Community energy in Mozambique

An annotated bibliography

CESET
Community Energy and the Sustainable Energy Transition in Ethiopia, Malawi and Mozambique

An annotated bibliography on community energy in Mozambique

This annotated bibliography is one of a three-part series produced by the CESET team. The annotated bibliographies provide an opportunity to:

1) Survey the body of published research in the area of community energy in Malawi, Ethiopia and Mozambique;
2) Review key insights and considerations already well documented in the literature as of July 2020;
3) Explore areas overlooked in current debates to date and that may help to identify critical gaps.

The methodology employed consisted of literature searches in databases with the terms' community energy' and 'energy policy' paired with each country. Those references were then reviewed and organized according to a reading guide. Please not that these annotated bibliographies take stoke of the literature available on each country as of July 2020. These are meant to be living documents that will be regularly uptaded by the CESET team as more work on the topic gets published and as the project evolves.

If you are aware relevant work and references missing from the bibliographies, please feel free to contact us: ceset@sheffield.ac.uk

This annotated bibliography focuses on Mozambique.

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Theme list

1. Mozambique overview

Mozambique is located on the east coast of Southern Africa on the Indian Ocean, host to almost 29 million people. The country is "*frequently found at the bottom of the development tables, such as the Human Development Index. In 2015, with a GDP per capita of US$380 per person, life expectancy at birth was 58 years, and 46% of people lived in poverty (down from 70% in the late 1990s)*" (Castán Broto et al. 2018, p. 648). About 63% of Mozambique's population lives in rural areas, and subsistence agriculture remains the main livelihood for many Mozambicans as it employs 80% of the labor force, with 95% of rural households working in the agricultural sector. Its climate varies (tropical and subtropical) with a dry winter season (April to September) and a rainy summer season (October to March). Mozambique is exceptionally vulnerable to the impacts of climate change, especially cyclones and flooding.

2. Geopolitics and the political economy of energy in Mozambique

Several papers authored by CESET team members have explored the political economy and geopolitics of energy in Mozambique, for example:

- Power et al. (2016) investigate the role of rising powers (China, Brazil, India) in the political economy of energy in Mozambique (in comparison with developments in South Africa);
- Castán Broto et al. (2018) present an analysis of Mozambique's political transition post-independence and its implications for energy justice; in this paper, the authors argue for a situated understanding of energy transitions and energy delivery – see also Baptista, 2015 for a discussion of electrification in Maputo specifically, in the colonial and postcolonial periods.
- Kirshner et al. (2019) explore how large scale energy infrastructure development have been used historically to further unity across the national territory (state building strategy) and to overcome territorial fragmentation. The paper mobilise the concept of energy landscapes to understand the relationship between state building, energy developments and the political economy of energy.
- Power and Kirshner (2019) look at the function of rural electrification and large infrastructure projects in the expansion of the Mozambique's state territorial authority, reflecting on their ambiguous implication for energy access and state-citizen relations;

In Mozambique, electricity grid expansion strategies have followed Frelimo-led state building efforts to expand its reach and control over rural territories (a point discussed in-depth in Power and Kirshner, 2019). [Frelimo is the Mozambique Liberation Front, dominant political party in Mozambique ruling since independence]. Several studies describe how corruption has compromised the electricity grid expansion, with contracts and projects awarded to companies close to the state apparatus (e.g. Power and Kirshner, 2019, Power et al., 2016). Furthermore, research has shown that the recent discovery of vast coal and gas resources has also pushed the national state to follow a developmental agenda "*heavily centered on extractive industries (especially coal and gas) and energy-intensive mega-projects*" (Power et al. 2016: 15). As a result, both high carbon and low-carbon development pathways are part of Mozambique's energy and development strategies, involving state actors (e.g. Ministries and national utility company), domestic elites, multilateral development banks (see Nhete (2007) for a discussion of World Bank-led regulatory reforms in Mozambique) and international investors, increasingly from China, India and Brazil.

In the recent years, reforms to allow Independent Power Producers to operate in Mozambique have allowed domestic and international private actors to invest in and develop energy projects, yet existing analyses suggest that recent energy developments have not improved energy access for the majority (Power et al., 2016). In line with previous research, Power et al. (2016) explained that the discovery of energy resources has created 'opportunities for resource rents.' The domestic business elite and foreign investors have captured rents from infrastructure projects and have contributed to increasing spatial and social polarization within the country. Commercial companies often seek quick returns on their energy projects, privileging the production of cheaper energy for large-scale industry actors.

Studies of the geopolitics of energy in Mozambique have indeed highlighted the role of foreign investors in shaping both high carbon and low carbon energy pathways. For instance, in their analysis of the role of international investors from China and India, Power et al. (2016) find that those are investing in high-carbon projects in Mozambique in the coal and gas sector. Actors from South Korea, Japan, and Thailand are also investing in offshore gas resources. In the renewable energy sector, Brazilian firms play a role in the development of biofuels (see Bruna 2019). The Export-Import Bank of India funded Mozambique's first solar PV module manufacturing plant in 2013. Thus, foreign investors have shaped Mozambique's most significant energy developments, with the cooperation of local elites involved in the energy industry in Ministries, public utility companies, and government agencies (see section 5, as well as Power and Kirshner 2019). The potential to derive much larger profits from large scale projects, and through exporting energy to neighboring countries, has meant that the development of smaller-scale off-grid renewable energy has remained relatively marginal in Mozambique's energy landscape. In this field, international aid agencies are increasingly influencial in shaping energy transitions in Mozambique as "*off-grid rural electrification and grid extension has frequently been funded by grants and soft loans from European bilateral donors*" (Power et al., 2016; p 16).

These different trends have led observers to question the national government's ability to hold sovereignty over its resources and its capacity to steer development pathways that support local job creation and negotiate favorable terms with investors. For instance Power and Kirshner (2019) have argued that Mozambique's strategy to produce electricity for exports threatens its energy sovereignty.

3. Energy Sectors in Mozambique

As previousely mentioned, Mozambicans rely both on high carbon and low carbon energy. The main sources of energy used in the country are biomass, hydroelectric power (dams), solar power, liquid fossil fuels (gasoline and petroleum) and natural gas (Cuvilas et al., 2010). Most of Mozambique's electricity comes from hydropower stations (Kirshner et al., 2019). Hydropower accounts for about 77% of all electricity generated (EDM, 2017), with a combined capacity of 565 MW (Cipriano et al., 2015). Mozambique's hydropower depends on two major plans in the Zambezi Valley, Cahora Bassa, and Mphanda Nkuwa. Uamusse et al. (2017) have highlighted that climate variability is likely to induce a shortage in hydropower and biomass production in Mozambique – as the country is vulnerable to both drought and flooding, making it one of the world's most vulnerable countries to the impact of climate change.

Mozambique is a significant exporter of hydropower, coal, and natural gas, although the natural gas exploitation has only started in the last years (IEA, 2014). Mahumane and Mulder, (2016) have attempted to map out future energy production and demand – from households, agriculture, transport, manufacturing, services and extractive industries, as well as government and demand from neighbourhing countries. Their scenario predicts that the country will see a ten times increase in energy demand by 2030, primarily driven by demand from neighbourhing countries. The authors anticipate that Mozambique will become a leading actor in exporting natural gas and coal. In a follow up study Mahumane and Mulder (2019) suggested that over time the share of modem renewable energy sources will become marginal in Mozambique's energy production mix while remaining stable in the energy consumption mix. Energy exports from Mozambique are linked to a third of GHG emissions associated with energy production in the country. The authors make a case for interventionist policies on the supply side to reduce emissions and encourage renewable energy production. These findings are relevant to CESET because community energy need to be understood in relation to the political economy of energy in Mozambique. If the country generates revenue from extractive industries and high carbon energy, it is necessary to understand whether and how this might impede the development of community-led renewable energy systems going forward.

Natural gas and fossil fuels

Several papers have looked into the development of the natural gas and fossil fuels sector in Mozambique and have highlighted future trends, particularly the likely increase in foreign direct investments into large scale extraction projects – this means that in the near future, the country is likely to continue to link its development strategy to high carbon energy pathways.

The country produces natural gas, which a decade ago was mostly exported to South Africa (Cuvilas et al., 2010). Given the gas reserves found in the Rovuma basin, Mozambique could become one of the leading East African exporters of liquefied natural gas (Colom-Jaen and Bidaurratzaga-Aurre, 2015). Since the 2000s, market reforms have contributed to opening up natural gas exploitation to Independent Power Producers (Kirshner et al., 2019) and international investors.

In their review of the energy situation in Mozambique, Cuvilas et al. (2010) highlighted trends in the coal sector, which increasingly attracts foreign direct investments (see section 2). Already known deposits at Moatize-Minjova, Senangoe, and Mucanha-Vanduzi, all in the Province of Tete, and Mozambique's total coal reserves are estimated at 2.4 billion tonnes (Colom-Jaen and Bidaurratzaga-Aurre 2015). The exact numbers may vary, but the reserves are, in any case, vast. Kirshner et al. (2019) note that the rise of global commodities prices in the mid-2000s motivated investments in coal operations at the Moatize coalface. International players such as the Brazilian mining firm Vale invested US$2m in 2004 for coal extraction in the city of Moatize, to supply markets in South and East Asia and the Gulf States. Since the early 2010s, other international corporations such as Vale, Rio Tinto and India-based Jindal have been exploiting coal from Mozambique.

Biogas

The potential of biogas has been rarely explored in the context of Mozambique. However, some observers indicate that crop residues for energy generation have great potential to support more sustainable and circular modes of energy production, particularly in rural areas (Allesina et al., 2018). In the context of CESET, it might be relevant to investigate the potential of biogas converters for providing energy to farming and cattle raising communities in rural areas, but also to explore their potential as a way to address sanitation issues and energy access challenges in urban areas.

Wind

Wind resources have not been a central focus of Mozambique's energy policy and research on this topic is almost non existent. Cuvilas et al. (2010) reviewed the National Energy Fund (FUNAE)'s efforts to promote the use of wind energy for water pumping, especially along the coast and highlands of the interior of Mozambique. It also mentions Eskom's investments in a wind power system in the southern Mozambican province of Inhambane in August 2009 (the project's cost was estimated to be US$1.5 million, with a generation capacity of 300 kW). As in Malawi and Ethiopia, the potential of hybrid wind-solar or wind-hydro systems should be assessed in discussions of community energy, because different technologies might support different usage (e.g. irrigation, school lighting, home appliances) and might allow to achieve continuity in energy provision.

Solar

Several papers have looked into solar technology development in Mozambique. While the public utility company (EDM) has traditionally focused on national grid expansion, FUNAE has been the dominant player in the development of off-grid energy in the country. In their review of Mozambique's energy landscape, Cuvilas et al. (2010) stressed its great potential for solar energy but the lack of available information on solar conditions across the country. Since 2006, the government promoted several solar PV projects that have primarily targeted schools and health centers in rural areas. One study has looked at the potential of solar energy to replace traditional cookstoves and address biomass depletion and health issues related to charcoal production (Otte, 2014). The study assessed the needs of twelve health institutions in Maputo and the Sofala Province. According to the study, solar cooking technologies address energy challenges for cooking but need to be combined with heat storage, back-up technologies or hybrid systems to ensure the reliability of the system in the evening and rainy days. The paper shows that understanding cooking habits, schedules of daily routines, and performance are also important considerations for the design of solar cooking technologies going forward.

Other studies have shown how solar technologies for water pumping (Chilundo et al., 2019) or fruit drying (Otte et al., 2018) could greatly benefit rural farming communities. Otte et al. (2018) studied farmers' perceptions of solar fruit drying technologies in rural Mozambique. The paper showed that the costs and benefits of solar fruit drying technologies are not shared evenly across genders and that deploying these technologies without gender-sensitive assessments runs the risk of reproducing traditional gender roles and uneven power relations. The study thus advocates for increased participation of women in solar agricultural technology development, from design to dissemination. Training programs and financial incentives targeting women to acquire the technologies will support women's participation within an intersectional approach to technology diffusion and adoption.

Power and Kirshner (2019) highlighted the potential disconnect between solar technology deployment efforts and users' needs or capacity to pay for the technology. Their study researched solar technology deployment in Mavonde, Manica Province, where residents reported that households living far from the town centers are often unable to repay loans offered by FUNAE for the installation of solar home systems (SHS). The study found that users felt that SHS was ill-fitted for their living conditions, for instance, taking up too much space in their homes. Kumar et al. (2019) argued that FUNAE's projects are often designed in a top-down fashion, "*with limited and often superficial user consultations,*" which leads to a situation where solar technologies cannot be modified or adapted to fit users' (changing) needs. The paper shows that questions of adaptability and flexibility are central to the success of off-grid solar technology if those are to serve users' needs in any meaningful and lasting way. The study also shows that solar is mainly used for lighting and water heating while cooking with charcoal continues even when solar technologies are being deployed. These findings are relevant to CESET, particularly because it illustrates how users involvement in project impact assessment can help reveal how individuals' position within a particular group or community shape how they benefit from and interact with different technological options.

Whilst most solar projects were small scale (community facility or household level), Kirshner et al. (2019) highlighted that the national utility company (EDM) - which has traditionally focused on the national grid expansion – recently turned to the construction of larger scale solar PV infrastructures, announcing in investments into a 40.5 MW photovoltaic power extension in Mocuba district, Zambezia province, Mozambique's first utility-scale solar project.

Hydro

Mozambique supplies electricity domestically but also to Zimbabwe and South Africa, mostly from its hydropower plants. The aluminum industry drives the domestic consumption of hydroelectricity (Cuvilas et al., 2010).

Studies have shown that large-scale hydropower projects are ridden with conflicts, negatively impacting local communities living in areas earmarked for large-scale am projects. Power et al. (2016) analyzed the conflicts arising from the construction of several large scale hydro-power projects in Mozambique. In their study, they show how local civil society organizations, such as Justiça Ambiental!, have denounced the socio-environmental impacts of those projects that displace local communities. As discussed in section 2, the paper also stresses the involvement of Chinese and Brazilian companies in those mega-projects. Kirshner et al., 2019 have presented similar findings, discussing the examples of the Mpanda Nkuwa dam close to Cahora Bassa is a paradigmatic case of top-down planning mixing state-building aspirations and foreign capital at the expense of local communities' lives and livelihoods.

Beyond mega-projects, small-scale hydro projects have also been documented in Mozambique. Hammar et al. (2012) develop a methodology to understand the feasibility of hydro developments in five sites across the country. The study aims to assist decision-making by offering a model to assess whether and how small scale hydro can be implemented in particular locations. Other studies have directly assessed the feasibility of small scale hydro to serve the needs of off-grid communities. Uamusse et al. (2015) looked at the potential of increasing the generation capacity at the Chua Micro Hydropower Plant to provide electricity to the rural population in the Manica District of Mozambique. The study is very short and concludes that capacity can be increased, contributing to enhancing livelihoods and leading to job creation. Uamusse et al. (2019) examined the potential of mini-grid hydropower for rural electrification. They calculated that mini-grid hydropower could help produce energy for 80-200 households, while also being used for food processing and pumping water for farming lots. The paper argues for a nexus approach that links energy provision to water and food security when developing hydropower infrastructures.

Small-scale hydropower developments have been critically examined by Power and Kirshner (2019), who looked at a EU funded mini-hydro projects in Majaua-Maia, Zambezia Province. The projects aimed to rehabilitate former hydraulic system used on a late colonial maize plantation in the 1960s and 1970s. The paper shows that residents were poorly involved. The projects overlooked local knowledges, needs and preexisting energy systems, and did not consider whether and how local communities could pay to use the electricity generated from these new projects. As for solar technologies, issues of maintenance, servicing, or user training where noted, jeopardizing the usefulness and sustainability of mini-hydro installations. These findings complement existing work by highligting the need to assess projects' feasibility and viability in relation to their broader cultural, social, economic and technical context of application.

Biofuels

In the mid-2000s, investments in biofuels production grew in Mozambique, as this strategy was thought to reduce its dependence on imported fuels (oil accounts from 14.6% of the country's domestic imports in 2006) and to provide job opportunities to lift people out of poverty in rural areas, as reported by Cuvilas et al. (2010). Studies have analysed these biofuel developments. For insance, Schut et al., (2010) highlight the role of companies such as Petromoc (Mozambique); Energem (Canada), and other Chinese, Italian, Portuguese and Brazilian companies investing in jatropha, stressing Mozambique's potential for biolfuel production given its land, water, and labor availability. Another series of studies by the same team has modelled land availability for biofuel production (van der Hilst and Faaij, 2012; van der Hilst et al., 2012; Verstegen et al., 2012).

As explained in section 2, various studies have documented the role of international investors in Mozambique's biofuel sector from a critical perspective. These have shown that biofuel has hardly improved Mozambique's energy security. Instead, biofuel production had made Mozambique dependent on foreign investors' interests and decisions. Di Lucia (2010) showed that the EU imposed its rules and values to promote their interests in biofuel trade with Mozambique. At the same time, biofuels crops such as jatropha are vulnerable to market turbulences (Slingerland and Schut, 2014). Franco et al. (2010) highlighted that biofuel projects in Mozambique have adversely affected rural communities, giving rise to conflicts. Biofuel projects occupy sites with access to skilled labor, infrastructures, storage and processing facilities rather than remote areas where they could create job opportunities for very disadvantaged communities (Schut et al., 2010). Finally, Schut and Florin (2015) have offered a preliminary assessment of how the sustainability of (small scale) biofueld projects can be assessed, particularly in relation to food security. They conclude that sustainability frameworks need to be context sensitive. These findings are not surprising but they are nonetheless interesting in that they call for a greater attention to small scale biofuel projects and their potential to support local food security and livelihoods – this is particularly important as a lot of research on biofuels has focused on the role of international actors and investors and the geopolitics of land grabbing in Mozambique.

Biomass

Cuvilas et al. (2010) reviewed Mozambique's energy challenges related to deforestation and charcoal use. Trees or other woody vegetations cover 78 % of Mozambique, but illegal harvesting is common in around 50–70% of the total national wood production. Charcoal remains the predominant energy source for many households across the country as documented by Castán Broto (2017). This state of play drives deforestation and poses rising health challenges. A more recent study looked at deforestation induced by charcoal production between 2008-2018, concluding that

> "*the total forest degraded extent in the study area during the 10-year study period covered 79 630 ha, which represents 68% of the available mopane woodlands in 2008. Only 5% of the available mopane woodlands area remain undisturbed in the study area. Total gross carbon emissions associated charcoal production during this 10-year period were estimated in 1.13 Mt*" (Sedano et al., 2020).

At the same time, charcoal production is an essential part of livelihoods for many Mozambicans: according to Cuvilas et al. (2010), about 15% of Mozambique's total population worked in charcoal production and trade (2005-2006 figures). In addition, Arthur et al. (2012) compared the income elasticity of different energy sources across urban and rural households: the study concluded that charcoal is the least responsive source to income variations, showing how difficult it might be to engage in energy transitions and to abandon charcoal as a primary energy source.

Studies have looked at the potential of improved cookstoves to address charcoal use and resource depletion. Mudombi et al. (2018) explored users' perceptions of ethanol fuel and cookstoves, to understand barriers to ethanol cookstoves uptake. The study finds that ethanol does not constitute a substitute for charcoal because it is too costly and remains inaccessible to many households. People also perceive that ethanol stoves are of poor quality. Indeed, studies have stressed that any attempts to address the challenges of biomass will need to account for communities' preferences and habits (Martins, 2018; Martins et al., 2015). Beyond technological innovations, other studies have stressed the need to develop more sustainable practices of charcoal production to address deforestation and poverty, particularly women's poverty (Zorrilla-Miras et al., 2018).

Finally, one study looked at the possibility to generate energy from agricultural residues: Vasco and Costa (2009) argue that power plants powered with combusted forest biomass residue could generate 32% of the energy consumed in the Maputo Province in 2004.

Hybrid off-grid systems

Only one study, Garrido et al. (2016), explored the feasibility of hybrid systems of solar PV-biomass gasification systems in Nampula, Mozambique, and concluded that it could provide cheaper electricity than diesel generators.

4. Mozambique's energy challenges

Bringing together existing evidence from the literature, it is possible to identify found major energy challenges in Mozambique:

- Resource constraints and environmental degradation: Barbosa et al. (2001) described the status of mangrove deforestation in Mozambique, finding a higher concentration of deforestation around main urban centers in Maputo and Beira. The biggest threats to mangroves were exploitation for firewood, industrial development along the coast, clearing of mangroves for solar salt production, oil pollution, and uncontrolled coastal migration. Urbanization also contributes to deforestation in the countryside (Jones et al., 2016; Mavhunga, 2013; Sedano et al., 2016).
- Energy access: Mozambique faces substantial challenges in reaching its goal of universal energy access (Kirshner et al., 2019). Several studies have explored issues of energy access and use in Mozambique. Castán Broto et al. (2018) offer an overview of Mozambique's enegry landscape where electrification rates have increased from 5% in 2001 to 26% in 2016; the vast majority (70%) of Mozambique's population lives in rural areas, of which only 5.7% have access to electricity (while 54.5% of urban dwellers have access to electricity). Biomass (fuelwood and charcoal) serves 85% of total domestic energy requirements (95% in rural areas). Biomass is used for cooking, and the majority of Mozambican households rely on traditional cooking stoves. The detrimental health impacts of charcoal as the main energy source for households are well documented (Curto et al., 2019). Electricity access rates have improved since the end of the civil war but only 22% of the country was connected to the grid in 2012 according to Baptista (2015, citing EDM 2014). According to the same author, unaffordability and intermittent supply mean that even when people who have a connection to the grid network may not be able to access electricity.
- Ageing infrastructures and territorial inequalities: Several studies have explored issues related to territorial fragmentation and uneven access to energy infrastructures in Mozambique. Kirshner et al. (2019) provide an extended analyses of network expansion strategies in Mozambique, whilst Castán Broto et al. 2018 highlight various dynamics of territorial fragmentation and uneven energy access at the national scale. Key findings show that in Mozambique, the electricity grid network remains limited in reach, and the state's priority since 2009 has been on extending the grid, particularly to the most remote regions of the country. EDM's remit is to unify this fragmented grid network. Still, network extension is costly, maintenance is lacking, and the infrastructures are further affected by the conditions of the system, including cyclones. Kirshner et al. (2019) stress that the northernmost province, Cabo Delgado, depends on a single transmission line, making it vulnerable to network failures (as one failure on one line can cut a vast area from the network). There are also substantial variations in access rates between urban, peri-urban, and rural areas (see previous paragraph).

Increasing demand in urban areas has also led to load excess capacity and deficiencies in electricity supply.

- Growing energy demand: The state has outsourced the projected growth in demand through the licensing and divestment of generation operations and the inclusion of independent power producers - although their presence is still anecdotal (Power and Kirshner, 2019). As mentioned in section 3, it is important to monitor the impact of increased energy demand on future energy development pathways and policy reforms: for instance, high carbon pathways might address increased demand coming from industry actors (e.g. transport) and neighbourhing countries, whilst low-carbon pathways might encourage the uptake of smaller scale, renewable energy technologies to address energy access gaps domestically, for instance targeting low and middle income users.

Energy challenges in urban areas

Several studies discuss energy access challenges in urban areas. Several studies led by CESET project partners have focused on the city Maputo and its periphery, offering theoretical, empirical and methodological insights that are relevant to research on community energy:

- Castán Broto et al. 2014: in this paper, the authors mobilise the concept of energy landscape to map out how communities relate to energy in their everyday life, focusing on the neigbourhood of Chamanculo C in Maputo. Results from a participatory mapping and walking exercise highlights how different froms of energy (e.g. charcoal, energy from street lighting, networked electricity through prepayment, etc) co-exist and are mobilized in people everyday lives. Through this work, the authors bring attention to the importance of everyday practices in shaping energy access, and warrant against energy access strategies focusing exclusively on grid extension. Instead, they advocate for an understanding of energy access and practices as plural and complex, rooted in people's everyday lives – this paper is important because it provides important contextual, methodological and theoretical insights into how community energy can build upon pre-existing practices of energy use and access whilst expanding access to renewable and more reliable energy for low-income users (this is further discussed in a briefing note for Practical Action, Castán Broto et al. 2015 and in Salazar et al. 2017).
- Baptista 2015 explores the impact of prepaid electricity in Maputo. New technologies, such as prepaid electricity, have been introduced to enhance access to electricity in urban areas, particularly for low income users. The paper traces the historical evolution of electricity deployment in Maputo and the introduction of prepaid electricity. The analysis is particularly relevant to CESET, because it offers theoretical and empirical material to think through how revenue collection systems (in this case prepaid electricity meters) mediate urban dwellers relationship to energy, as well as energy flows, and how those mediate both the fragmentation and integration of urban infrastructure landscapes. Whilst it focuses on Maputo, this work has broader relevance, and it will be informative when thinking about financial models for community energy, not just in terms of governance but also in terms of payment technologies and their implications for the reproduction of urban, peri-urban and rural livelihoods.
- Castán Broto 2017: the paper discusses the experiences of residents living in Chamanculo C to develop the concept of energy sovereignty and explore its implications for development planning. The paper provides empirical information on infrastructure governance in Maputo (including the role of local associations in road maintenance, sanitation, waste collection and electricity collection). From a conceptual standpoint, it is a key paper to understand how energy strategies and projects can enhance or hinder energy sovereignty for urban dwellers. In this paper, energy sovereignty is defined as:

> *"First, energy sovereignty emphasises a reciprocal relationship between society and ecosystems. Second, energy sovereignty advocates self-determination in relation to*

> *business models and technologies. Third, energy sovereignty promotes participation in decision making and innovation."*

This definition is relevant to CESET aims and can inform the planning of community energy projects beyond cities, through partnerships and collaborations.

More broadly, existing research shows that many low-income urban and peri-urban communities face energy access challenges. They find themselves in a situation where they lack grid access but fall outside FUNAE's state-subsidized rural energy initiative (Kirshner et al., 2019). Most urban dwellers still rely on charcoal for cooking. Since the 1980s, consumption has grown despite the introduction of alternatives to firewood, such as paraffin, gas, and electricity. Brouwer and Falcao (2004) showed that both poor households and higher-income households consume charcoal. Higher-income households use charcoal in combination with other non-woody fuels because fuels do not substitute each other; they are stacked.

Energy challenges in rural areas

FUNAE, Mozambique's National Energy Fund, was set up within the Ministry of Energy in 1997. Its focus is on rural electrification, renewable energy, and off-grid technologies, mobilizing funding from donor programs. Several studies have argued that electrification efforts led by FUNAE in rural areas have been concentrated only on hospitals, schools, and higher-income groups (Cuvilas et al., 2010; Power and Kirshner, 2019). As Power and Kirshner (2019) argue, in rural and peri-urban areas lacking coverage, most households are deemed not profitable by energy suppliers. FUNAE thus serves more affluent rural areas.

5. Energy Governance in Mozambique

In Mozambique, national grid extension is led by EDM (Electricidade de Mocambique), a state-owned electricity utility, was created in 1977 to overcome the fragmentation of the colonial system, and to integrate 26 dispersed colonial production and distribution units (for a more in-depth discussion, see Baptista, 2017). EDM supports national state-building efforts focusing on grid expansion (mostly in urban and peri-urban areas) and large scale energy infrastructures, with support from the donor community, regional partners, and foreign investors. Since its creation, the grid has expanded substantially.

In addition to grid extention, EDM and the Ministry of Mineral Resources and Energy (MIREME) work with foreign mining and infrastructure companies, pursuing hydrocarbon revenue streams, extractive industries and fossil-fuel based power generation (Power et al., 2016). Existing research has highlighted the close relationships between government officials and the extractive industry: Chivangue and Cortez, (2015) highlight that senior MIREME officials (appointed by Frelimo) have established companies that can service the extractive industries and related infrastructure developments, and the Ministry also has strong links with international mining and energy conglomerates as well as donor institution.

In rural areas, FUNAE, is in charge of electrification. Power and Kirshner (2019) highlight the important role of the donors community in FUNAE's activities

> "*is funded through the state budget, with revenues from taxes and levies from petroleum and electricity concessions, along with donor support from the World Bank, the EU, several European bilateral donors, and more recently*".

For instance, their research finds that the World Bank has been particularly influential, pushing for market and regulatory reforms, advocating tariff increases and opening up energy markets to

Independent Power Producers, while also encouraging off-grid approaches to accelerate energy access (Power and Kirshner, 2019)

This dual governance of Mozambique's energy landscape – with EDM leading on grid expansion and extractive resource management, and FUNAE focusing on rural electrification and renewable energy – also maps onto the dichotomy between urban/rural areas. Some studies have shown that this way of governing energy developments fails to recognize that often both in urban and rural areas, where people can mobilize a mix of grid and off-grid solutions to address energy needs (Castán Broto et al., 2018). In the context of CESET, it will be particularly important to expand on this work to explore the alternatives that exist between grid extension, off-grid, and renewable energy technologies as part of holistic energy strategies.

Furthermore, more work is needed to understand the role of the many actors involved in off-grid technology deployment, expanding on the work of Ahlborg and Hammar (2014), who showed that innovation in off-grid technologies for rural electrification occurs in an uncoordinated fashion, including national development strategies (FUNAE), donor programs as well as bottom-up initiatives by industry players and churches. They also identified barriers to RE deployment: lack of human capital, planning deficit, reliance on donor funding, low development of rural markets, and lack of interest from the private sector, as well as difficulties in installing equipment in traditional buildings. These barriers to renewable energy deployment need to be further assessed in the broader geopolitical context of energy in Mozambique, and it is key to understand whether what kinds of communit-led models of energy delivery can help address those barriers.

6. Key insights

In summary, various studies from CESET team members have highlighted the complexity of Mozambique's energy landscape, situating it within broader geopolitical developments (during the colonial and postcolonial era) and investigating the roles of transnational actors such as China, India and Brazil, and more traditional entities such as the World Bank, in the country's energy development pathways. This work highlights that the country is pursuing simulatenous strategies, including the commercial opportunities opened up by high carbon developments (e.g. in the coal sector), grid expansion connecting urban areas, and renewable and offgrid technologies promotion as a solution to energy access gaps in rural areas. This is the context within which community energy projects will need to be designed and implemented, and accounting for these different dynamics will be essential to understand how different technologies, partnerships and financial models can be adequate to address energy access in different locations. Also work by Cuvilas and others has mapped the landscape of renewable energy in the country.

However, despite previous work there are big gaps in terms of understanding the practical barriers to community energy and the potential impact of community energy on communities. CESET's intersectional approach will be innovative in the context of renewable energy in Mozambique.

Several studies in urban and rural areas have highlighted the need to adopt approaches to technology deployment that are grounded in and attune with their cultural, social and economic context, notably through co-design and user engagement at different stages of the project. Building on this literature will be essential in CESET.

Biogas and wind energy developments are a blindspot in existing research on energy in Mozambique. However, energy derived from biogas converter can help address waste and sanitation alongside energy access issues (e.g. clean cooking). Furthermore, experiences from other countries suggest that biogas technology can also support food production (through the production of high quality fertilizer). Through CESET, we might be able to explore whether these are interesting and viable solutions in the context of Mozambique.

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