The role of community energy systems to facilitate energy transitions in Ethiopia and Mozambique

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The role of community energy systems to facilitate energy transitions in Ethiopia and Mozambique

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Abstract

Policymakers and academics are focusing on energy transition to provide affordable, sustainable, and green energy for everyone. This is being driven by a combination of the lack of electricity access to millions of people particularly in the African continent and the requirement for the reduction of environmental impact through the use of greener energy resources and systems. This paper summarizes an interdisciplinary research program investigating community energy systems in Ethiopia and Mozambique to facilitate energy transitions. Specifically, it compares community energy landscapes, progress made, and existing challenges and opportunities. To determine the status of community energy development in the two countries, recent publications and official policies were reviewed, and community energy managers were interviewed. The review showed that renewable energy sources are the dominant focus for community energy developments, which is key to achieving a cleaner energy future. However, progress in community energy development has been slow in these countries. There are several reasons that hinder community energy systems from driving the necessary energy transition to a cleaner, modern, and affordable energy. Some of these reasons are the absence of favorable regulatory frameworks, incentive package, knowledge on business models, weak commitments from stakeholders, and insufficient community involvement. These issues vary in degree between the two countries.

Keywords Community energy · Energy governance · Energy flows · Energy choreographies · Energy transition

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1 Introduction

Policymakers and academics are pushing for energy transition to achieve accessible, modern, sustainable, and green energy for all. This is due to millions of people in Africa lacking electricity access and the need to reduce environmental impact with greener, renewable sources and systems [1]. Energy transitions are complex and require a comprehensive understanding of the historical and spatial aspects of energy systems [2]. A transition depends on structural transformations that require massive capital [3], Integration of local materials and institution with the global value chains [4], and it is sensitive to the context and spatially specific [5]. Transitioning to a greener future requires considering sustainability and energy security. The World Energy Transitions Outlook 2022 report advises governments to expedite this change to address the global energy and climate crisis by providing affordable energy for all while also promoting resilience [6].

To move towards a cleaner future, we need energy systems that rely on sustainable, decarbonized sources. This involves switching from fossil fuels to renewable energy and improving efficiency across generation and demand [7]. The resurgence to use low carbon nuclear energy is also becoming one of the critical mix to the energy sources needed for the transition [8]. According to the Africa Energy Outlook 2022 report, energy efficiency and renewables are considered as the driving force for energy transitions in the continent [9]. This indicates that using renewable energy sources is seen as a way to make the necessary changes that the world aims to achieve. As part of the development of renewable energy systems, off-grid energy systems are getting considerable attention because of their suitability to facilitate access in remote areas and aid the transition to a greener economy in countries with limited energy access. Community energy systems are commonly used in the Global North particularly in Europe to give communities more control over their energy generation and usage, as a part of off-grid energy solutions [10, 11]. In certain European countries and in Canada, community energy projects are also being initiated by both the desire to meet renewable energy goals and increase energy efficiency [12, 13]. With these understandings, the European Union has put community energy at center of its strategy and policy [14–16], with the United States lagging behind in creating energy communities because of its reliance on top-down strategies [17].

The development of community energy systems is characterized by exploiting decentralized local renewable energy sources, ensuring lower carbon emissions and reduced transmission losses [18]. These systems can facilitate equitable energy transitions and make the system more greener and resilient [19, 20], but it encounters obstacles even in developed countries due to governmental policy shifts [21]. A study of community energy systems in France found that involving various actors, including businesses and the government, challenges the idea that communities hold a central role in project governance though its impact is minimal [22]. Additional difficulties involve meeting regulatory requirements, managing data when implementing novel technologies, and securing funding for new initiatives [15]. Some critics of the European strategies suggest that community energy policies lack true citizen empowerment and democratization [23]. Nonetheless, initiatives like Zeeuwind in the Netherlands have demonstrated resilience in the face of policy changes [24].

Several researchers agree that the rise of community energy projects in developed economies, such as the European Union, is largely driven by policies and incentives that support renewable energy [25–27]. Factors such as citizen involvement, creative funding, advanced technology, public support, and profitable business strategies are also promoting community energy growth [28].

In the global South, the focus is on how to provide energy access to millions of people while transitioning to low-carbon economies [29, 30]. The development of community energy is growing albeit with slower pace. Malawi has demonstrated some progress in developing community energy in recent years [31, 32], with Studies in South Africa indicate that developing bioenergy at a community level can empower communities and enhance energy security [33]. A study on community energy systems in Sub-Saharan Africa concluded that these systems frequently fail to engage the community adequately in their development and are not effective in facilitating the transition to sustainable energy on the continent [10]. However, there is insufficient empirical evidence in Ethiopia and Mozambique on how community energy initiatives' governance, energy flows, and energy use operates within socio-cultural, political, and technological contexts, which is also the case in most of the Sub- Saharan Africa (SSA) countries [34, 35].

This paper aims to analyze community energy development in Ethiopia and Mozambique by answering two key questions: (1) What are the challenges and opportunities in developing community energy systems based on context specific parameters in Ethiopia and Mozambique? (2) How are these context specific parameters compared in the two focus countries? To address these two questions, this research summarizes an interdisciplinary program aiming to comprehend how community energy systems function and affect Ethiopia and Mozambique's energy transitions. Community energy system development differs in pace, scale, and objectives in the two countries. This paper compares the development of community energy systems, highlighting the challenges and opportunities in their respective energy landscapes. It examines differences in energy governance, flows, and energy use. This helps identify effective strategies for expanding the use of community energy systems in these two countries and across Africa.

The paper consists of five sections. Section 2 presents the methodology employed in this research. Section 3 provides a comparative analysis of community energy landscapes, and Sect. 4 outlines the effective instruments that can support the development of community energy. Section 5 contains concluding remarks.

2 Methodology

2.1 Description of the study area

Ethiopia and Mozambique, two sub-Saharan African countries, are facing energy access challenges despite their efforts to provide universal energy access through grid and off-grid systems. Although they have policies in place to achieve this goal, Ethiopia's energy access rate is at 46.7% and Mozambique's is at 34.9% [36]. Although electricity access is low in Africa, the development of off-grid energy sources is making progress. The Africa Energy Outlook 2022 report states that nearly 58% of electricity access comes from off-grid energy sources, with 27% from standalone systems and 31% from mini-grid systems [9]. Advancements in technology, abundant renewable energy sources, financial aid from donors and private sector involvement are factors driving this shift towards sustainable energy. Ethiopia and Mozambique have adopted mini-grid community energy initiatives to promote off-grid energy systems, as demonstrated in Fig. 1. Both countries must increase and speed up the deployment of community energy systems in rural areas where access to electricity is limited in order to achieve necessary energy transitions.

This study focused on these two countries to understand the challenges and opportunities in the development of community energy and its contribution to facilitate energy transitions.

2.2 Source of data

The analysis utilized primary and secondary data sources obtained through various methods. Primary data was gathered through monthly collective dialogues from April 2019 to December 2022 as part of the CESET project. The minutes from these meetings provide valuable insight into community energy initiatives, such as planning, development, administration, operation, and maintenance, in the two countries. The study also gathered information by conducting informal interviews with six community energy experts and local energy agency administrators in those countries. The secondary data consisted of a systematic review of academic and policy publications, current legislation, and regulations from both national and international sources.

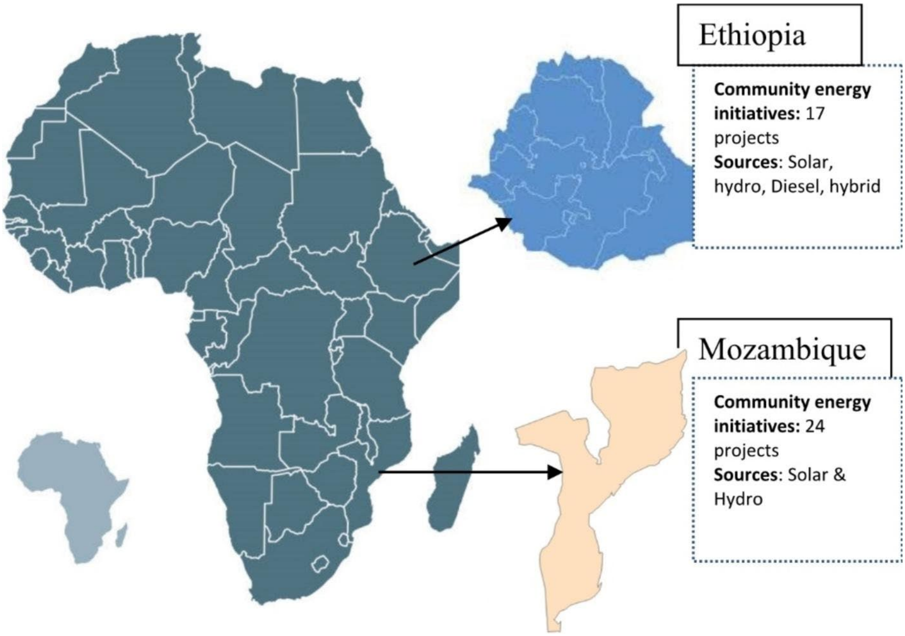


Fig. 1 Community energy development initiatives in Ethiopia and Mozambique

2.3 Research approach

This study implemented the qualitative research approach. According to Boodhoo and Purmessur's study [37], qualitative research offers a more realistic understanding of the studied conditions through adaptable data collection, analysis, and interpretation methods. The qualitative approach was chosen for this research as it focused on gathering subjective opinions from respondents. This type of research relies on the insights and impressions of both the respondents and the researcher, and results are typically not subjected to rigorous quantitative analysis.

2.4 Data analysis procedures

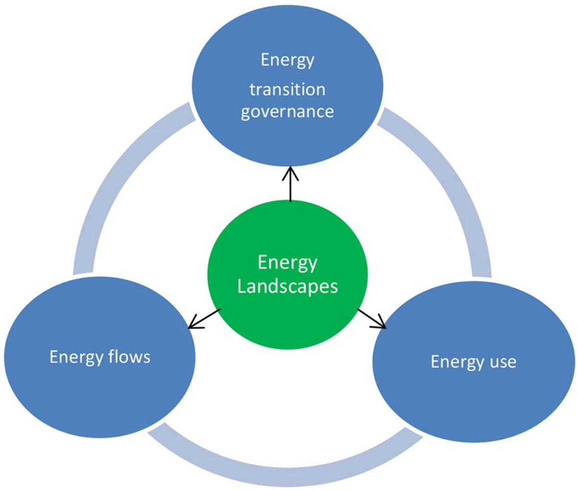
The collected data, such as interview transcripts, meeting minutes, academic and policy reviews, were analyzed by comparing the findings of the two countries and cross-referencing with existing literature. This helped to gain a deep understanding of the challenges and opportunities in community energy development from the perspective of researchers and participants. The data was presented qualitatively and comparatively with tables to describe the problem in the two focus countries.

3 Comparative analysis of community energy landscapes

3.1 Understanding the energy landscapes

Energy landscapes refer to the complexity and integration of energy within a specific setting. These landscapes are composed of three related components: energy transitions governance, energy flows, and energy use, as seen in Fig. 2. Energy landscapes are influenced by energy transition governance, which includes regulations and policies related to energy, such as energy access strategies and decarbonization plans. For

Fig. 2 Components of the energy landscape [39]



example, regulations on private sector involvement and feed-in tariffs play a crucial role in either supporting or impeding clean energy company operations across different nations [38]. The issue of governance encompasses various entities that impact energy system changes, such as national, local, and regional governments, public or private utility companies, independent power producers, international governmental and non-governmental organizations, communities, and others.

In East Africa, multiple institutions at different levels (such as donors, governments, investors, and banks) influence energy transitions in varied and occasionally uncoordinated manners. Policy frameworks establishing renewable energy targets or providing financial and institutional support to particular energy sources and modes of energy provision influence different actors' ability to take part in the governance of energy transitions. These measures also shape the trajectory of energy transitions.

Energy landscapes are influenced by energy flows, which are the ways resources are organized and integrated into systems that provide energy services. This concept has been studied in urban areas and applies to larger scales such as national level [40]. Mapping resource flows can help understand how energy and infrastructure are provided in different scales and countries, which is crucial for energy and resource governance. Energy landscapes are also influenced by the energy use, which are the human activities that shape how energy is used in areas like housing, service delivery, and work. Examining the energy use involves analyzing energy requirements, consumption, and how society structures itself around energy movements.

3.2 Conceptualization of community energy

In Ethiopia and Mozambique, the energy landscape is categorized as national grid and off-grid systems, as specified in official documents such as energy policies and regulations. While there is no clear definition of community energy, it can be included in the off-grid system category. Mozambique also lacks a clear definition of community energy but is currently viewed as part of the off-grid energy system. However, there are attempts to define community energy by scholars around the world. Examples include a study by Klein and Coffey [17] that considers community energy projects managed by cooperatives that could serve from a single household to a medium-sized system. It is a decentralized system created with significant community involvement in the development process for their own use [41, 42]. The absence of clear definition and adoption of community energy in Ethiopia and Mozambique is hindering its deployment. Establishing a clear definition would aid in implementing effective governance and development strategies, which are currently the main obstacles for installing community energy systems in these countries. For example, discussions with Ethiopian communities and government officials revealed a lack of knowledge about appropriate business models. The involvement of communities in the development of the systems is also very limited in Mozambique contradicting the core phrase "Greater involvement of communities", which is the base to define and characterize community energy systems.

3.3 Analysis of the community energy landscapes

Governments are taking steps to create supportive policies, although progress varies widely between nations. The analysis of community energy developments in the two countries revealed notable differences in energy governance, flows, and energy use. This is due to variations in:

- Policies and strategies.
- Stakeholder commitments from governments, private sector, and communities.
- Access to financial and technical resources.

Existing community energy systems face operational and management challenges that affect their sustainability and community uptake. Sustainability challenges experienced by these systems are hindering the diffusion and deployment of related technologies. Subsequent subsections provide details on the comparative analysis of community energy landscapes in both countries.

Table 1 Comparative analysis of the community energy governance

Energy landscape		Ethiopia	Mozambique
Energy governance			
EG1	Supportive policy for community energy deployment	√	√
EG2	Grid arrival policy	√x	√
EG3	Cost reflective tariffs	x	x
EG4	Integrated planning of community energy development with the grid systems	√x	x
EG5	Involvement of private sector in the community energy development	√	√x
EG6	Greater involvement of community	√x	x
EG7	Community energy development related incentive packages[a]	x	√x
EG8	Clarity on the administration (operation and maintenance) of community energy systems	√	√
EG9	Clarity on the community energy business models	x	x
EG10	Clarity on the duties and responsibilities of the funding organs, owners, and management of the community energy systems	√x	√
EG11	Ease of licensing process	√x	√x

[a]Incentive packages may include but not limited to: Community energy development related Import Tax reduction, reduction of income Tax, Providing land at nominal price, low interest loans etc

Key: √ = Yes; x = No; √x = yes but either vague or not implemented properly

3.3.1 Community energy governance

Table 1 compares the energy governance in Ethiopia and Mozambique. The energy policy in Ethiopia is generally supportive of community energy development but faces challenges in implementation and timely revision to address recent changes in the sector. For instance, there is a grid arrival policy that is unclear, with the law stating that community energy systems should be integrated into the grid in case of overlapping (EG2). However, there are no mechanisms in place to ensure that these systems are developed to a standard that is suitable for integration into the grid. Mozambique's energy policy promotes community energy development, but lacks community involvement, which is crucial for sustaining the systems similar to practices in the developed economies [28]. These findings align with other research that shows insufficient regulatory systems as a significant obstacle in SSA [43, 33, 34, 44, 45].

In Ethiopia, integrated planning is a priority and strategies are being developed to support this effort (EG4). However, these strategies are not being put into action, leading to community energy projects lacking integrated planning. Conversely, in Mozambique, the government is less focused on integrated planning and instead prioritizes expanding global access to electricity. Both countries involve the private sector to varying degrees in developing community energy systems (EG5) though engagement of a diverse stakeholders is considered crucial for the success of community energy according to the success stories of community energy development [28].

To ensure the sustainability of systems, it is recommended to involve the community more during the inception, design, and management phases through stakeholder engagement tools [46–48]. However, in Ethiopia, community involvement varied at different stages of development according to our assessment (EG6). During the project's inception, stakeholders discuss the need for the project and the role of community involvement, including financial and in-kind support. Community involvement is limited during the design and layout phase. In Mozambique, there is no public consultation process for making land available for community energy projects. Instead, communities are only notified after a site has been selected for implementation. Existing experiences of stakeholder, particularly community engagement in Ethiopia and Mozambique reveals that the research findings are consistent with those in other areas in SSA [49–52], emphasizing the need for governments and stakeholders to take significant action.

Both countries lack the necessary incentive packages for community energy projects (EG7), which are crucial for successful implementation in the Global North [25–27]. There is uncertainty regarding the most sustainable business model to adopt and implement (EG9) in the two countries. Other SSA countries also have similar challenges because of the lack of institutional supports [34]. The administrators of a community energy project in Ethiopia collect money from users based on a tariff that is not cost reflective, which results in a shortage of cash flow for necessary expenses such as maintenance and technical expert salaries. It is important for the administrators to determine the most appropriate business model before collecting money from users. The sustainability of systems is being impacted by the confusion and failure to adjust tariffs based on market prices.

During the development of community energy systems in Ethiopia, stakeholders are clear on their duties and responsibilities (EG10). However, in some projects, stakeholders lack clarity on how to manage the systems after they are commissioned. This is due to a lack of technical skills and expertise in managing community energy projects, which is a common issue in other SSA countries [53, 54]. There is a lack of follow-up and adjusting tariffs based on the changes in operational costs. In Mozambique, the roles and responsibilities of involved parties are clear. The government is responsible for implementing, managing, and maintaining the project, creating a straightforward relationship between the service provider (government) and the beneficiary (community/customer), with no other involvement. However, there are drawbacks to this approach as it excludes community involvement and ownership. This is a common issue across other SSA countries where government or elite organizations wholly own projects without transferring power to local communities [55, 56, 35, 11, 50, 33]. This has resulted in limited community involvement through top-down approaches [17, 57–59], similar to those in the United States [17].

In Ethiopia, there is a licensing process in place for community and/or off-grid energy development (EG11). All sizes of community energy projects require a license, which can slow down deployment due to the additional burden on both the licenser and licensee. Similarly, stakeholders in Mozambique have identified the involvement of multiple government institutions as the main bottleneck in the licensing process, causing it to be slow and unpredictable.

3.3.2 Community energy flows

The energy patterns of the communities in both countries are mostly similar, as seen in Table 2. However, there is one significant difference: in Ethiopia, communities connected to energy systems still primarily use biomass for energy-intensive tasks like cooking and baking (EF1). The community energy systems in both countries rely heavily on solar and mini-hydro power (EF2). As a result, these systems have led to changes in the energy patterns of the communities, including the sources, applications, and environmental impacts associated with energy generation and utilization.

Table 2 Comparative analysis of the community energy flows

Energy landscape		Ethiopia	Mozambique
Energy Flows			
EF1	The use of biomass for cooking and backing applications in community energy connected households	√x	x
EF2	Strong emphasis for the development of community energy/off-grid energy using solar and mini-hydro	√	√
EF3	Community energy changes the energy patterns of communities	√	√

Table 3 Comparative analysis of the community energy choreographies

Energy landscape		Ethiopia	Mozambique
Energy use			
EC1	Social structures/cultural norms negatively influence community energy development	x	x
EC2	Challenges of community energy integration into the existing architecture	x	x
EC3	Challenges for new entrants of community energy technologies	x	x
EC4	Challenges related to sustainability of electricity supply from community energy systems	√	√

3.3.3 Community energy use

Table 3 illustrates that the community energy practices in both countries are comparable. The communities prioritize acquiring electricity, which drives their willingness to adopt any new energy technologies (EC3). The choice of technology used to provide energy services is less of a concern for the communities compared to their lack of access to electricity. A major challenge for community energy systems is ensuring their sustainability. Lack of organized maintenance management and insufficient funding for experts are the primary reasons for system failures (EC4). Stakeholders often miscalculate community tariffs based on consumption, resulting in insufficient funds for system upkeep. This is often due to a lack of understanding of optimal business models. Additionally, communities may lack maintenance experts, either internally or in nearby areas, resulting in delays for repairs.

4 Effective instruments for developing community energy

The findings indicate that in both focus countries, policies supporting stakeholder engagement and community empowerment in energy projects were in place, but the regulatory frameworks did not effectively facilitate their implementation. These challenges are against the very notion of championing of the energy projects as initiatives that involve communities in the generation, distribution, and consumption of the energy. Maintaining and sustaining community energy services is also a significant operational challenge. The application of community energy systems in Ethiopia is also limited to lighting, charging, and television. These barriers are preventing community energy from enhancing energy access, supporting sustainable development goals, and empowering local communities to participate in the countries' energy transition. To address these challenges, we suggest the following approaches:

Policy and regulatory frameworks It is crucial to develop enabling policies and regulations that support community energy projects based on evidence and localized approaches that take into account the local context [50, 53, 60–62]. Policies and regulations such as feed-in tariffs, grid arrival policy, and simplified permitting for local renewable energy projects could help overcome the identified barriers and support community energy development.

Stakeholder engagement and social inclusion Engaging stakeholders, including community members, local authorities, NGOs, and civil society organizations throughout the project implementation from the inception to the operation, is crucial for successful community energy development in SSA [63, 64]. Ensuring the active participation of marginalized and vulnerable groups in decision-making processes and benefit-sharing mechanisms is important for achieving inclusive and equitable outcomes. Effective stakeholder engagement can also provide technical expertise, financial resources, and management support, while ensuring community engagement and benefit sharing. Effective stakeholder engagement from project inception throughout its lifespan can promote co-design and address possible barriers, as observed in certain African nations like Kenya and Cameroon [51, 57, 65].

Capacity building and knowledge sharing Technical training and capacity-building programs for local communities can improve their understanding of energy technologies and management, such as through workshops, seminars, and educational campaigns focusing on business models, management skills, renewable energy sources, energy efficiency, and project planning [10]. This helps close the knowledge gap in technical skills for community maintenance, business models, management, and other areas.

Financial support and incentives Financing mechanisms and incentives, like grants, loans, and subsidies, are crucial in supporting community energy projects by making them accessible and affordable [66, 67]. These funds can be used for purchasing, installing, and maintaining equipment. Creating investment funds dedicated to community energy projects can also encourage private sector involvement.

Local market development Local energy markets can benefit communities by creating income opportunities [60, 68]. This includes selling excess energy to the national grid, encouraging energy entrepreneurship, and promoting small and medium energy enterprises within communities.

Technology adaptation Encouraging the use of technology that fits the community at local context can enhance community energy initiatives. This includes exploring new options such as microgrids, renewable energy mini-grids, off-grid systems, and energy storage systems designed for the community's specific requirements.

5 Conclusions

This research is a summary of an interdisciplinary program focusing on community energy systems. The goal is to understand the impact of such systems in facilitating energy transitions in East Africa. The program specifically looks at cases in Ethiopia and Mozambique to explore how communities can support just energy transitions. This paper examines the energy landscapes in two countries where community energy is emerging, and presents a comparative analysis of their progress so far. It details the challenges and opportunities that exist during the development of community energy systems. The study shows that community energy initiatives mainly use clean and renewable resources, a crucial step towards a greener energy system. However, progress in these countries is sluggish due to unfavorable regulations, no incentives, limited knowledge of business models, weak commitment from stakeholders, and inadequate community engagement with a varying degree in the two countries. These key issues are hindering the contribution of community energy systems in driving the necessary energy transitions to a cleaner, modern and affordable energy. East African governments and the continent as a whole should utilize available renewable energy resources to expand various forms of off-grid energy systems. This can be achieved by creating a favorable environment for communities, the private sector, development partners, and government bodies involved in developing such systems. Off-grid energy systems are a cost-effective solution for bringing electricity to remote areas of Africa where many people live. This technology has great potential for facilitating energy access to millions of people on the continent.

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Declarations

Competing interests 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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