CHAPTER 5

Financial Aspects of Community Energy Systems

Aran Eales

Abstract This chapter analyses the process of financing community energy, emphasising delivering sustainable projects that do not add additional burdens for communities. Community energy depends on developing micro- and pico-systems, which have specific financial requirements due to their small size. A key challenge is ensuring the financial sustainability of projects once installed and when the initial capital runs out. The chapter advocates putting the community at the centre of a structured financial planning process, negotiating cost reductions and revenue models, and diversifying the revenue stream by looking beyond conventional sources of finance. The analysis of a case study of financing two micro-grids in Malawi demonstrates the obstacles faced by financing projects. These small projects face enormous challenges that drive up costs, including difficulties in accessing supply chains for solar equipment, inflation and foreign exchange fluctuations, and limited technical capacity to maintain the system. A sustainable energy transition should help reduce these costs to facilitate the expansion of the micro-grid model. Until such

A. Eales (✉)
University of Strathclyde, Glasgow, UK
e-mail: aran.eales@strath.ac.uk

V. Castán Broto (ed.), *Community Energy and Sustainable Energy Transitions*, https://doi.org/10.1007/978-3-031-57938-7_5

expansion takes place, the sustainability of micro-grids will depend on public support and external grants to top up the income from consumer tariffs.

Keywords Community energy finance · Capital costs · Operational costs · Supply chains

5.1 Introduction

Community Energy Systems (CES) play a pivotal role in providing sustainable and affordable electricity in off-grid communities. Yet, a comprehensive understanding of their financial landscape is crucial for successful implementation. This chapter aims to shed light on economic considerations that shape the viability and sustainability of CES, with a specific emphasis on micro- and pico-grid systems (1 to 50 kW) operating commercially in rural areas of the Global South. Given their smaller size, such systems will have different requirements in terms of resources, materials, and capacity than larger or grid-connected systems and may depend on different funding mechanisms.

The financial management of CES has garnered increasing attention as a pivotal aspect of sustainable and decentralised energy solutions, particularly in the context of mini-grids and off-grid systems. Several high-level industry reports have provided valuable insights into the global state of play, market trends, potential investment opportunities within this sector, and trends in technology costs and business models. While industry reports offer a macroscopic view, detailed case studies with specific shared primary data on financial performance, crucial for a nuanced understanding, remain rare. An emerging body of academic literature assesses CES in terms of techno-economic perspectives and business modelling. Still, there is a lack of robust academic discourse that explores, systematically interrogates, and quantitatively assesses the business feasibility and financial management of CES. Ultimately, despite growing interest and increasing discourse, proven sustainable financial models are scarce for CES, and the specific landscape of CES financial models remains largely uncharted.

The chapter discusses some principles for the financial management of CES. It outlines steps for developing a financial plan for their sustainable deployment and operation, drawing on previous experiences with micro-grids. These steps broadly involve balancing capital and operating expenditure with revenue from selling electricity, considering characteristics unique or particularly relevant to CES. A key lesson is to ensure that the operational costs of CES are considered in financial planning. The chapter thus explains the main costs and sources of revenue for CES, as well as considering multiple sources of finance. A case of a CES in Malawi helps demonstrate how these principles apply in practice.

5.2 Principles for the Financial Management of CES

CES require upfront capital to construct and install the systems, including developing ancillary infrastructures to make the project viable. Sustaining the CES's functionality over the project life requires an additional, continuous, reliable revenue stream. Sufficient funds are needed for ongoing operations, maintenance, and the effective management of the systems (Safdar, 2017). This dual financial strategy ensures the successful implementation, longevity, and effectiveness of CES by addressing both its foundational development and sustained operational needs.

Off-grid renewable energy systems have historically encountered sustainability challenges. While donor capital has been deployed to develop energy infrastructure, the absence of a financially sustainable business model has frequently led to insufficient resources for maintenance or the replacement of components. This deficit in ongoing funding and adequate business models has, in turn, resulted in the deterioration of systems over time (Dauenhauer et al., 2019). Accordingly, a key guiding principle in the financial management of CES is to ensure sufficient resources are available to cover the costs of operation, maintenance, and management to ensure long-term sustainability. Such costs can be covered with revenues from connection fees and electricity sales and, where available, from subsidies or donor support. In any case, ensuring a reliable and ongoing source of revenue is vital to the project's sustainability (IRENA, 2018).

Another key guiding principle regarding the financial management of CES is to carry out a cost–benefit analysis for the project that assesses the relation between the cost of the proposed CES and the value of the resulting benefits, specifically to the community it serves. The benefits considered in such an assessment can be both tangible and intangible:

- **Tangible Benefits:** Direct, measurable advantages such as reduced energy costs for community members, increased economic activities, and job creation.
- **Intangible Benefits:** Less quantifiable yet impactful outcomes, including enhanced community cohesion, improved health outcomes, and environmental conservation.

Creating a robust financial plan for a CES requires a systematic and iterative approach. The process involves estimating costs, developing an initial revenue model, and testing it through community consultation so that the project aligns with the community's demand. This iterative process ensures flexibility and adaptability to unique community needs. Figure 5.1 outlines a typical process based on micro-grid literature (Weston et al., 2018). The model puts the community at the centre of financial planning.

The steps begin with a detailed estimation of the costs of implementing and operating the CES. This includes infrastructure, technology, personnel, and ongoing maintenance expenses. A revenue model is then developed based on projected energy demand and potential tariffs balanced with community affordability. Additional revenue streams, including grants, subsidies, or income-generating activities linked to the CES, can help diversify the revenue stream.

Engaging the community in the financial planning process is needed to align the revenue model with community needs, ensure community buy-in, and ultimately contribute to long-term sustainability. This is achieved

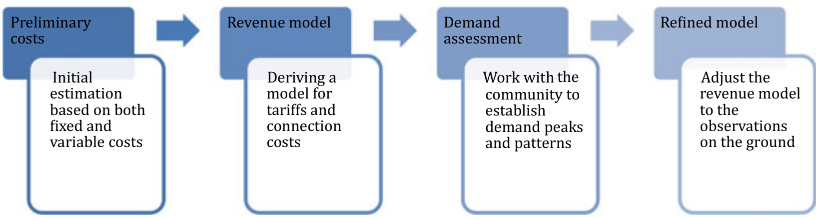


Fig. 5.1 Steps towards the development of a financial plan

through clearly understanding customer demand and seeking input on affordability, expectations, and potential contributions to the CES. The initial revenue model can then be tested against the community's feedback, analysing its feasibility and refining it based on community preferences to ensure it aligns with the overall objectives of energy access and community resilience.

Direct negotiation with the community may also help to reduce specific costs. This involves collaborative decision-making on maintenance, resource allocation, or shared responsibilities. Establishing a continuous review process to monitor the financial plan's performance, which regularly assesses whether the CES's financial objectives align with the evolving needs and dynamics of the community, is also required.

5.3 Costs of CESs

From the point of view of investment and financial management of a CES, it is helpful to distinguish between capital expenditure (CAPEX) costs and operating expenses (OPEX).

- CAPEX are the major investments that will take place during the project's life. In terms of investment, they include long-term capital expenditures (infrastructure and equipment) for purchases that will be used for longer than a year.
- In contrast, operating expenses (OPEX) are the expenses that are required to keep the infrastructure working, such as maintenance contracts, site staff wages, as well as business costs, including rent, transport, and overheads.

Fully understanding CAPEX and OPEX costs requires substantial stakeholder engagement, technical design iteration, financial modelling iteration, regulatory approvals, community governance, and developing sustainable operational models (Fig. 5.2). There can be a tendency to underestimate overheads, transaction costs and the management of customer relationships, which should be avoided through project planning.

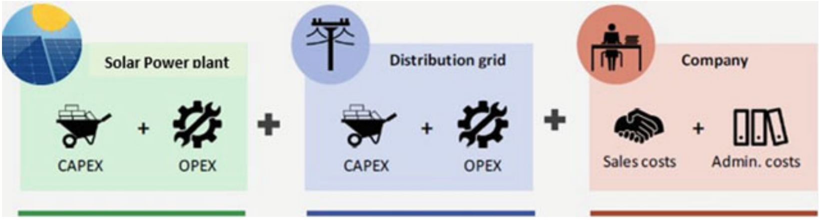


Fig. 5.2 Costs of installing and operating a solar micro-grid CES

5.3.1 *Capital Expenditure (CAPEX)*

A micro-grid generally comprises a generation unit (solar, wind, hydro, bioenergy, or diesel), distribution infrastructure (wires and poles for transporting the electricity to customer connections as well as premises wiring), customer consumption monitoring (meters or smart meters), and remote monitoring (AMDA, 2020).

Calculating CAPEX for a CES involves a systematic approach encompassing multiple key steps. Once a community has been identified through detailed site selection, factors such as geographical location and community needs are considered, and a comprehensive demand assessment is carried out. This is conducted through surveys or utilising measured data from analogous projects and provides insights into the energy requirements of the targeted community. Subsequently, the technical design phase involves sizing components for the generation and distribution aspects to meet the demand using the available renewable resources, which informs a detailed Bill of Quantities[1] with associated costs derived from local suppliers. Figure 5.3 shows a typical breakdown of Capex for a 30 kW solar-diesel hybrid micro-grid.

In addition to CAPEX for components for the CES, installation costs must be included taking into consideration wages, transport, and other overheads of the local installation team. Community engagement is another integral cost, evaluated in terms of organising awareness programmes, fostering local support, and ensuring the active involvement of community members through training and workshops. Other

[1] A Bill of Quantities or BoQ is a tendering document most frequently used in construction and project delivery that presents an itemized list of costs, including materials, parts, and labour.

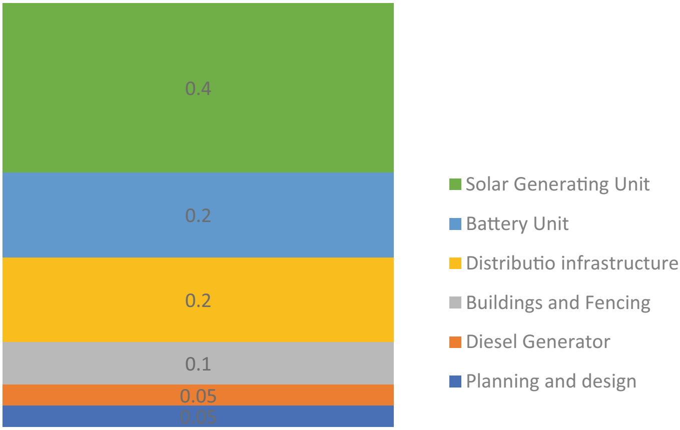


Fig. 5.3 CAPEX for a 30 kW solar mini-grid

additional non-technical CAPEX costs are getting the project up and running, including the cost of obtaining necessary approvals, and licences and navigating regulatory frameworks. Such non-technical considerations are fundamental for the holistic and sustainable development of a CES, aligning technical goals with the broader community context.

A pico-system such as the one proposed in CESET may require further investment down the line to cover additional CAPEX financing needs that may not be covered by the project budget and that will continue after the funded period has ended. These CAPEX costs cover sporadic instances and require investment that cannot be fully accounted for in the current year, all depending on the quality of negotiations with the community (Table 5.1).

High upfront CAPEX can pose a challenge for CES, especially when dealing with individual sites, despite global trends of reduction in costs for components such as photovoltaic (PV) panels and batteries. Implementing bulk purchasing strategies allows for economies of scale, enabling cost efficiencies in acquiring necessary components. Further, improvements in supply chains, marked by reduced transport fees and streamlined logistics, contribute to overall CAPEX reduction. In some countries, policymakers and businesses have explored opportunities to waive import duties and taxes, which can make the deployment of CES more financially feasible and sustainable.

Table 5.1 Additional CAPEX costs unique to CES systems

Types of costs	*Elements that require negotiation with the community*
Consumer/community finance to address the affordability gap of end users and lack of access to financing for small enterprise and community initiatives	Community engagement to determine which appliances are needed, what the affordability is of the customers including payments on loans as well as legal and financial services fees
Handover costs of transferring micro-grid ownership and management to a community body	Handover staff training Support from CESET/current owner during transition
Extension to generation or distribution systems	Assessment of load growth and potential future demand of customers. Potential new customers wanting to be connected

5.3.2 Operational Expenses (OPEX)

Unlike CAPEX, which addresses initial capital needs, OPEX caters to the day-to-day expenses incurred during the lifespan of CES. An understanding of the intricacies of ongoing operational costs is key to ensuring CES functionality, optimising resource allocation for routine activities, ensuring the longevity of projects, and crucial for establishing a robust financial framework that contributes to the enduring success and resilience of CES.

Examples of OPEX costs include maintenance contracts, monitoring fees (e.g. data or SaaS), security, fuel, customer service, billing, collection, and land rent. Costs can either be fixed (e.g. the depreciation of assets, interest on debts, fixed taxes, and fees) or vary based on demand or number of customers. A breakdown of routine costs for a 30 kW solar micro-grid is shown in Fig. 5.4, while a summary of different types of OPEX costs is outlined in Table 5.2.

OPEX costs do not typically become known until after financial close, and often after months of steady operations. However, to aid planning, pre-project financial modelling use rules to anticipate what OPEX costs may be. One approach is to estimate OPEX costs as 20% of expected total annual revenues; another is around 5–10% of total CAPEX costs. For example, if CESET has a maximum CAPEX budget of £75,000, OPEX costs could be in the region of £3–10,000 per annum. This value is entirely dependent on the nature of the micro-grid installed, including

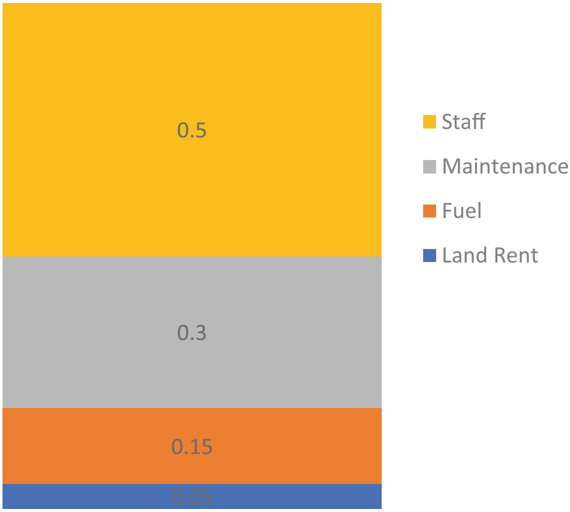


Fig. 5.4 Example OPEX costs for a 30 kW solar-diesel mini-grid

Table 5.2 Standard types of OPEX costs

OPEX type	*Description*	*Example*
Fixed costs	Do not vary with changes in volume demand, peak demand, or no. of customers	Overheads and transactions costs, local operation costs, office costs, management staff
Demand variable costs	Vary with changes in the volume of demand	Fuel costs, lubrication oil, maintenance related to throughput, revenue-dependent taxes
Customer variable costs	Vary with changes in the number of customers	Marketing and outreach campaigns, data fees for smart meters

its scale, the existing and future demand on the grid and the baseline economic situation at the chosen site.

In addition to typical OPEX costs incurred by mini-grid developers, CES may have additional OPEX costs to consider accounting for the enhanced community involvement outlined in Table 5.3.

Table 5.3 Examples of exceptional OPEX costs related to CES

Types of costs	*Elements that require negotiation with the community*
Operational costs involved in the collection and management of metering, billing, and payments	• Consideration must be given to the implications of choosing mobile, token, or cash-based payment systems and of choosing the authority responsible for payment collection • Consideration must also be given to the adequacy of different modes of payment: prepayment, pay-as-you-go, post payment
Operational costs involved in after sales and customer service	• Customer issues • Customer/staff training and capacity building • Customer onboarding, marketing, and upselling
Operational costs involved in technical maintenance	• Call outs for minor repairs • Call outs for component replacements • Call outs for infrastructure repairs, upgrades, and expansion • Safety checks • Further considerations include the need for agreements with third-party suppliers (e.g. metering and payments vendors), and contracts with post-project contractors that will need to be agreed upon to deliver operational support and services
Capacity building	• Investment in community capacity building to enhance financial literacy and understanding of the CES's financial dynamics • Training on safe use of electricity or using electricity to start businesses to promote economic development
Monitoring and evaluation	• Implementing robust monitoring and evaluation mechanisms to track the financial plan's effectiveness, including regular assessments of revenue generation, cost management, and overall financial sustainability • Measuring the social impact of the CES in order to adapt the delivery model to improve value to the community

According to a survey of 13 African Minigrids (International Finance Corporation, 2017), OPEX typically account for 58% of revenue, while when combined with administrative costs, the total expenditure reaches 128% of revenue. Such high OPEX costs are due to high operational expenditure from challenges of reaching remote locations and the need to trial unproven operational strategies, coupled with the fact that revenue is low (IRENA, 2018). The use of smart meters and remote monitoring can reduce OPEX costs by improving maintenance efficiency and reducing staff time. Additionally, CES can engage with the community to carry out routine maintenance to further reduce costs.

5.4 Revenue Model

The financial sustainability for CES, tariff modifications, and business model planning all depend on understanding revenue generation, aiming for a positive balance to be struck between income from electricity sales and operational costs for staff, maintenance, and other running costs. Revenue is earned through connection fees, electricity sales, and grants/subsidies and is reliant on variables including demand for electricity, the ability and willingness to pay and the tariffs set for consumers (USAID[2]). There is, however, an enormous gap in recognising and valorising the multiple benefits provided by community energy beyond producing sales revenues.

Tariffs need to be affordable to customers but also need to be at levels able to generate adequate revenues to meet recurring expenditures and other liabilities and, in some cases, generate an adequate profit and recover the capital cost of the system to be fully commercial (NDC Partnership[3]). Tariffs should be set based on projected demand, and in order for the scheme to be viable, they should cover all the costs, both fixed (e.g. operation, wages) and variable (e.g. maintenance, spare parts, training) of the CES (NREL, 2018). A basic rule generally accepted in rural electrification planning is that, regardless of the scheme chosen, a tariff should at least cover the system's running costs to ensure the ongoing operation of a system through its lifetime.

[2] https://www.usaid.gov/energy/mini-grids/regulation/tariffs, retrieved January 16, 2024.

[3] https://ndcpartnership.org/case-study/smart-incentives-mini-grids-through-retail-tariff-and-subsidy-design, retrieved January 8, 2024.

In crafting a robust tariff model for CES, several crucial factors demand consideration. Operational costs comprising an in-depth analysis of project-related expenses outlined above provide the foundation to determine the minimum revenue required for ensuring the financial sustainability of the project. The technology lifecycle adds an additional layer of complexity. Long-term financial planning into the tariff structure must incorporate the lifespan and depreciation of energy-generation technologies. Additional costs to cover may include interest on loans or equity demands from investors and potential income from subsidies or grants. The total revenue requirement is then compared with community affordability to devise tariffs to cover costs, ensuring tariffs are aligned with the community's ability and willingness to pay. This multifaceted approach ensures the development of a tariff model that is not only financially sustainable but also socially inclusive and considerate of the diverse dynamics within the community.

In delving into the critical aspect of community acceptance, actionable strategies for actively engaging communities throughout the tariff-setting process are required. Prioritising clear and transparent communication becomes paramount, highlighting the costs and benefits intricately linked to the tariff structure to foster community comprehension. Integrating community voices and preferences stands central in the process, employing consultative approaches to gather feedback and align the tariff model with local expectations, fostering a sense of community ownership. The implementation of educational programmes can enhance community understanding by shedding light on the factors influencing tariff rates and emphasising the broader benefits stemming from their contributions.

The ability and willingness to pay varies depending on the geographic location. Areas with larger population densities tend to have more vibrant economies; hence, micro-grids operating in those areas tend to be more profitable than those operating in remote locations (Bhattacharyya, 2018). Ideally, systems designed in rural areas should adopt a pro-poor approach to ensure affordability even for low-income consumers. However, micro- and pico-grids may have different requirements and can organise the tariff system in different ways. In our case, the tariff structure will have to be closely negotiated with the community and a realistic assessment of their capacity to make payments. Examples of tariffs paid by rural mini-grid customers in Africa are outlined in Table 5.4.

Within CES, there exists a spectrum of tariff models, each catering to specific requirements. Key tariff principles for CES include simplicity,

Table 5.4 Examples of cost reflective tariffs on mini-grids in Africa

Country	*CRT*	*System*	*Source*
Tanzania	USD 0.74/kWh	7 kW system	NREL (2018)
Ghana	USD 0.75—0.80 per kWh	100-household village, PV-diesel hybrid	NREL (2018)
Malawi	USD 0.5—1.2 kWh	12 kW system	EASE (2022)

fairness, transparency, justifiability, reasonability, and consideration of seasonality. Figure 5.5 shows some of the considerations involved when choosing different tariffs, while Table 5.5 provides an overview of various tariff types. It is worth noting a pertinent insight from the mini-grid literature, suggesting that pay-as-you-go systems may compromise the operation of mini-grids due to the absence of a consistent revenue stream (Bandi et al., 2022). This underscores the need for thoughtful consideration and adaptation in selecting tariff models to ensure the sustained success and resilience of CESs in dynamic community environments. Cross-subsidisation can be considered, exploring models that allow more affluent users to subsidise access for economically disadvantaged community members, fostering a balanced and equitable energy distribution system.

Navigating the development of a tariff model for CES presents inherent challenges that demand careful consideration. One significant hurdle involves managing the fluctuating energy demand within the community and formulating tariffs that can effectively accommodate these variations. Striking the right balance between simplicity for community comprehension and the necessary complexity to accurately represent the actual cost of energy provision adds another layer of complexity. Additionally, ensuring regulatory compliance is crucial, requiring a delicate approach to uphold established frameworks while also remaining adaptable to meet the unique needs of the community.

5.5 Finding the Finance

Funding is a critical aspect of CES development, influencing their sustainability and impact. From mini-grid experiences, financing the system requires looking beyond the material aspects of the projects. CES will require at least two types of financing:

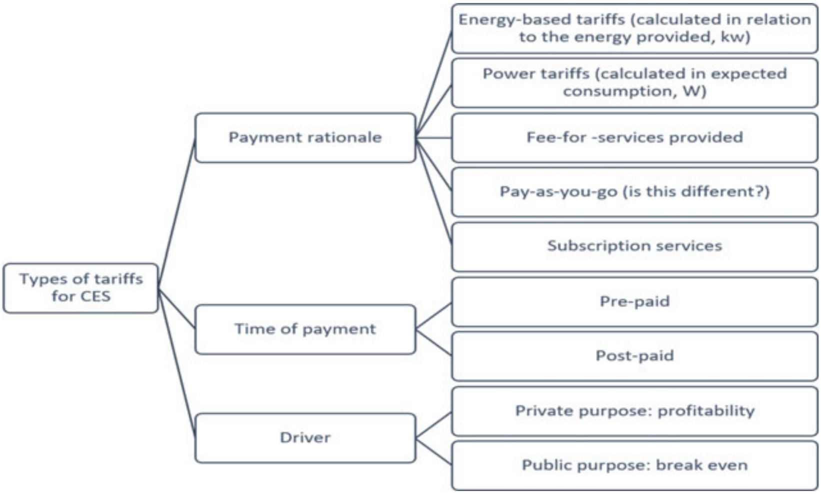


Fig. 5.5 Considerations for tariffs

1. Energy end users, for example, may lack the ability to pay for new appliances or one-time connection fees and, therefore, require financial assistance to be able to receive electricity from the grid.
2. Energy producers, those that install and operate the grid infrastructure.

Table 5.6 outlines the typical financial needs of different stakeholders.

As previously mentioned, the upfront costs of deploying remote infrastructure in rural areas are still high despite recent cost reductions in solar PV and batteries (IRENA, 2015). Additionally, due to uncertain demand, perceived low ability to pay, and challenges relating to maintaining energy infrastructure in remote areas, CES, such as micro-grids, are perceived as high risk by investors and donors (IRENA, 2018). To address these challenges, practitioners and project developers have trialled a variety of financing mechanisms, including public-private partnerships, crowd-funding, and micro-finance programmes. An outline of the key funding models for CES is summarised in Table 5.7.

Public financing, patient, long-term private financing, and public/private financing are all top-down state and market-driven approaches to increasing energy access through the financing of CES. These approaches

Table 5.5 Types of tariffs

Type of Tariff	*Description*
Energy-based	Charges are based on the amount of energy consumed, typically measured in kilowatt-hours (kWh). Users pay for the actual energy they use
Power-based	Charges are based on the maximum power demand or capacity required by the user, often measured in kilowatts (kW). The tariff is determined by the peak power demand
Flat rate or service tariff	Users pay a fixed rate or fee for the service, regardless of the amount of energy consumed or power demanded. It provides simplicity and predictability
Pay in advance or after usage	Payment is made either before using the energy or after consumption. Prepayment models are common in off-grid systems to ensure revenue collection
Limited or unlimited power consumption	Users may have a capped limit on the amount of power they can consume (limited), or they enjoy unrestricted consumption (unlimited) within a specified period

rely on governments or businesses providing capital or subsidies for the construction and operation of energy infrastructure (USAID[4]). The benefits of these approaches include lower upfront costs and access to a larger pool of capital. However, drawbacks can also include a lack of flexibility, high transaction costs, and a lack of local control.

Alternatively, bottom-up, cooperative, and social enterprise models have been deployed to deliver community energy in recent years, providing an alternative to traditional financing models. These models are characterised by increased community involvement and ownership, with local stakeholders actively participating in the design and implementation of CES (Safdar, 2017). While these models require more upfront

[4] https://www.usaid.gov/energy/mini-grids/financing/capital, retrieved January 16, 2024.

Table 5.6 Stakeholder types and financing requirements for these two user types

Stakeholder	*Indicative list of typical financing needs*
Energy End Users • Households • Small enterprises and local livelihoods (including agriculture) • Health, education, and community institutions	• One-time down payment for energy system (e.g. connection fee) • Ongoing payments for energy system (e.g. kWh tariff) • Maintenance fees and service payments • Purchase of efficient appliances/ equipment (particularly small enterprises, local livelihoods and health, education and community institutions) • Upgrading energy system (e.g. higher tariff) • Start-up capital for livelihoods/ enterprises resulting from energy access (productive use of energy)
Energy producers • For-profit enterprises- micro, medium, and small sized • NGOs engaged in service delivery	• Capital for early stage innovation, R&D and installation and procurement • Pilots and demonstrations to prove the service model • Working capital for operations • Consumer finance/credit to address affordability gap of end users • Internal capacity building and training • Credit for growth and expansion • Capital for diversification of products, solution and upgrading technology to meet consumer needs • Credit or fee to enable servicing in distant/ remote areas

effort and resources, they can also provide more autonomy and greater local ownership in the long term. This model points towards the need to examine the costs in practice as they unfold in each context. While micro-grids are dependent on a solid investment plan to attract businesses or other organisations (such as cooperatives) who want to run them, community energy systems may depend on the reduction of operating costs to the minimum.

Table 5.7 Key Funding models for CES

	Advantages	*Disadvantages*
Grants and Subsidies	• Provides upfront capital without the need for immediate repayment • Alleviates financial burden on communities during the initial project stages • Often targeted at renewable energy projects, encouraging sustainable practices	• Dependency on external funding sources, which may be limited or subject to policy changes • Grants may have specific criteria, restricting flexibility in project design
Private Sector Finance (Debt and Equity)	• Can provide significant capital through debt or equity arrangements, supporting the financial needs of CES projects • Attracts investors seeking financial returns, aligning with profit-driven motives and potentially facilitating large-scale funding	• Debt financing requires repayment with interest, increasing financial obligations for the CES project • Equity investors may seek ownership stakes or dividends, potentially compromising community control over the project • Contingent on the financial viability and creditworthiness of the CES project
Public–Private Partnerships (PPPs)	• Combines public and private resources, sharing risks and responsibilities • Attracts private sector expertise and investment	• Complex negotiations and potential conflicts of interest • Profit-driven motives of private partners may clash with community-focused objectives
Community-Based Financing	• Fosters a sense of ownership and empowerment within the community • Aligns with the principles of social and economic development	• Limited capacity in communities to raise substantial capital • Slow pace of fund accumulation, potentially delaying project implementation

(continued)

Table 5.7 (continued)

	Advantages	*Disadvantages*
Impact Investing	• Attracts private capital to match financial return and positive social and environmental impacts • Aligns with the increasing trend of socially responsible investing	• May prioritise financial returns over community needs • Limited availability of impact investors in some regions
Crowdfunding	• Engages a broader audience in supporting community energy projects • Accessible and transparent fundraising model	• Reliance on the community's ability to mobilise support • Uncertainty in achieving large-scale funding goals

Several key considerations play a crucial role when selecting funding models for CES. First and foremost is the level of community involvement and their willingness to contribute financially, emphasising the importance of understanding local dynamics. The scale and complexity of the project are also pivotal factors, with different funding models aligning better with varying project sizes and intricacies. Additionally, stakeholders must evaluate their risk tolerance, accounting for financial stability and uncertainties inherent in the project. Being mindful of the regulatory environment, encompassing local and national regulations governing energy project funding, is essential. Furthermore, the consideration of the long-term sustainability of the chosen funding model extends beyond the project's initial phases, ensuring enduring success and impact.

5.6 Community Energy in Malawi

The Rural Energy Access through Social Enterprise and Decentralisation (EASE) project,[5] whose aim was to progress the SDG7 in Malawi, ran from 2018 to 2024 with funding from the Scottish Government. EASE was coordinated by the University of Strathclyde in partnership with Self Help Africa. The objective was to increase access to sustainable energy

[5] https://ease.eee.strath.ac.uk/.

for rural communities in Dedza and Balaka, enabling economic development and improved livelihoods. Two solar micro-grids were installed in the Dedza district through EASE, generating and distributing power for localised domestic and productive uses (Fig. 5.6).

The key lessons learned from these installations were:

- Capital and operational costs were high when compared with established benchmarks, underscoring the emergent nature of this market in Malawi.
- Demand and ability to pay for electricity services were both found to be high, despite the rural location and low incomes of the community.
- While revenue generated from electricity sales adequately covers on-site operational expenses encompassing maintenance contracts, data management, and site agents, it falls short of covering broader organisational costs like transportation and staff salaries.

Fig. 5.6 12 kW solar micro-grid, Mthembanji, Malawi

Table 5.8 Technical overview of Malawi micro-grids

	Kudembe	*Mthembanji*
Installed	2022	2020
Number of customers	50	60
PV Generation	11 kW	12 kW
Distribution grid	240 V single phase	
Battery Capacity	20 kWh Li-ion	19.8 kWh Li-ion
Inverter manufacturer	SMA	
Installation and Maintenance	BNG Electrical, Lilongwe	
Smart Meters	Steamaco	

- Community micro-grids in Malawi depend on continued donor support and subsidies to achieve financial sustainability.

A summary of the technical parameters comprising solar PV, lithium-ion batteries and a single-phase distribution grad are summarised in Table 5.8.

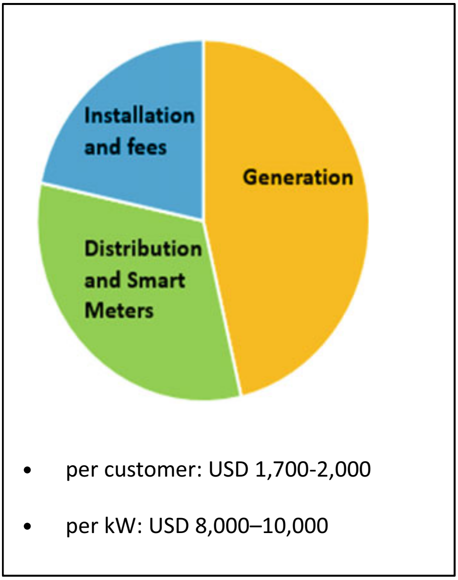
5.6.1 Capital and Operational Costs

Capital costs have been found to be high. These are pioneering projects in Malawi and costs are expected to reduce as more micro-grids are installed creating economies of scale. Transport costs from South Africa increased the costs further.

In the future, the strengthening of local supply chains for solar equipment may drive these costs, including transport, down. However, high costs are also due to inflation and foreign exchange rate fluctuations, pushing local fuel and labour prices up and resulting in significant cost increases for local component and contractor costs. Macroeconomic volatility has a direct impact on local supply chains and micro-grid project costs and is likely to be a key influencing factor on future micro-grid CAPEX in Malawi (Fig. 5.7).

Site-based operational costs for one of the micro-grids total USD 316.4 per month on average or USD 3,796.80 annually. Operational costs include site agent and security guard salaries, data and SaaS fees for smart meters, and a generation and distribution maintenance contract, but do not include field and management staff costs, transport costs

Fig. 5.7 Malawi case study CAPEX



and business overheads, as these have been covered through EASE grant funding.

The cost per customer per month (USD 4.27) is on the high side of benchmark estimates for sub-Saharan Africa, which tend to be in the bracket of USD 2.50–6.00 (AMDA, 2020) (Fig. 5.8). A comparison with monthly revenue reveals income only just covering site-based costs, compromising financial sustainability without interventions on tariffs or demand.

The majority of OPEX costs come from a maintenance contract with a Lilongwe-based electrical contractor. This is currently the only option given the lack of technical capacity to conduct robust maintenance on micro-grids. There is great potential to reduce these costs through in-house maintenance technicians, with salaries paid through central funds, and only paying for transport/material costs needed for maintenance trips. Travel to different micro-grid sites could be combined, and efficient logistics strategies could be employed to reduce travel times and save on costs.

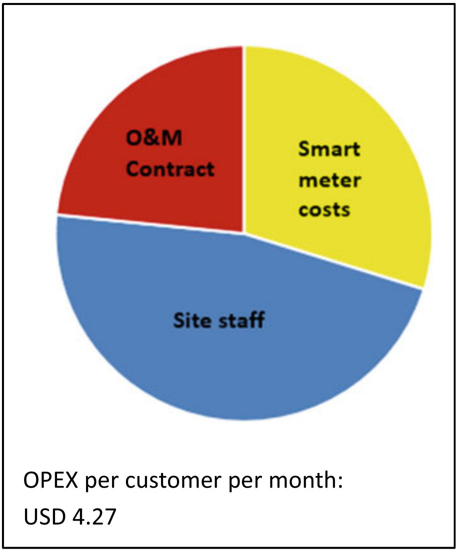


Fig. 5.8 Malawi case study OPEX costs

5.6.2 Setting Up Tariffs

Tariffs are paid through site agents in a PAYGO format, where customer balances are topped up through the SteamaCo platform.[6] The tariffs have been set and adjusted through ongoing community engagement and negotiations on willingness to pay, with different tariffs designed to cater for different customer segments, as outlined in Table 5.9.

The Banja tariffs offer a set allocation of energy for a daily fee, which allows for domestic use including lights, phone charging, and TV. The Ufulu tariff for business customers is tiered and reduced for higher energy users. A significant daytime discount (75%) promotes demand when excess electricity is available during sunlight hours.

Figure 5.9 shows Average Revenue Per User (ARPU) per month for 2021, disaggregated by customer segment. Residential ARPU follows a seasonal trend, with higher spending corresponding to the rice harvest season in July, while business ARPU is considerably higher and follows a less prominent seasonal trend. The mean ARPU for the year is 5.43

[6] More information on the commercial page. https://steama.co/#home, retrieved January 16, 2024.

Table 5.9 Tariff summary for Mthembanji and Kudembe

Bundle	*Services*	*Payment type*
Banja Monthly (Household)	A set allocation of energy (260 Wh per day) which approximately equates to a daily service of: – 3 lights for 3 hours – 1 light for 8 hours – 1 hour of TV – 2 hours of phone charging	Monthly service fee
Ufulu (Freedom)	Unlimited electricity paid for per unit. A cheaper rate applies for higher use	Pay as you Go
Ufulu Daytime	Daytime discount 75% reduction in standard Ufulu costs	Pay as you Go
Midzi (Community)	Electricity for Schools, Churches, or other community groups based on your needs	Pay as you Go

USD/month, which is higher than estimates for Tanzania ($4.58), Kenya ($2.96), and Nigeria ($4.83) (AMDA, 2020).

The seasonal trends corresponding to harvest seasons can be used to plan timings of appliance financing programmes or seasonal tariffs. Acknowledging the mean ARPU of businesses (USD 8.48) is more than double residential (USD 3.89) highlights the importance of increasing revenue through promoting productive Uses of Energy with targeted

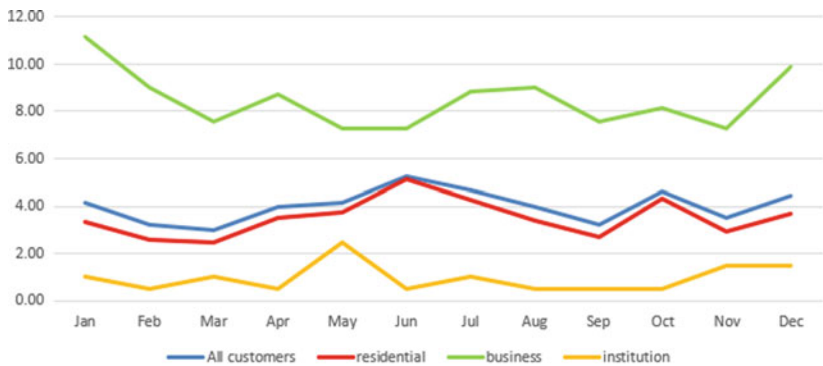


Fig. 5.9 Customer disaggregated Average Revenue per user per month (USD), 2021, Mthembanji

business support. In the case of Mthembanji, the income only covers the monthly OPEX costs, and provides no support for additional staff costs, transport, or wider business costs.

The ARPU data provides valuable insight into rural customers' ability and willingness to pay. The community initially found the tariff too high, resulting in complaints and negotiations conducted over time to find an acceptable tariff. Ongoing assessment of willingness to pay is essential for finding appropriate tariffs, ensuring customer satisfaction and sustainable electricity consumption levels that don't further impoverish communities. Data sharing of ARPU between micro-grid developers progresses the knowledge base to inform sustainable business models with affordable tariffs.

5.7 Conclusions

This chapter has outlined the basic financial features of CES development. Selecting appropriate financial management approaches and funding models are strategic decisions that necessitate careful consideration of community dynamics, project characteristics, and the broader socio-economic context. By exploring and understanding the advantages and disadvantages of different approaches, CES developers can tailor their strategies to ensure both short-term success and enduring impact.

Advancing the understanding of the financial management of CES requires closer collaboration between academic institutions and practitioners, leveraging data analysis and knowledge exchange. Techno-economic business modelling should be a priority, with a focus on developing and testing CES business models linked to innovative financing mechanisms. Additionally, research should emphasise CES performance monitoring through data acquisition and analysis, understanding demand patterns, and exploring productive use opportunities and their contribution to sustainable business models. Longitudinal studies assessing social impact, conducted through cross-disciplinary collaboration and social impact surveys following established frameworks and best practice guides, will provide insights into community benefits, guiding recommendations for interventions to increase community participation and impact from electricity connections. These research areas collectively contribute to accelerating CES deployment and ensuring financial sustainability.

The introduction of smart subsidies is essential to address the financial challenges faced by CES. These subsidies, supported by the government, can enable CES to connect and provide reliable electricity services to rural communities, balancing affordable tariffs with operational sustainability. A well-designed subsidy system, based on data sharing among active CES projects, can be economically modelled to determine the necessary support. Removing barriers such as VAT and Import Tax on CES components can significantly reduce capital expenditure, fostering a more favourable financial environment. Investing in research and capacity building is crucial, involving efforts to develop skilled technicians, system designers, and business expertise through government-supported training programmes, business development initiatives, and collaboration with academia on research and development initiatives. Collectively, these policy recommendations aim to create an enabling environment for the sustainable financial management and deployment of CES.

The main financial question is whether a CES can be integrated within a community in a way that the community can reduce its operating costs and support its long-term viability. It follows that a process of negotiation of community governance may help redefine the terms of implementation and, hence, support the viability of alternative finance models or subscriptions. The question that follows is which of those costs could be supported by the community. These are two complicated questions which we hope we will be able to answer within the life of the project CESET.

Acknowledgements This chapter is inspired by and expands preliminary work presented in CESET's briefing note "Financial aspects of micro- and pico-community energy systems", available at https://cesetproject.com/sites/default/files/Financial%20aspects%20of%20community%20energy%20systems.pdf.

References

AMDA African Minigrids Development Association. (2020). *Benchmarking Africa's Mini-grids*. Retrieved January 8, 2024, from https://shellfoundation.org/learning/amda-benchmarking-africas-mini-grids/

Bandi, V., Sahrakorpi, T., Paatero, J., & Lahdelma, R. (2022). The paradox of mini-grid business models: A conflict between business viability and customer affordability in rural India. *Energy Research & Social Science, 89*, 102535. https://doi.org/10.1016/j.erss.2022.102535

Bhattacharyya, S. C. (2018). Mini-grids for the base of the pyramid market: A critical review. *Energies, 11*(4), 813. https://doi.org/10.3390/en11040813

Dauenhauer, P., Frame, D., Eales, A., Strachan, S., Galloway, S., & Buckland, H. (2019). Sustainability evaluation of community-based, solar photovoltaic projects in Malawi. *Energy Sustainability and Society, 10*(1), 1–20.

EASE. (2022). *Deploying Solar Microgrids in Malawi*. Technical Report. Retrieved January 16, 2024, from https://ease.eee.strath.ac.uk/wp-content/uploads/2022/11/Deploying-Solar-Microgrids-in-Malawi-Technical-Report.pdf

International Finance Corporation. (2017). *Operational and financial performance of mini-grid descos*. Retrieved January 8, 2024, from http://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/IFC_Minigrids_Benchmarking_Report_Single_Pages_January_2017.pdf

IRENA. (2015). *Off-grid renewable energy systems: status and methodological issues*. Working Paper. Retrieved January 16, 2024, from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_Off-grid_Renewable_Systems_WP_2015.pdf

IRENA. (2018). *Policies and regulations for renewable energy mini-grids*. Retrieved January 16, 2024, from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Oct/IRENA_mini-grid_policies_2018.pdf

NREL. (2018). *Tariff considerations for microgrids in sub-Saharan Africa*. Retrieved January 8, 2024, from https://www.nrel.gov/docs/fy18osti/69044.pdf

Safdar, T. (2017). *Business models for mini-grids*. Smart Villages Technical Report 9. Retrieved January 8, 2024, from http://e4sv.org/wp-content/uploads/2017/05/TR9.pdf

Weston, P., Kalhoro, W., Lockhart, E., Reber, T. J., & Booth, S. S. (2018) *Financial and operational bundling strategies for sustainable micro-grid business models* (No. NREL/TP-7A40-72088). National Renewable Energy Lab.