12% of EDM's revenue collection [40]

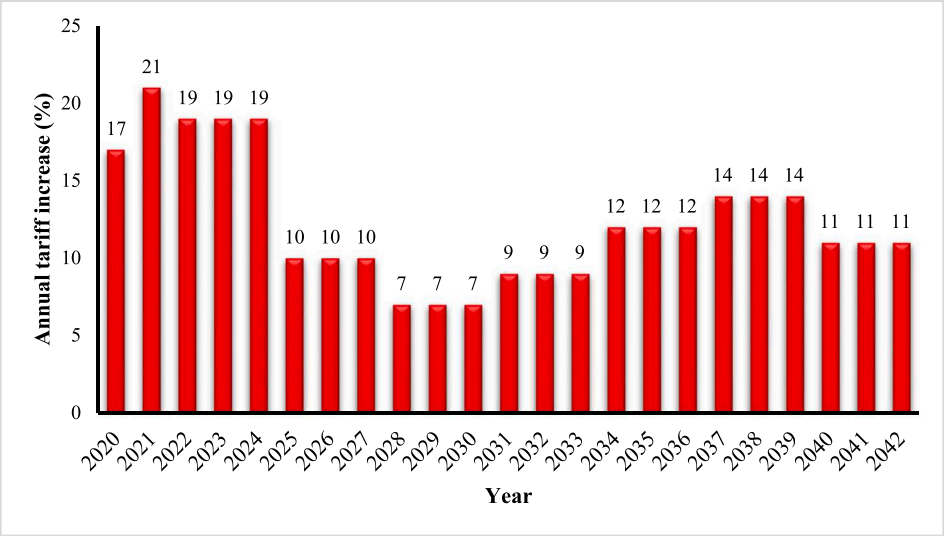

Fig. 6. Average tariff increase scenario from 2020 to 2030 (Source: [72]).

Mozambique's largest cities. Electricity reliability, affordability and sustainability influences efforts to boost energy access, along with wider socio-economic development and environmental security [75]. These goals are also proving ever more challenging as electricity connections rapidly increase to meet national policy goals of nominal universal access by 2030, patterns of electricity demand changes, and the concentration of customers increases (particularly in urban centres). Together these elements place increasing pressure on obsolete and overloaded grid infrastructure. Accordingly, Matola and Maputo, as the most densely populated cities, have registered more power cuts than Beira and Nampula, as many substations and distribution lines are frequently overloaded. This suggests that increases in access to electricity should go hand-in-hand with increases in load capacity, monitoring and maintenance. Indeed, as Table 1 demonstrates, EDM has decreased the duration of power cuts in all four cities by 15–20% over the past three years, with the exception of Beira, which registered an 8% increase in 2019, likely a result of Cyclone Idai's infrastructural disruptions. However, EDM still struggles to reach international standards in responding to customers' concerns, including addressing voltage oscillation and damage to domestic appliances.

Poor institutional capacity may contribute substantially to problems of service reliability, though EDM blames the company's insufficient financial resources for its operational problems, with financial solvency viewed as the long-term solution. Many factors contribute to EDM's ongoing financial problems: electricity transmission losses, debts and unpaid electricity bills, currency devaluation following the wider debt scandal, among others. However, the long-term impacts of non-cost-reflective tariffs are EDM's main focus. While EDM has made impressive strides in electrification, starting from a very low baseline, the challenges it faces are multifaceted and complex. The design of incremental increases in tariffs to produce conditions of revenue accumulation for further investment has been EDM's main focus. Despite the role that tariffs play in EDM's overall financial health, however, this policy has resulted in applying tariffs that are currently unaffordable to the average household, absorbing up to 59% of their salary. Customers may widely accept limited tariff increases as long as electricity service is reliable and good quality [76], however, this has not been the experience of electricity service users in Mozambique.

Such increases constitute a widening energy poverty for consumers since it is not accompanied by substantial increments in citizens' salaries and employment rates. Additionally, tariffs are widely viewed as unfair. Law n^{o} 21/97 is designed to ensure fairness in electricity service provision, ensuring minimal cost for consumers, and compatibility with the quality of the service provided [60]. If EDM increases its generation capacity by tapping into domestic energy resources, or purchases electricity from IPPs at well negotiated and sustainable prices, savings can be passed along to users and used for the company's operations and viability. These two conditions are not yet met. Although EDM has planned numerous power generation projects using gas, coal, large hydro and renewables (solar and wind) to increase its generation capacity by 4172 MW and sustain domestic demand, these projects are dependent on the limited state budget and external funds from donors, private investors or concessional loans [15].

More widely, Mozambique now appears to be mired in an era of 'permanent crisis' [77], with resurgent violence, social polarization, growing environmental insecurity, and vast state indebtedness and corruption scandals that could push the country into insolvency. This socio-political and economic outlook along with the current governance failures in EDM and state, political and regulatory risks will increasingly constrain external financing of EDM's operations and the state budget. It may also compromise external investment in network expansion, improvement of transmission and distribution capacity, and quality and reliability of electricity to support the company's goal of widening access, consistent with ambitious state targets (Interview, EDM-Maputo, June 2020). Additional aims include strengthening grid interconnection with neighbouring Malawi, Tanzania and Zimbabwe to become a regional energy hub in southern Africa [15].

State influence over EDM's operations, goals and trajectories under the pretence of socio-economic development has affected the viability of operations and financial sustainability of the utility, while enabling financial accumulation for the Frelimo party and small group of affiliated elites. These structural challenges have constrained EDM's capacity and performance, and will affect the wider power sector, if not directly addressed. Conversely, following the examples of Uganda, Kenya and Ghana [37,38], unbundling the electricity sector would allow EDM to be managed independently. This would reduce state-induced inefficiencies and enable institutional capacity building that would benefit the company and its customers, including direct negotiations of PPAs, currently done by state decree. Renegotiating the long-term PPA with IPPs, as Kenya and Ghana have done in order to pay for a lower investment recovery tariff for the electricity consumed [78], instead of paying unsustainable prices for all the electricity produced, should be major policy goals.

Mutually beneficial contracts and unbundling would allow EDM to improve its financial outlook and credibility by revising and stabilising its average annual tariffs adjustments of 12.3% for the next 22 years

(Fig. 5). EDM should also update the 15-year-old tariff structure in line with South African inflation. These measures would allow EDM greater capital resources to reinvest in maintenance and upgrade of its infrastructure and processes, improve the quality of power supply, and attend to the impacts of the technical and non-technical losses on its financial health and on tariffs. This includes the losses caused by frequent power interruptions and overloaded lines and transformers. Kojima and Trimble [76] argue that if African utilities could reduce their losses to 10%, electricity access deficits could be substantially eased. Greater capital would also allow EDM to invest in low-caron energy technologies, including solar PV and wind, furthering a climate change-sensitive energy policy agenda advocated by the state and donors, in keeping with the Paris Agreement and the UN 2030 SDGs. However, such achievements would also require enhanced institutional capabilities to provide the necessary skills, processes, and knowledge for the implementation of the projects and for efficient revenue collection to cross subsidise the electricity infrastructure, while ensuring the provision of affordable and reliable electricity [5].

An unbundled power sector would open space for ARENE to fulfil its role as an independent regulator, and to oversee compliance, set service quality standards, make transparent decisions on tariffs, and impartially represent stakeholder interests across the sector. This includes ensuring stronger enforcement of EDM's duties towards safeguarding consumer rights, and scrutinising the privileging of certain customer groups based upon consumption levels, as has been the case with heavy industrial users in Matola. This would provide a practical mechanism to advance energy justice by reprioritising access to the poorest consumers. Ensuring ARENE's independence would help to reduce market uncertainty, corruption and poor governance that has constrained investments in, performance and development of the sector, and hence the country's wider development [79]. This would also improve transparency surrounding service provision costs, increasing consumers' confidence in the relationship between revenue-raising and supply network investments.

As we argued above, a better investment environment along with incentives (e.g., exemption on import taxes) to implement off-grid projects would create conditions for secure private investment to boost the coverage of off-grid provision. These changes would, in turn, increase the availability of affordable and high quality solar-based systems that would increase consumer confidence and garner additional state revenue [80]. Off-grid provision could widen energy access, potentially improve service reliability, and improve the social perception of tariff increases. Beyond these concerns, there is still hope that the new electricity law will bring the necessary changes that will facilitate the much-needed reform of Mozambique's electricity sector. As we have shown, the multifaceted challenges in providing energy access connect with wider gaps in energy sector reform, while demonstrating that ongoing structural economic and environmental inequalities combine to reinforce a range of constraints faced in the daily lives of Mozambicans.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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