SUSTAINABILITY, INCLUSIVENESS AND GOVERNANCE OF MINI-GRIDS IN AFRICA (SIGMA) RESEARCH PROJECT

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UNDERSTANDING BUSINESS MODELS AND ACCESS TO FINANCE FOR MINI GRID DEVELOPMENT IN SUB-SAHARAN AFRICA

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Abstract

This paper is based on a comprehensive literature review of publications from academia, industry, governmental and international institutions relating to business models, finance, and operational risks and challenges of mini grids in SSA. Firstly, we investigate the different business models that currently exist for mini grids in SSA and provide insights into the opportunities and challenges of each approach. Secondly, we identify access to finance as a prominent challenge to the further expansion of 'third generation' or solar/ solar-hybrid mini grids in the region. In so doing, we explore the different configurations of actors, institutions and processes involved in the provision of finance and investment for the sector. Finally, we examine some of the key investment, regulatory and operational risks and challenges in the sector's current and future development. Through such a study we shed light on the challenges and opportunities faced by the evolving sector in the region and consider successful approaches and best practices to advance sustainable energy access.

Despite notable growth in connections to solar or solar-hybrid mini grids in SSA and elsewhere, progress in bridging the rural electrification gap has been slow, with more than 560 million people still lacking energy access in SSA, particularly in remote areas considered too poor to afford cost-reflective tariffs. More clarity is needed between the optimistic promises and enthusiasm expressed in influential energy publications regarding solar mini grid development, and the level and quality of finance available for mini grids in the region. Moreover, while financial sustainability is often regarded as the main challenge for mini grid expansion, there is a complementary need for proven, successful, and scalable business models.

While the literature points to hybrid ownership, partially subsidised models, a focus on anchor customers, and the bundling of projects into financial portfolios as the most promising business strategies, we argue that there is no one-size-fits-all solution for mini grid business models in SSA. Success depends on specific external and internal challenges unique to each context (Franz et al., 2014; Safdar, 2017). Through our review, we find that an optimistic narrative towards private sector participation may not always translate into greater accessibility and affordability, particularly for geographically remote and low-income users and that while the mini grid sector in SSA has grown significantly in recent years, securing adequate and appropriate external finance remains a key challenge.

Keywords

Mini grids; business models; sub-Saharan Africa; financial sustainability; energy access; risks

CONTENTS

UNDERSTANDING BUSINESS MODELS AND ACCESS TO FINANCE FOR MINI GRID DEVELOPMENT IN SUB-SAHARAN AFRICA

Adriana Fajardo, Lucy Baker, Subhes Bhattacharyya, Temilade Sesan, Maneno Katyega, Daniel Kerr, Andrew Barnett

Acronyms

A-B-C	Anchor Business Consumer Model
AFD	French Development Agency
AfDB	Africa Development Bank
AMDA	Africa Mini grids Developers Association
ARE	Alliance for Rural Electrification
CAPEX	Capital expenditure
CIF	Climate Investment Funds
DFI	Development finance institution
EPC	Engineering, Procurement, and Construction
ESMAP	Energy Sector Management Assistance Program
GIZ	German Corporation for International Cooperation
GEP	Global Electrification Platform
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
KMM	Key Maker Model
O&M	Operation and maintenance
OPEX	Operating expenditure
PAYG	Pay-as-you-go
PPA	Power purchase agreement
PPP	Public-private partnership
PV	Photovoltaic
REA	Rural Electrification Agency
RECP	Africa-EU Renewable Energy Cooperation Programme
RBF	Results-based finance
RESCO	Renewable energy service companies
SDG	Sustainable Development Goals
SSA	sub-Saharan Africa

1. INTRODUCTION

By 2022, 650 million people globally lacked access to electricity, most of them in sub-Saharan Africa (SSA), where 58 per cent of the continent's population lives in rural areas (World Bank 2023). Significant gains in energy access worldwide between 2015 and 2019 have since been undermined by the Covid-19 pandemic, Russia's invasion of Ukraine and global inflation. Electrification progress has particularly lagged behind rural population growth in SSA. By 2021, SSA's access deficit was almost the same as in 2010, casting doubt on the electrification efforts promoted by national and international players. Based on figures at the time of writing, more than 500 million people will need to be connected in order for SSA to achieve the sustainable development goal 7 (SDG 7) target of "access to affordable, reliable, sustainable, and modern energy for all" by 2030, including 380 million connected to mini grid systems (ESMAP 2022:35).

Despite the growth of the solar and solar-hybrid mini grid sector in recent years, there is a disconnect between the enthusiasm expressed by energy and development institutions regarding the sector's actual and potential contribution to the realisation of energy access for all in SSA, and the level of finance and investment currently provided. According to estimations of ESMAP's Global Electrification Platform (GEP 2022:85), from the $91 billion investment requirement in SSA to connect 380 million people through mini grids, almost all in solar hybrid systems, by 2022 less than 10 per cent had been approved. Commitments from DFIs, including the World Bank, Climate Investment Funds (CIF), French Development Agency (AFD), the African Development Bank (AfDB), and the German Corporation for International Cooperation (GIZ), currently dominate the financing landscape for mini grids in SSA and serve to leverage private sector investments.

Moreover, while financial sustainability is often put forward as the most significant challenge for mini grid expansion (Tsuchiya et al 2020, Moner-Girona et al 2018, Ogeya et al 2021), it is also vital to recognise the complementary need for proven successful and scalable business models (ESMAP 2020, BNEF 2020) a term that we use to refer to ownership and management, revenue generation, customer focus, and implementation approaches. The nature of the business model plays a crucial role in ensuring the financial viability and long-term success of any mini grid project.

With this in mind, we carry out a literature review in order to firstly explore the different mini grid business models that currently exist in SSA and provide insights into the opportunities and challenges of each approach. Secondly, we identify access to finance as a prominent challenge to the further expansion of 'third generation' or solar/ solar-hybrid mini grids in the region. In so doing, we explore the different configurations of actors, institutions and processes involved in the provision of finance and investment for the sector. Finally, we examine some of the key investment, regulatory and operational risks and challenges in the sector's current and future development. Through such a study we shed light on the challenges faced by the evolving sector in the region and identify lessons about how mini grids could contribute to energy access goals more effectively.

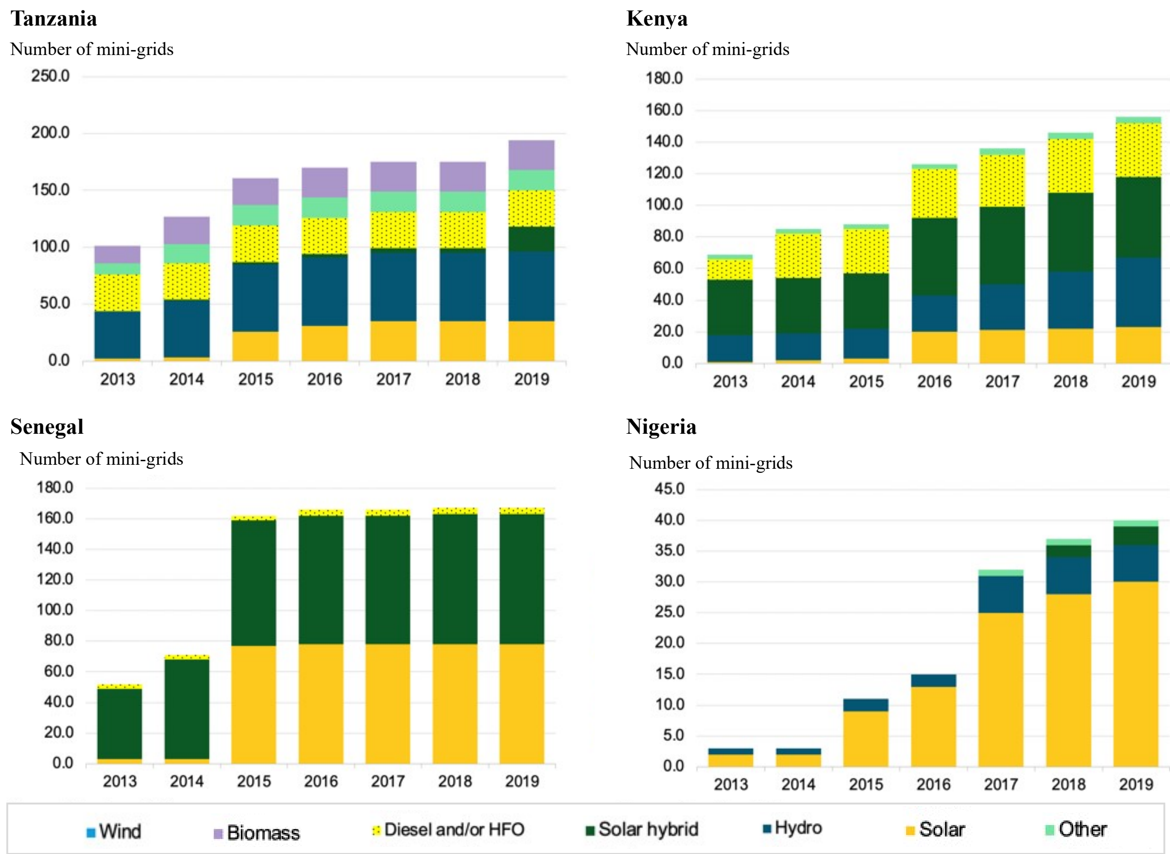
The term mini grid refers to a low-voltage or medium-voltage generation and electricity distribution network which can operate in isolation from the main grid, but also connect to it should the network expand. The nature of a mini grid is such that power can be generated much closer to the point of consumption (ESMAP 2019). Sometimes referred to as the 'missing middle' between the centralised electricity grid and solar home systems (SHSs), there is no clearly agreed definition of a mini grid in terms of size, generation capacity, customer base or energy source. It is a term through which the often-competing objectives of productive use, energy access and rural electrification are conflated (Baker et al 2022).

The installed capacity of a mini grid can also vary considerably depending on the context and the country, but typically falls within a range of 10 kW to 10 MW (Muchunku et al 2018:7). This, as compared to that of a micro grid which is usually between 1-10 kW (Ibid). Mini grids can also be differentiated from SHSs, which are based on Direct Current (DC) and largely deployed for the provision of energy access such as lighting, radio and mobile telephone charging. While SHSs sit under tiers one to three of the multi-tier framework for measuring electricity access, mini grids generally sit in tiers four and five (World Bank et al 2015) and can be converted to Alternating Current (AC).

While larger mini grids are better suited for more densely populated communities with higher demand levels, SHSs and smaller mini grids are considered the most cost-effective solution to connect poor, remote and often rural communities (ESMAP 2022; AMDA 2022). Mini grids are perceived as able to support productive use in addition to energy access (Bhattacharyya and Palit 2016). According to the African Mini grid Developers Association (AMDA 2020:41), in SSA mini grids can be deployed faster than the main grid and provide more reliable electricity, including to productive use customers.

The falling price of solar technology and battery storage has encouraged the growth of solar PV and solar-hybrid or 'third-generation' mini grids, as compared to previous systems, which were predominantly diesel and hydro-powered (ESMAP 2019). At the time of writing, 50 per cent of the approximately 21,500 existing mini grids worldwide were solar PV-generated (ESMAP 2022:30). Figure 1 shows the increasing trend in solar mini grids in four different countries of the region.

Figure 1. Mini-gids by type of technology in Tanzania, Kenya, Senegal and Nigeria



Source: Authors' own using information from Blomberg NEF database, 2022

Experience to date has shown that finding a balance between affordable service provision and adequate cost recovery is a key challenge for the financial viability of mini grids in the region, particularly where the project serves low electricity consumers with limited ability to pay in remote locations. Various options have been put forward in this instance, including the provision of public subsidies for either the project capex and/or the tariff, and the anchor customer-based model. However, as we find, there is no 'gold-standard' business model for financial sustainability and scalability. Additionally, the lack of quantitative evidence in the literature hinders the ability to compare and accurately correlate business models with financial outcomes. Similarly, while evidence from the literature points to hybrid ownership, partially subsidised, the inclusion of anchor customers, and financial bundling portfolios as the most promising business strategies, no bulletproof mini grid business model has proven to always work for SSA. Success is highly context-specific depending on external and internal challenges (Franz et al 2014, Safdar 2017).

The structure of this paper is as follows. Section 2 describes the methodology used for the literature review. Section 3 unpacks the different approaches to business models while Section 4 explores the main actors, institutions and processes involved in accessing finance for third generation mini grids in SSA. Section 5 goes on to examine the main investment risks and challenges of the mini grid sector to date. The paper concludes with a summary of the literature review findings by each type of business model, suggesting that a deeper understanding of business models is required given that the positive narrative towards private sector participation does not necessarily make electricity more accessible and affordable for users at the last mile.

2. LITERATURE REVIEW METHODOLOGY

This literature review draws from academic articles and reports by the energy industry published between 2005 (the earliest year for which publications on mini grids were available) and 2022. Publications were selected based on their relevance to the development of the mini grid sector, particularly their analysis of the SSA context. Industry reports covering other developing countries and global perspectives were also analysed. A search process was carried out using the following academic databases: Scopus, ResearchGate, and Google Scholar. While there are a limited number of academic articles specific to mini grid business models, the review examined the literature focusing on the socioeconomic performance and sustainability of the sector. The scope of the review is briefly summarised in Table 1.

Table 1. Scope of the review

Scope element	Inclusion criteria
Electricity systems	Mini grids
Geographical scope	Low and middle-income countries (particularly from SSA)
Publication date	2005 onwards (lack of publications before this year)
Publication format	Journal articles, working papers, evaluations, institutional reports, and media
Methodological approach	Primary and empirical studies using quantitative or qualitative data
Publication language	English and French

Source: Authors' own

The literature reviewed consisted of 109 documents, of which 52 per cent were peer-reviewed academic papers, and 48 per cent were grey literature and media. The literature consulted was mainly in English, except for some country reports in French. In reflection of the sector's development, most publications focus on the last eight years, from 2015 to 2022, followed by the preceding six years, with relatively fewer publications covering the period between 2006 and 2007. The growing number of papers and reports on mini grids in recent years reflects an increasing interest and relevance of the role of mini grids in energy access in developing countries, particularly in SSA. Countries including Tanzania, Kenya, and India are the most analysed in the literature, suggesting that one of the limitations of the literature is the lack of comparative case studies from elsewhere.

This research also included quantitative analysis from databases, such as Bloomberg NEF. However, the absence of quantitative methods to assess the influence of business models on mini grid profitability hindered the capacity to compare their financial sustainability. The former suggests the need for mini grid databases and more case-study analyses on business models to reach comparable information among and within countries.

The literature analysis was conducted using Nvivo software, and the information was coded in three main areas: business models, access to finance, and risk and challenges. Within each section, a list of sub-codes aggregates the most significant themes mentioned by the literature, as described in Table 2.

Table 2. Literature review coding

Main code	Business models	Risks and challenges	Access to finance
Sub-codes	- Ownership - Source of revenue - Customer focus - Implementation	- Regulation and market access - Demand and sizing - Macroeconomic risks - Affordability - Governance - Skills and technical - Social risks	- Type of funding - Sources of funding

Source: Authors' own

3. UNPACKING MINI GRID BUSINESS MODELS

There is no single definition of a business model in the literature—the term is used differently according to value creation, operations, and delivery structures. As a result, the description of a business model can serve different purposes. Business models for mini grids are defined in the literature according to different approaches to ownership and operations management (AfDB 2016, Franz et al 2014, Korkovelos et al 2020, Peters et al 2019, Safdar 2017, ECREEE 2016), the revenue models (Schnitzer et al 2014), the customer focus (Knuckles 2016, Ramachandran et al 2016), and the delivery and implementation schemes (ARE 2014; Weston et al 2018). The ownership approach is the model that is most covered in the literature, by multiple authors and international development agencies. In this section we disaggregate the different typologies identified in the literature, providing a summary of the various mini grid business models and approaches and insights into the challenges and opportunities of each type in the SSA context.

3.1 Ownership and management models

Mini grid ownership models vary according to who holds and operates the project's assets, including generation and distribution: these include public utility, private sector, community, and hybrid models. The ownership model often depends on the initial source of financing and the party responsible for managing the operations after installation. This characterisation of business models is the most used by industry reports. However, there is a lack of sufficient quantitative information regarding business models that allows for comparison. For example, according to the Bloomberg NEF 2022 database, out of the 984 mini grids identified in four countries in SSA (Nigeria, Senegal, Tanzania, and Kenya), only 470 were defined by ownership type. Table 3 shows the number of mini grids in those four countries by ownership model, indicating that public ownership is the predominant model in Senegal and Kenya, as compared to Tanzania and Nigeria, where the private sector has a larger market share.

Table 3. Number of mini grids by ownership model

Country	Total database	Public	Private	Public Private Partnership (PPP)	Community	Unknown
Nigeria	67	1	45	10	1	10
Senegal	431	107	1	6	7	310
Tanzania	278	36	112	5	42	83
Kenya	208	70	6	4	17	111
Total	**984**	**214**	**164**	**25**	**67**	**514**

Source: Authors' own using information from Bloomberg NEF Database 2022

The nature of mini grid ownership also depends on the regulatory framework where the mini grid is implemented (BNEF 2020) and context-specific variables, such as geography, and socio-economic and political factors (Safdar 2017). As discussed below, the literature suggests that none of the established ownership models has proven successful in SSA. However, according to industry reports, including by the AfDB and Bloomberg NEF, the public-private partnership (PPP) model has the most potential for scale-up, by leveraging collaboration and the advantages of each sector, assuming that the appropriate balance between private and public ownership and control can be established (AfDB 2016, BNEF 2020, ESMAP 2022:152).

3.1.1 Public utility model

Under a public utility model, the national electricity utility owns and operates the mini grids, as is the case in Senegal and Kenya for instance (see Table 3) and is responsible for installing, managing, and maintaining the system. The initial financing is likely to be provided by the utility and subsidised by public funds from government or DFIs through support for national electrification programmes (AfDB 2016, IED 2013, Safdar 2017). This model is seen as crucial to meeting the social objectives of electricity access and, in some countries, e.g. Namibia and South Africa, the utility often matches the grid's national tariffs, which are cross-subsidised by other customers (AfDB 2016, RECP 2014, Safdar 2017).

State-owned mini grids are relatively common in SSA and national utility companies have been key players in early mini grid development in SSA, including TANESCO in Tanzania and KPLC in Kenya (ESMAP 2019, Baker et al 2022), though they have primarily depended on conventional technologies and hybrid systems (Pedersen 2017). Despite the potential role that the public utility model could play in electricity provision, the industry often perceives it as more expensive and inefficient than privately-developed mini grids and there is inconsistent evidence on the success of this model (Antonanzas-Torres et al 2021, ARE 2014). Indeed, as some argue, most utilities in SSA are not financially solvent, sell at a loss, often lack the necessary technical expertise and frequently prioritise social and political outcomes over financial sustainability (Trimble et al 2016, USAID 2017, ESMAP 2022:152).

3.1.2 Private model

In this model, a private company develops, owns, and operates the mini grid, as is the case for instance in Tanzania and Nigeria (see Table 3). The funding can come from different sources, including private equity, commercial loans, and subsidised finance such as grants, results-based finance, or public sector loan guarantees (AfDB 2016, Franz et al 2014, Safdar 2017). The demands and expectations of equity investment are such that the mini grid must provide returns proportionate to the risk, which is a challenge given the lack of cost-reflective tariffs in certain countries (Weston et al 2018).

In recent years, the private sector has largely developed third generation mini grids in parallel with technological innovation and cost reductions in solar components (ESMAP 2022:82).

International energy institutions have called for more extensive private participation in SSA's rural electrification targets, arguing that with appropriate investment, the private sector model is better able to provide higher quality service and efficiency than other ownership models (ARE 2014, IEA 2022, ESMAP 2022). Access to subsidies or grants may enable the expansion of this business model. That said, private participation has faced its own challenges and few initiatives have achieved financial sustainability due to the lack of cost-reflective tariffs covering investment and operational costs.

The increasing interest of the private sector in mini grids is influenced by regulatory frameworks that promote market access for private-sector investment (AfDB 2016, Safdar 2017, ESMAP 2022). However, for the private sector to recover its investment costs, it tends to prioritise locations with commercial viability, including where anchor customers and productive users with higher demand are present (Safdar 2017:17). Consequently, scaling up private sector participation in mini grid development relies on regulatory frameworks that permit developers to charge cost-reflective tariffs (Knuckles 2016, ESMAP 2019).

3.1.3 Hybrid model

Hybrid models combine the features of public and private models, with different parties building, owning, and operating the distribution and generation assets of the mini grid. These models are based on a division of responsibilities through various contractual arrangements including PPPs, renewable energy service companies (RESCOs), concessions, power purchase agreements (PPA), and others, as discussed in Table 4. The shift towards private participation, together with the need for public utility involvement in reaching last-mile communities calls for the right balance between private and public participation and a clear regulatory framework that sets out the roles and responsibilities of both parties.

Table 4. Contractual options for Hybrid models

Public Private Partnership (PPP)	Contractual agreement between a public and a private party that combines financing, ownership, and management capacities.
Renewable Energy Service Company (RESCO)	RESCO companies work similarly to utilities at smaller scale, whereby the assets are purchased and owned by the government while RESCOs operate and maintain the mini grid.
Concession Model	A holder of a concession, usually a private developer, has beneficial terms for providing electricity services. Those terms can be translated in preferential market access for specific timeframes or specially designed tariffs for the area of operation.
Power Purchase Agreement (PPA)	A PPA is a contractual arrangement between the public and private sector parties for delivery of electricity where the public entity will purchase the power generated by the private energy producer over a certain time frame and under an agreed tariff structure. PPA is also mandatory for the public utility to sell power to a private company which is also a distribution network operator.

Source: Authors' compilation based on relevant literature cited in this section.

The most common hybrid models are PPPs with public ownership and private operation or split-asset models with public ownership of the distribution assets and developers owning the generation assets (BNEF 2020, ESMAP 2022:152). According to Gershenson et al (2015), the private sector finds risk allocation more efficient in this structure than fully private funded ones, as developers have a greater influence in defining the project's risks and benefiting from de-risking mechanisms from the public sector. It has been argued that PPP structures can overcome government budgetary constraints, diversify project risk between actors, and optimise the expertise and efficiencies of the private sector.

The participation of the private sector in mini grid development has been driven primarily by concessional instruments from DFIs and climate investment institutions, including low-interest and long-tenor project loans, public guarantees, and grant-based capacity building programmes (ESMAP 2022:131), building on the industry discourse of utility inefficiency and promoting private sector participation.

ESMAP (2022) has argued that one of the success factors of hybrid models is the collaboration between different players, bringing together experience in the sector, access to finance, technical capacity, and operational efficiencies. However, others have indicated that these models rely on the clarity of property rights regarding the assets, governance and technical arrangements, and interconnection policies concerning the utility's grid expansion (Safdar 2017, Weston et al 2018). Currently, there is a lack of quantitative analysis and case studies to demonstrate the effectiveness of this approach in enhancing the profitability of mini grids.

3.1.4 Community model

In this model, the mini grid is owned and operated by a local community that may have received mini grid assets from a government programme, a non-profit, or a development institution (BNEF 2020). Communities may also receive external support in designing, financing, and installing the mini grids, such as grants and in-kind contributions (AfDB 2016, Peters et al 2019, Safdar 2017). This model is more common in isolated rural areas that do not attract private-sector or utility interest because of the high cost of supply and where consumers may be too poor to afford cost-covering tariffs (ARE 2014, ECREEE 2016). This model is predominant in the development aid electrification projects aiming to empower local actors (AfDB 2016). Community-owned and operated mini grids often require technical assistance and support to train staff in operations and finance to provide a solid economic model that can continue in the long run.

Some authors have pointed out difficulties in building local capacity and the risk of donor dependency, raising questions regarding this model's sustainability and long-term viability (Franz et al 2014, Yadoo 2012, Duran & Sahinyazan 2021). Others argue that community models often require subsidies, continuing funding, and technical support (Gershenson et al 2015). Ilskog & Kjellström (2008) suggest that the sustainability of the community model could improve if it operates as a rural power cooperative whereby financial discipline mirrors a private model.

3.2 Consumer focused models

While it is often assumed that mini grids will provide access to low-income, rural, and isolated communities, developers and financial actors generally consider the level of electricity demand within such communities too low to ensure the economic sustainability of the system (Peters et al 2019). Many have therefore argued that the limited ability of low-income households to pay increases the need to foster productive energy use and integrate larger commercial and anchor customers to increase demand (AfDB 2016, Pueyo et al 2020, AMDA 2020:40). Likewise, ESMAP (2022:117) points out that mini grid sustainability relies on increasing the productive uses of electricity, stimulating demand, and community engagement.

Under consumer focused models, new approaches to incentivise productive energy use have become a priority for designing and implementing many mini grid projects. However, there is little available evidence to date about whether strategies to promote productive use are succeeding in improving mini grid profitability. While some studies show positive impacts, e.g. Kirubi et al. (2009), others show no evidence of improvement in enterprise profits and productivity (Pueyo & DeMartino 2018).

3.2.1 Households and small businesses approach

In low-income markets, off grid solar systems often serve households and small businesses, sometimes providing electricity for a lower price than other energy sources, such as kerosene (Knuckles, 2016). However, mini grid tariffs which are often more expensive than subsidised grid electricity, can create an affordability barrier for off-grid populations. Indeed, there was little evidence in the literature to suggest that mini grids can achieve long term financial sustainability by focusing on household and small businesses customers alone (Peters et al 2019, Pueyo & DeMartino 2018). In rural SSA, the average consumption per mini grid customer tends to be very low, with limited ability to pay (AMDA 2020:37). Moreover, rural electricity demand tends to fluctuate alongside seasonal household income and so fails to match the regular expected demand estimate for the systems (Peters et al 2019).

Various authors have therefore called for increasing and promoting productive users and facilitating access to appliances, e.g. water pumps, freezers, and milling machines, and fostering community engagement in order to stimulate demand, achieve a sizeable and stable load and ultimately the revenue streams of the developer (Bahaj & James 2019, Sharma & Palit 2020, Uamusse et al 2020). To do this, ESMAP (2022:8) argued that increasing the uptake of productive-use equipment would require approximately $3.6 billion in affordable consumer finance.

The Key-Maker model (KMM), which combines mini grid operations with an energy-intensive commercial activity, stands out among approaches to promote productive uses (Peterschmidt 2019a) and has been pioneered by the Tanzanian mini grid developer JUMEME (Pueyo et al 2022). Under the KMM, the mini grid developer diversifies from electricity generation by offering only electricity with another complementary pre-processed good. This secondary business line is energy-intensive, e.g. manufacturing, often using the natural resources and supply chains already available in the community. For instance, the mini grid company buys local agricultural products, processes them using electricity generated by the mini grid, and transports them to be sold in urban areas. This way, the developer sets up a stable demand for the mini grid while making profits further downstream (Peterschmidt 2019a:8). However, a key challenge of the KMM relates to the capacities and knowledge needed to operate a business beyond the mini grid (Pueyo et al 2022).

3.2.2 Anchor Business Consumer – A-B-C model

The A-B-C model was first developed in India in association with the telecom sector (GIZ 2014). Under this model, a large industrial customer with a high and stable load, such as an agro-processing or mining company that requires access to reliable electricity for their operations, or a group of industrials with reliable cash flows, act as anchor clients. The electricity supply for these customers is prioritised, followed by small productive users and households (Franz et al 2014, Ramachandran et al 2016, ESMAP 2022). This model aims for stable revenue that improves the sustainability of mini-grid operations, reducing the risk of connecting smaller consumers with lower payment capacity by lowering the unit cost of electricity (Beath et al 2021). The mini grid size may be defined primarily by the demand needs of the anchor load. Two examples include Sincro Sitewatch in Tanzania and Kirchner Solar in Uganda (EEP 2015, EAPN 2018).

While the main success factor of the A-B-C model is the long-term relationship with the anchor customer, prioritising the demands of the anchor customer can limit the mini grid capacity to extend connections and guarantee service reliability to smaller users, raising questions about the extent to which it will increase access to energy for low-income households (Bhati & Singh 2018). Moreover, the lack of availability of large businesses in many rural areas may limit the scalability of this business model. The nature of this model could also lead to cherry-picking and neglect of poorer communities (EEP 2015).

3.3 Cost recovery models

Business models can differ in their financial and organisational structure between for-profit, partially subsidised, and fully subsidised (Schnitzer et al 2014). These business models also differentiate between commercial and non-commercial operated mini grids defined by the approach to tariff revenue versus subsidised systems. The sustainability and inclusivity of cost recovery models depend on finding a balance between for-profit and subsidised approaches. When more grants and subsidies are provided, it results in lower tariffs, which, in turn, makes the service more affordable for end-users.

3.3.1 For-profit model

The for-profit model refers to mini grids that must cover their investment and operational costs through tariff collection. This model focuses on the customers' payment capacity, particularly looking at productive users (Schnitzer et al 2014). For-profit models share the same commercial approach as the private ownership business model, as both require cost-reflective tariff structures (Schnitzer et al 2014). This model therefore prioritises medium to large electricity consumers and communities with greater demand and payment capacity. Concerns have been raised that the nature of this business model is unlikely to assist with access to energy for low-income consumers. Not least, the low payment capacity in many rural areas and the inability to apply cost-recovery tariffs poses a challenge to the model's viability. The need for tariff subsidisation has therefore been emphasised as a solution (Knuckles 2016, Muchunku et al 2018).

3.3.2 Partially subsidised model

There is a strong call in much of the literature for the need for subsidies to guarantee cost-reflective tariffs that match those of the utility. Approaches that involve the public sector as a stakeholder in mini grid projects allow for the implementation of cross-subsidised tariffs.

The partially subsidised model is based on grants or subsidies from government electrification programmes and DFIs for initial investment costs but relies on tariff collection to cover operations and maintenance. The social orientation of the funded capital requires that the mini grid guarantee energy access to a pool of off-grid customers while assuring the tariff collection for its operation (Schnitzer et al 2014, Antonanzas-Torres et al 2021). Therefore, this model mixes the need for financial sustainability with the purpose of providing access to multiple types of customers. Facilitating affordable tariffs requires the mini grid developer to innovate in the project's economic structure, for instance, allowing differential tariffs by type of customer, smart metering and pay-as-you-go (PAYG) systems (Schnitzer et al 2014). The most significant challenge for the viability of this model is its dependence on subsidised support and the risks of not offering a cost-effective and affordable supply.

3.3.3 Fully subsidised model

While the literature consulted argues strongly for the need for subsidies, the evidence is inconsistent on the level of assistance required and the best financial structures with which to channel it. Moreover, while financial support may allow for the setting of affordable tariffs, fully subsidised models may challenge developer autonomy and set a dependency on the donor.

The fully subsidised model covers all its costs through subsidies or grants from the government and DFIs, in-kind contributions from communities, and tariff collection to cover a percentage of the operation and maintenance expenses. This model follows the interest of the funding source, commonly targeting areas with low payment capacity or a remote or difficult-to-reach location, and often works with local communities to stimulate electricity demand (Schnitzer et al 2014). Therefore, the developer allows a tariff structure that fits the affordability needs of the consumer rather than prioritising cost recovery through tariff collection. The fully subsidised business model is similar to the community ownership models, as both are fully funded by a third party and focus on social impact over financial sustainability. This model depends on a clearly defined role for each party involved, strong engagement with communities to build local capacity and long-term engagement from donors (Schnitzer et al 2014).

3.4 Bundling models

Building an investment portfolio of mini grids, which may involve bundling projects by location, operations, and/or financial structures can help lower costs and risks for developers and investors (Franz et al 2014, Safdar 2017, Weston et al 2018). Bundling initiatives are attractive for private players and financial institutions due to their potential to help scale up the mini grid market size, lower operational costs and ensure economies of scale in project management, procurement, and installation (ESMAP 2022:66, Bhattacharyya & Palit 2016).

3.4.1 Clustering and operational bundling

The clustering approach aggregates mini grids in neighbouring villages in order to provide an interlinked electricity market through distribution lines and smart control systems (Waswa 2021). Mini grids are bundled under an operational management structure to economise overheads, such as administration, maintenance, and transport costs (Franz et al 2014, Safdar 2017). The operation of a group of mini grids in the same region can lead to lower installation costs per system and makes operation and maintenance activities more efficient (Moner-Girona et al 2018). As a result, DFIs are increasingly encouraging operators with proven track records to implement this model to accelerate scalability (ESMAP 2022).

However, while clustering can help to lower the cost of capital for mini grid operators and reduce transaction costs for investors, distribution remains a capital-intensive activity. Few investors have shown interest in paying for distribution costs in the SSA energy market, instead relying on the participation of utilities (Safdar 2017, Weston et al 2018). Moreover, there is little evidence about whether these approaches improve mini grid profitability or whether regulatory frameworks are leaning towards creating a single structure through integrating mini grids (Safdar 2017, Sharma & Palit 2020). Although this model establishes opportunities for economies of scale, the literature points to technological challenges and the need for strong managerial and operational skills to succeed, limiting its scalability capacity in SSA.

3.4.2 Portfolio diversification and financial bundling

The financial bundling approach aggregates projects into an investment portfolio to reduce risk and encourage private investment. This approach is partly a response to the high-risk perception of investors towards the mini grid sector (Weston et al 2018, BNEF 2020). A portfolio of mini grids diversifies the investment risk by matching investors with pooled funds of bundled mini grid projects that can benefit from economies of scale, lowering the transaction costs and the capital costs per connection (Gershenson et al 2015, Weston et al 2018, ESMAP 2019). Some authors suggest that portfolio diversification of mini grids lowers the investment risks related to high transaction costs, market risks of investing in a single geographical jurisdiction and the unfavourable risk-return profiles of many projects (Malhotra et al 2017, Gershenson et al 2015). This approach, they argue, can therefore reduce finance costs, increase the scale of the investment, and unlock the participation of new financiers. Alternative portfolio diversification strategies are identified in the literature e.g. by geography (urban and rural), delivery models (EPC and energy as a service), and by sector (commercial, agriculture, and industrial) (Huber et al 2021).

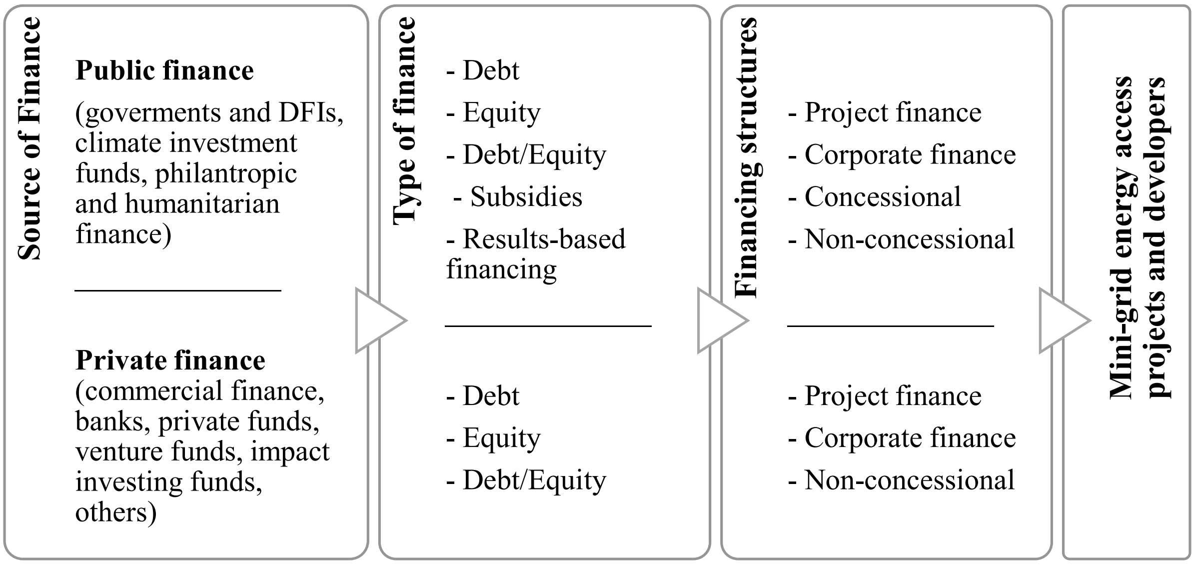
4. ACCESS TO FINANCE: ACTORS, INSTITUTIONS, AND PROCESSES

The lack of access to finance has been identified as one of the most significant obstacles to mini grid expansion in developing economies, particularly SSA (Peterschmidt 2019b, Phillips et al 2020, Wang et al 2020). As mentioned above, ESMAP (2022) has called for 380 million people in SSA to be connected to mini grids by 2030 in order to help meet the targets of SDG7, for which an estimated $91 billion in investment will be needed. By 2021, about 60 per cent of mini grid financing in SSA came from governments and development partners (AMDA 2022:13), but according to ESMAP (2022), to reach the 2030 electrification goal, at least 50 per cent of any future funding will need to come from private investment. While the involvement of DFIs has been critical in encouraging the private sector to participate in the market and helping them overcome some of the perceived risks due to lack of scale, developer track record, regulatory uncertainties, and limited electricity demand (BNEF 2020), commercial financiers are calling for additional subsidies, and guarantees over concessional capital. In SSA, grant and concessional capital deployment is not flowing at a rate that fully supports existing pipelines, impacting mini grids' ability to scale, and limiting new commercial investments (AMDA 2022:14).

In addition, as previously discussed by IRENA (2015), there is a clash of perspectives between DFIs and project developers. While funding agencies indicate that there is no shortage of funding, developers state that they find it difficult and time-consuming to comply with all the procedures and checks required before any public funds can be approved. Accordingly, there is a problem with funds reaching the projects in a timely manner.

To understand the financial needs of the mini grid sector, it is critical to look at the sources of finance available and the financing options and structures which vary among public and private institutions (see Figure 2). DFIs have been the most prominent players in the sector to date.

Figure 2. Phases of access to finance



Source: Authors' own analysis based on relevant literature cited in this section.

As debt has increased its participation in the sector in the last few years, equity has declined (ESMAP 2022). While the increasing availability of debt suggests that the mini grid sector is maturing, debt finance remains expensive and often carries an interest rate of 15 per cent or more for developers in SSA (Agenbroad et al 2018). Therefore, the financial sustainability of developers still relies on subsidies at different stages of project development. The evidence from the literature is strong and consistent in suggesting that no unique source of finance can overcome all the barriers and risks of the mini grid sector (Bahaj & James 2019, BNEF 2020, Weston et al 2018). Likewise, the scalability of mini grids requires different financing packages combining equity, debt, subsidy, and de-risking mechanisms according to the needs of different mini grid business models.

According to BNEF (2020), increasing the availability of long-term equity and debt in mini grid projects through project finance is required to move forward a mature decentralised energy market in SSA where developers can access financing to continue developing projects. As mini grids are typically built on the developer's balance sheet, the investor is exposed to all other risks that the company faces (BNEF 2020). Isolating mini grid assets from the companies that own and operate them, and allocating the infrastructure and operational risks to the developer allows for the aggregation mini grid assets into large, diversified portfolios that can attract long-term equity and debt (Huber et al 2021) (See section 3.4 – Financial bundling).

4.1 Sources of finance: from public and private

Public funding from governments and DFIs plays a key role in supporting the scalability of the mini grid sector by providing grants, subsidies, concessional loans, and loan guarantees (BNEF 2020). Indeed, in SSA public finance for up-front capital investment in mini grids has increased in the last decade (Hosier et al 2017, ESMAP 2022). By 2021, in SSA, 60 per cent of mini grid funding has been from national and international sources (AMDA 2022:13). Fifteen international DFIs and development partners have collectively committed more than $2.4 billion for mini grid development in SSA to date, excluding funding to governments for technical assistance and research (ESMAP 2019, 2022). Of this funding, which has largely focused on energy access, the World Bank accounted for 25 per cent by 2021 (ESMAP 2022). However, DFIs' funding for mini grids is observed to lean toward countries with active private-sector involvement and a robust legal and regulatory framework that supports mini grid development, including Tanzania, Rwanda, and Nigeria (Odarno et al 2017, Bukari et al 2021). Countries with higher market entry barriers for private players and lower electricity demand therefore find it harder to secure finance from DFIs. The lack of coordination between bi-lateral and multi-lateral DFIs for mini grid programmes has also been raised as a problem (Dye 2020).

As an infrastructure development activity with high upfront capital costs, the mini grid sector requires patient, long-term capital with low return expectations. However, the low volume of the transactions and high-risk perception of the projects has discouraged private sector investment. Moreover, the tenure of private debt capital is usually too short for the nascent mini grid market, and the 'bridging capital' (i.e., capital with high-risk appetite, low return expectations, and long tenure) is missing (Bhattacharyya 2018). Public sector financing structures are therefore essential in encouraging private sector participation in mini grids by decreasing perceptions of investment risk (REPP & AMDA 2023).

Compared to public sector finance from governments, DFIs, and climate investment funds, there has been limited private investment for mini grids in SSA (and indeed elsewhere). Most private investment in the mini grid sector has been made possible through parallel support from de-risking mechanisms with DFIs, given that grants and subsidies from governments or DFIs can increase confidence in future cash flows for private investors (Weston et al 2018, Bukari et al 2021). For instance, in Tanzania, the

World Bank's International Development Association (IDA) has provided risk guarantees to mini grid investors.

Private investors, which include commercial banks, private equity funds, venture capital funds, and impact investors, among others, have invested in the mini grid sector through equity, debt, and grant structures. In recent years, impact investors, which include Acumen, Bamboo Capital Partners, Cross-boundary Energy, and InfraCo Africa, have increased their commercial interest in supporting mini grids while recognising the project's social impact and are therefore willing to accept lower-than-market returns. Sometimes, they offer loans at single-digit interest rates, lasting up to ten years (BNEF 2020:94).

4.2 Type of finance

Developers face various barriers and challenges in accessing the different types of funding as summarised below. While the shift towards private participation in mini grid development increases the call for equity participation, debt and grant alternatives from multilateral DFIs represent an essential block for lowering the risk perception of equity investors.

4.2.1 Debt

There are two main types of debt finance: commercial loans and concessional loans. While commercial debt is often provided by local and regional banks, usually at double-digit interest rates, with shorter repayment terms, concessional debt is often provided by national energy agencies and DFIs at lower, sometimes single-digit, interest rates and for more extended periods (BNEF 2020:94, Baker 2022).

Developers face a significant obstacle in many SSA countries due to the reluctance of commercial banks to provide affordable debt finance to mini grid projects. This reluctance often stems from a lack of mini grid knowledge by the banks, meaning that they perceive mini grids as a financially risky endeavour (ESMAP 2022, Odarno et al 2017). In addition, in many SSA countries, local banks lack the sufficient technical expertise to conduct due diligence and project appraisals, which increases the interest rate and capital costs for the developer (UNDP 2018). Consequently, access to debt through local banks often requires additional support from financial institutions that provide guarantees to the lender.

Access to commercial debt finance is easier for private investors with previous track records and suitable balance sheets (Baker 2022). In contrast, a small community-owned project will struggle to meet the lending requirements. The organisation may have no formal standing, no previous credit record, very limited own-funding, and hardly any security for loan guarantee purposes. This limits the ability of such organisations to integrate with the mainstream capital market and to ensure the financial sustainability of their projects (Bhattacharyya 2018). Moreover, given that developers must always repay loans regardless of performance, such a risk is often too great for a smaller actor.

In some instances, governments and DFIs offer concessional loans to help mini grid developers address the risk perception of commercial lenders, so that commercial lenders can be repaid first (ESMAP 2022). However, accessing concessional loans can involve relatively complex due diligence and high transaction costs, making it more accessible for larger projects and mature developers and very difficult for small and local developers (Weston et al 2018). There are further challenges to obtaining concessional debt. For instance, lenders prefer to finance developers with existing operating assets or those with a proven track record. As with commercial debt, there is a preference for 'high-impact' projects, limiting funds for early-stage developers. Concessional loans are often difficult to obtain and require a long time to process, as well as having onerous requirements for implementation, management, oversight and reporting. Such challenges can make it impossible for a smaller developer to access even concessional debt despite the lower interest rates.

4.2.2 Equity

Thus far, the majority of equity investment in mini grids has come from impact investment funds (Safdar 2017, ESMAP 2022) as discussed in Section 4.1, though other sources include funds from project developers, corporate sponsors, and commercial investors. Raising equity for mini grids in most markets in SSA is challenging based on unproven business models and a lack of guarantees over investment return (BNEF 2020).

As indicated in Figure 2, mini grid developers can either raise equity and/or debt through multiple financing structures, including project finance and corporate finance. The choice between the two depends on the developer's financial strategy and the nature of the funding requirements. Project finance targets the financing needs of a single project and structures the financing around the cash flows generated by that project. Corporate finance raises equity and/or debt at the company level and involves using the company's overall assets to secure returns for investors and creditors rather than solely relying on the revenues generated by a specific project (Baker 2022). While project finance is primarily available for larger projects run by developers with a well-established track record, smaller projects are more likely to use corporate finance. However, project finance requires project aggregation at different levels to achieve bankable projects with guaranteed cash flows. Neither are easy to achieve (REPP & AMDA 2023).

The key challenges to accessing and managing equity investment include: uncertainty about future macroeconomic conditions which discourages investment; developers often cannot charge fully cost reflective tariffs because many potential consumers cannot afford to pay, reducing their investment recovery capacity; as with commercial lenders many potential private investors lack experience with mini grids, considering them too risky; and despite the long term nature of a mini grid project, some investors may still expect more immediate and short term returns.

4.2.3 Subsidies

SSA's mini grid sector needs some degree of subsidy to bridge the gap between the high cost of infrastructure and the low incomes of the communities they serve (AMDA 2022). Subsidies, which are often provided by DFIs and administered by government, can be provided during different stages of a mini grid project: capex subsidies cover upfront capital costs, while demand-side subsidies may also be required to match affordability in rural and densely populated communities (see Table 5). Capex subsidies may also support the construction and user connections as a substitute for debt and equity funding. While making mini grids a viable option for electrification requires significant subsidies to achieve a cost-reflective tariff regime for developers that also matches the ability to pay for end-users (Weston et al 2018), there are numerous challenges to accessing them. First, subsidies are limited in availability, subject to stiff competition and allocated in small amounts as compared to the total investment costs. The process to access them has high transaction costs, usually lacks transparency and is highly bureaucratic; and providers of subsidies often impose conditions that may limit the developer action plan.

Table 5. Types of subsidies

Subsidy	Description
Pre-investment subsidies	Pre-investment subsidies are provided to support market and resource assessments, geospatial planning, pre-feasibility and feasibility studies, and technical assistance (ESMAP 2019). This type of subsidy is available primarily through DFIs.
Up-front capital subsidy	This type of subsidy is necessary to cover mini grids high initial investment costs. The CAPEX subsidy is disbursed before the mini grid installation, and calculated based on installation cost, the number of connections, and the internal project rate of return (IRR) (Franz et al 2014). Up-front grants have been the most common subsidy for mini grids (ESMAP 2019).
Demand-side subsidies	Demand-side subsidies target the tariff structure, such as lifeline tariffs, and provide subsidies to customers for purchasing energy-efficient appliances and productive equipment. These subsidies are available through government programmes and electrification plans. Subsidising the demand enables more extensive electricity use while improving the mini grids revenues (ECA & AMDA 2020).

Source: Authors' compilation based on relevant literature cited in this section.

4.2.4 Results-Based Financing (RBF)

Results-based financing (RBF), also known as performance-based grants, provides a subsidy according to the number of successful connections met by the mini grid

(BNEF 2020). RBF has been given by DFIs to mini grid entrepreneurs and some governments are also starting to adapt this mechanism. RBF is perceived to provide greater control and certainty over the project, and to reduce the risks of early-stage financing, providing a mechanism to combine commercial funding with subsidies, where the former provides the initial investment costs, having the guarantee of returns after installation (Bukari et al 2021, ECA & AMDA 2020).

In SSA, RBF emerged in 2019 in six African countries, Nigeria, Algeria, Ethiopia, Mali, Burkina Faso, and Togo, led by DFIs (Antonanzas-Torres et al 2021). For example, Nigeria's performance-based grant (PBG) programme has made $150 million available to mini grid developers, offering between $350 to $600 per new connection with a minimum total grant of $10.000 per mini grid (ESMAP 2019). This programme was launched in 2018 as part of the Nigerian Electrification Project (NEP), supported by the World Bank and the AfDB which aims to increase the participation of hybrid solar mini grids in 250 designated sites, with a total budget of $48 million (BNEF 2020:130).

5. EXPLORING KEY RISKS AND CHALLENGES

The literature on mini grid business models indicates that success is highly context-specific depending on internal and external challenges (BNEF 2020), where the former includes project-specific aspects that the mini grid developer can control or avoid, and the latter are uncontrollable for the developer, exogenous and inherent to a specific market or country.

Investment risks in mini grids relate to factors that reduce the developer's probability of having sufficient cash flow to repay the debt or meet the expected return (EEP 2015, BNEF 2020, ESMAP 2020). Thus, the risks associated with mini grid projects in SSA are often not aligned with the risk-return expectations of international investors. While improvements in technology and the involvement of DFIs in the mini grid sector have reduced perceptions of investor risk, the absence of proven business models and market challenges have increased it (BNEF 2020, ESMAP 2022). Achieving the industry call to increase private-sector investment in mini grids requires reducing the internal and external challenges that raise the investors' risk perception and addressing the developers' barriers to affordable financing. The main areas of risk are summarised in Table 6 and discussed in more detail below.

Table 6. Summary of risks and challenges for mini grids

Risks and challenges		**Elements**	**Coping mechanisms**
External Risks	Regulation and market access	Licensing processes Tariff setting rules Rules for main grid arrival and mini grid integration	Reduce the sizing of mini grids Bundling mini grids into portfolios Grid-interconnection ready technologies
	Demand uncertainty and poor forecasting	Lack of accurate demand data Errors on sizing the mini grid	Use technology to improve data reliability Stimulate productive uses of electricity De-risking finance mechanisms
	Country and macroeconomic risks	Inflation Currency mismatch between funding and revenues Exchange-rate fluctuations	Use long-term currency volatility assessment Access and availability of credit in local currency
Internal Risks	Customer credit and non-payments risk	End-users limited and unpredictable income Enforcement of payment collection mechanisms	Prepaid collection methods (e.g. PAYG) Smart metering systems Financing for productive equipment
	Governance risk	Developer's track record and expertise Transparency and monitoring	Clear accounting and reporting mechanisms Integration of ESG standards
	Labour risk	Lack of a skilled local workforce Lack of adequate technical resources	Investing in local operations and management capacity Ensuring the supply of quality spare parts
	Community engagement challenges	Risk of non-acceptance due to public opinion, lack of transparency, and low	Implementing clear communication channels

Risks and challenges		Elements	Coping mechanisms
		local workforce involvement Low social perception of the service	Involvement of traditional authorities and local champions Timely available information on tariffs and service

Source: Authors' compilation based on relevant literature cited in this section.

5.1 External risk for mini grids

5.1.1 Regulation and market access

A lack of policy and regulation for mini grid development and indeed in electricity governance more generally is perceived as the most significant challenge by developers and investors (AfDB 2016, BNEF 2020, AMDA 2022). In 2014 most countries in SSA lacked specific policies for mini grids in their national electrification plans (EEP 2015), for which reason mini grid development in the region has often occurred without national regulation (Baker et al 2022). However, in some countries this has shifted in recent years, including in Nigeria, Kenya, and Tanzania.

Obtaining licensing or authorisation for mini grids is often a lengthy and bureaucratic process lacking in clarity, particularly in countries where mini grid developers are governed and regulated by the same institutions that oversee national utilities. For instance, as AMDA explores, the requirement in many countries that each mini grid project go through the same licensing process as a grid-connected, utility-scale project creates a heavy burden on mini grid developers and can serve as a barrier to access (AMDA 2020).

Critical areas of regulatory risk include market entry procedures, rules for tariff-setting, and policies relating to the arrival of the main grid into the vicinity of the mini grid (see Table 6, SE4ALL & AfDB 2019, BNEF 2020, ESMAP 2022). In certain countries in SSA, national and/or local regulations may prevent or inhibit cost-reflective tariffs for mini grids, as is the case for instance in Senegal, which therefore reduces cost recovery options for developers (Weston et al., 2018). Investment uncertainty is further increased by the unpredictability of tariff policy, which may result from changes in government and political pressure from vested interests (Gershenson et al 2015, Baker et al 2022).

Perhaps the most significant concern for investors and developers is the risk that the utility may extend the national grid to the community being served by the mini grid, particularly in countries where there is no regulation or compensation for such circumstances (Muchunku et al 2018, ECA & AMDA 2020, Baker et al 2022). The uncertainty as to whether or not developers will be able to recoup their investment in the case of grid arrival may pose as a deterrent (Bukari et al 2021). One possible way to mitigate this risk is for developers to ensure that their systems are technically capable of connecting with the main grid and other mini grid projects, though this would still require mini grid operators being able to lease the distribution assets of the centralised utility. Consequently, the literature calls for policy guarantees that provide clear conditions about operating alongside the main grid and compensation schemes (Tenenbaum et al 2014).

5.1.2 Demand uncertainty and poor forecasting

Low demand is one critical element of risk for both developers and investors. Developers use demand estimates to inform the sizing and design of the mini grid and thus, to secure financing. However, as mentioned in Table 6, errors in assessing the electricity demand can lead to forecasting errors and revenue deficits, directly affecting the investment return (Peters et al 2019). Given that demand for mini grid electricity varies widely within and between countries, estimating demand remains challenging for developers (ESMAP 2022:81). It is also difficult to accurately project the future electricity demand of a mini grid before electrification (Bahaj & James 2019, Hartvigsson et al 2021).

The lack of familiarity with electricity provision, use, and cost in rural communities is challenging for data reliability (Bahaj & James 2019). As a result, the load profile assessment might not reflect the reality of electricity consumption, increasing the risk of under or oversizing the mini grid. While large mini grids increase the initial and operational costs, a smaller generation capacity may decrease the quality of service for the end-user (Hartvigsson et al 2021). There are various options to mitigate such risk. First, a geospatial approach using geographic information system (GIS) software and associated web-based and mobile technologies can be used to perform more accurate site assessments and extend the availability of data (ESMAP 2019). Second, encouraging income-generating activities through the financing of productive-use appliances, or tariffs that encourage electricity consumption for productive use (ECA & AMDA 2020). Finally, the provision of concessional loans from DFIs which guarantee repayment first to private investors can help de-risk some of the demand uncertainty, as discussed in Section 4.2.

5.1.3 Political and macroeconomic risks

Country-specific risks, including political instability, social unrest and macroeconomic conditions such as currency risks and inflation, extend beyond the context of any individual mini grid project (See Table 6, Baker 2022). However, they are likely to increase the cost of capital for mini grid developers who will also need to demonstrate their capacity to minimise these risks when possible (ESMAP 2019, Malhotra et al 2017).

International valuations of country risks, such as the Marsh World Risk Review (2021) and the World Bank Doing Business Ranking (2021), offer initial assessments for international investors. However, conducting thorough due diligence on a project remains crucial for making investment decisions (ESMAP 2019). While political risk assessment examines a country's fiscal and monetary policies, legal and regulatory challenges, and social unrest risks, the Doing Business Ranking measures the ease of starting a business in a specific country (See Table 8). A comparison based on the Doing Business Ranking indicates that Kenya for example, provides a more favourable regulatory environment and lower country risk than Tanzania, given the latter's business environment and regulatory framework.

In summary, country-specific risks and broader economic conditions can impact the feasibility and financing costs of mini grid projects, and thorough due diligence is essential to assess investment viability in a specific context.

Table 7. Doing business ranking 2020

Country	Global Rank (total 190)	Rank within SSA (total 48)
Kenya	56	3
Nigeria	131	17
Senegal	123	16
Tanzania	141	22

Source: Authors' own, adapted from Doing Business Ranking (World Bank 2020)

Returning to the risks in Table 6, inflation significantly affects tariff-setting for mini grids, directly impacting the developer's operational costs, revenue, and the financial sustainability of the investment (Odarno et al 2017). Developers are usually not allowed to change their tariffs once the tariff schedule has been approved and must therefore adjust tariffs to allow for inflation at the outset (Ilskog & Kjellström 2008, ESMAP 2020). Local currency depreciation will also impact financing and revenue costs, given that most mini grid financing in SSA is in a foreign currency such as dollars or euros, while revenues are received in local currency over the lifespan of the project of approximately 20 years (Gershenson et al 2015, Franz et al 2014). Foreign investors and debt financiers will therefore look at the long-term exchange rate to assess currency volatility risk (BNEF 2020:102). Although international hedging tools are available, e.g. locking the exchange rate in for all or part of the duration of the investment, this option would increase the cost of capital for developers. Avoiding those risks requires credit availability in local currency, which is still limited in SSA (See Section 4.2).

5.2 Internal challenges for mini grids

5.2.1 Customer credit and non-payment risk

Penetration of third-generation mini grids has grown based on increasing consumer demand for electricity services, as well as innovations in telecommunications, which enabled the rise of smart metering and Pay-As-You-Go (PAYG) models for small-scale systems (BNEF 2020, Baker et al 2022). Although data that has been enabled from new technologies provides lenders and investors with more confidence regarding the end-user payment capacity and affordability, mini grids are still exposed to credit risk and non-payment by end users (GOGLA 2019). In addition, the high upfront cost of connection and payment for the electricity service poses an entry barrier for the most vulnerable customer. The willingness and/or ability to pay often becomes a challenge when mini grid tariffs are compared to tariffs from the main grid, or the community expects assistance programmes that provide lower-cost electricity access (Peters et al 2019, Schmidt et al 2013). Some low-income households in SSA may not be able to budget for high and regular energy costs, particularly as compared to traditional energy sources such as kerosene (Inensus in AfDB 2016, Bahaj & James 2019).

In addition to the introduction of PAYGO systems, pre-paid electricity metering schemes have also been introduced in mini grid design and implementation, including in Kenya, Tanzania, Uganda, Nigeria, and Rwanda, with the aim of addressing non-payment risk; reducing the operational costs of the individual collection of payment; and providing greater transparency for the consumer on electricity use and costs (Bahaj & James 2019, IEA 2022, Jack & Smith 2015). Third-generation mini grids are already integrating smart meters that provide prepaid options for end-users while incentivising customers to use efficient household appliances and equipment for income-generating activities (Niyonteze et al 2019, ESMAP 2022:69). For productive users with limited or seasonal cash flows, waiving the flat rate standing charge and facilitating access to credit for equipment would reduce their credit risk. Mini grid developers could partner with financing agencies or equipment sellers to support access to credit for productive equipment (Cheney 2016). Therefore, strategies to decrease credit risk must also reflect the needs of both households and productive users in terms of an affordable tariff structure and workable payment collection method.

5.2.2 Governance risk

The literature review on business models suggests that investors consider governance concerns from the experience of the mini grid developer in decision-making, and monitoring (Franz et al 2014, Peters et al 2019). Investors require that developers internalise the feasibility assessments, fulfil the technical standards, and set transparent accounting and reporting mechanisms (ESMAP 2022). In addition, the developer's track record is essential to access finance and improve scalability given that, as companies develop more expertise, they become more attractive in investment terms for equity and debt investors (BNEF 2020). Finally, integrating environmental, social, and governance (ESG) standards facilitates the governance risk assessment and reduce potential conflict of interest between financiers and developers (IEA 2022).

5.2.3 Labour challenges

The need to develop appropriate human capital for the scale up of third generation mini grids is often challenged by the lack of a skilled local workforce, particularly given the geographical remoteness of the systems (See Table 8) (ESMAP 2022:287). Mini grid developers are usually required to integrate capacity-building with community engagement strategies in order to train local staff to carry out operation and maintenance, thereby reducing the need for external support and lowering the project's operational costs (Duran & Sahinyazan 2021, Lillo et al 2015). In some countries support is provided for capacity building of local technicians, for instance, in Tanzania by the Rural Energy Agency.

The lack of adequate technical resources, such as spare parts in the local market and poor quality of components, adds to the labour risk and challenges, increasing the reliance on external consultants and suppliers and raising the operational cost of the project (Sharma & Palit 2020, Azimoh et al 2017, Yadoo & Cruikshank 2012). Therefore, investing in operations and management capacity-building, training at a local level, and ensuring the supply of spare parts in the medium and long term is essential to reduce the labour and technical skills risk for mini grids.

5.2.4 Community engagement challenge

Inadequate or inappropriate community engagement can create socio-economic challenges which in turn affects the successful implementation of a project by undermining local support, reducing electricity demand from the end-users, and increasing the risk of local disputes and non-payment (Malhotra et al 2017). Unfavourable public opinion, lack of transparency, insufficient local workforce involvement, and poor local capacity development are some of the elements that can contribute to the risk of non-acceptance of the mini grid (Franz et al 2014). Misleading information regarding tariffs and/or the reliability of the service will also create mistrust of the energy provider and the system among users, who in turn are more likely to miss payments (Peters et al 2019, Lillo et al 2015). Potential challenges may also arise from business models that prioritise commercial users and limit access to energy for low-income customers, thereby exacerbating existing inequalities in access to electricity.

All of these challenges highlight the importance of addressing the communities' needs, concerns and expectations in mini grid development, adopting a holistic approach to providing energy access to low-income consumers, and ensuring equitable electricity distribution. As Duran & Sahinyazan (2021) explore, working with local authorities and including local champions to connect the community to the mini grid helps to reduce reputational risks. Likewise, providing accessible and continuous communication regarding the tariffs and the service strengthens trust. Effective community engagement is a challenge for mini grid developers (Chaurey et al 2012), for which reason, argues ESMAP (2022) it is important to involve them in every phase of the mini grid project.

6. CONCLUSION

The positive narrative with regards to the key role that third-generation mini grids can play in achieving SDG7 goals in SSA has so far come mainly from the private sector and DFIs. Consequently, the industry calls for further private sector participation in third-generation mini grids in SSA, especially to reach rural, dispersed and densely populated communities with high demand levels. In this review we have explored the various different mini grid business models that currently exist; the main actors, institutions and processes involved in accessing finance for third generation mini grids; and some of the key investment risks and challenges to the further deployment of mini grids in the region. We find that various mini grid business models exist to support advancing universal electrification in the region, which may vary by ownership, cost-recovery, customer focus and implementation strategy. While evidence from the literature points to hybrid ownership, the role of subsidies, the inclusion of anchor customers, and financial bundling portfolios as promising business strategies, there is no gold standard business model for mini grid development which is financially sustainable, scalable and replicable. Mini grid business models are still evolving and adapting to various economic, social, and political variables. Their success and scalability are context-specific and depend on multiple internal and external challenges.

The lack of quantitative analysis on mini grid financial performance, makes it difficult to know whether specific approaches to the mini grid business model will have more or less sustainable outcomes. Mini grid experiences across the region suggest that balancing affordable service provision with acceptable cost recovery remains difficult to achieve (Bhattacharyya et al 2019, Moner-Girona et al 2018, Pueyo & DeMartino 2018). While financial sustainability is often considered the most significant challenge for mini grid expansion, this is affected by other critical factors which drive the risk perception of financiers, including regulatory uncertainties, tariff regulation, low electricity demand, and low payment capacity in rural communities. With this in mind, we now offer the following five conclusions.

First, the categorisation of business models is very diverse. Each of the models explored shed light on the different success factors (See Section 3). However, the literature has focused on the nature of ownership. The operations are led either by the public utility, the private sector, the community, or a blended approach where both governments and private developers have shared obligations. All of these approaches have been shown to work under different circumstances. In Tanzania for example, the deployment of mini grids based on PPPs in rural areas has been quite successful. However, contrary to the dominant narrative that prioritises private models away from monopoly utilities, expanding energy access depends on identifying the right balance between private and public ownership and control, as a private sector approach does not necessarily make electricity more accessible and affordable for users at the last mile.

Second, a mini grid focused on sustainable cost recovery would require that operation and maintenance costs be recovered from tariffs and/or targeted public subsidies that allow remote and rural populations to access electricity at the same subsidised price as their urban counterparts. There is therefore a balance to be struck between private competitiveness and public support. As regards the customer-focus approach, the literature suggests that one way to make the mini grid business model viable would be to pursue an A-B-C model that provides a consistently high load to cover investment and operational costs. Long-term contracts with anchor clients can guarantee a large portion of mini grid revenue, improve the project's financial sustainability, support upfront fees, and help attract long-term financing. However, the lack of anchor customers in SSA challenges the viability of this model, which explains DFIs' interest in stimulating and supporting productive use. Moreover, the literature is still incipient and contradictory on the impact of productive use mini grids on income generation. Finally, the literature suggests that operational and financial bundling of mini grids is a potential solution for the challenges of economic sustainability because it can create economies of scale, reduce transaction costs, and promote diversification of risks. However, the lack of examples in the literature limits the ability to conclude the scalability of this model in SSA.

A third conclusion relates to access to finance as a key challenge. The evidence presented in the literature is clear that no unique source of finance can overcome all the barriers and risks of the market. Moreover, the scalability of the mini grid sector requires different financial arrangements combining grants, equity, debt, subsidy, and de-risking instruments. The literature consistently suggests that most mini grid developers require grants for the initial stages, such as construction, installation, and user connection. Thus far non-reimbursable grants to fund CAPEX for mini grids under rural electrification programmes have been the most committed financing for the sector in developing countries. In contrast, some developers have also raised debt or equity from either foundations or commercial finance, which requires them to show a certain level of return from their business operations and minimise risk.

Fourth, the literature indicates that the success of a mini grid project is highly context-specific and dependent on internal and external challenges. The former includes project-specific aspects that the mini grid developer may be able to control or influence, while the latter are beyond the control of the developer and often inherent to a specific market or country. According to the literature reviewed, the greatest risks and challenges in the SSA mini grid sector relate to regulation and market access, followed by the risk of grid arrival, and the lack of a sizeable and stable demand. The risks associated with mini grid projects in SSA countries are mostly external, leaving the investor's risk perception as the risk the developers face and need to overcome. The lack of proven business models increases the risk perception from commercial investors that interpret the lack of coping mechanisms as a lack of expertise in the sector. Thus, the high requirements regarding the developer's track record and collaterals from financiers reflect an imbalance between financial expectations of returns and the challenges mini grid developers face. These conditions prioritise larger, mature, and often international developers, limiting opportunities for local mini grid endeavours. Thus, achieving the industry call to increase private-sector investment in mini grids requires reducing the internal and external challenges that raise the investors' risk perception and coping with the developers' barriers to affordable financing.

Finally, the grey literature in particular points to macroeconomic challenges, non-payment risk by mini grid customers and governance, social and technical challenges. But this literature has primarily built on qualitative analysis, and there are few publicly available quantitative assessments of the impact of those risks on the profitability of mini grids. A deeper critical and comparative analysis of different business models' coping mechanisms could therefore help to understand the complex success factors that could define the most sustainable approach to mini grids.

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