



# The Economics of Mini-Grids in Sub-Saharan Africa

## -A review of the literature-

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Adriana Fajardo and Ana Pueyo



# Introduction

- Mini-grids hailed as the “the missing piece of the integrated electrification puzzle”; or the technology that will “change the world (again)”
- From a niche solution into a widely deployed technology-more than 26,000 installed and planned mini-grid projects around the world, 1,500 operating and 4,000 planned in Africa.
- Academic interest has grown exponentially
- Least cost electrification models provide inconsistent estimates of the role of mini-grids for universal access, and are often untransparent in their inputs, methods and assumptions
- Increasing evidence about what works and what does not- the time is ripe for a comprehensive literature review of economic feasibility.
- The review of economic literature on mini-grids aims to understand if their risk-return profile is appropriate for scalability
- **Can mini-grids provide cost-effective and affordable supply in SSA and other developing countries, at present and in the future?**

# Research questions

## Main questions

- **RQ1:** Are mini-grids financially sustainable in developing countries, and in SSA in particular?
- **RQ2:** Do mini-grids provide affordable electricity in developing countries and in SSA in particular?
- **RQ3:** Which business models are used, and which ones are deemed successful and on what basis?

## Additional questions

- **RQ4:** What is the risk profile of mini-grids in developing countries, and SSA?
- **RQ5:** Is there access to finance for mini-grids in developing countries, and SSA?

# Scope of the review

- Technological scope: renewable, hybrid, and diesel mini-grids
- Geographic scope: low and middle income countries
- Publication date: from 2000
- Types of literature: academic, grey literature and media
- Methodological approach: empirical studies
- Publication language: English

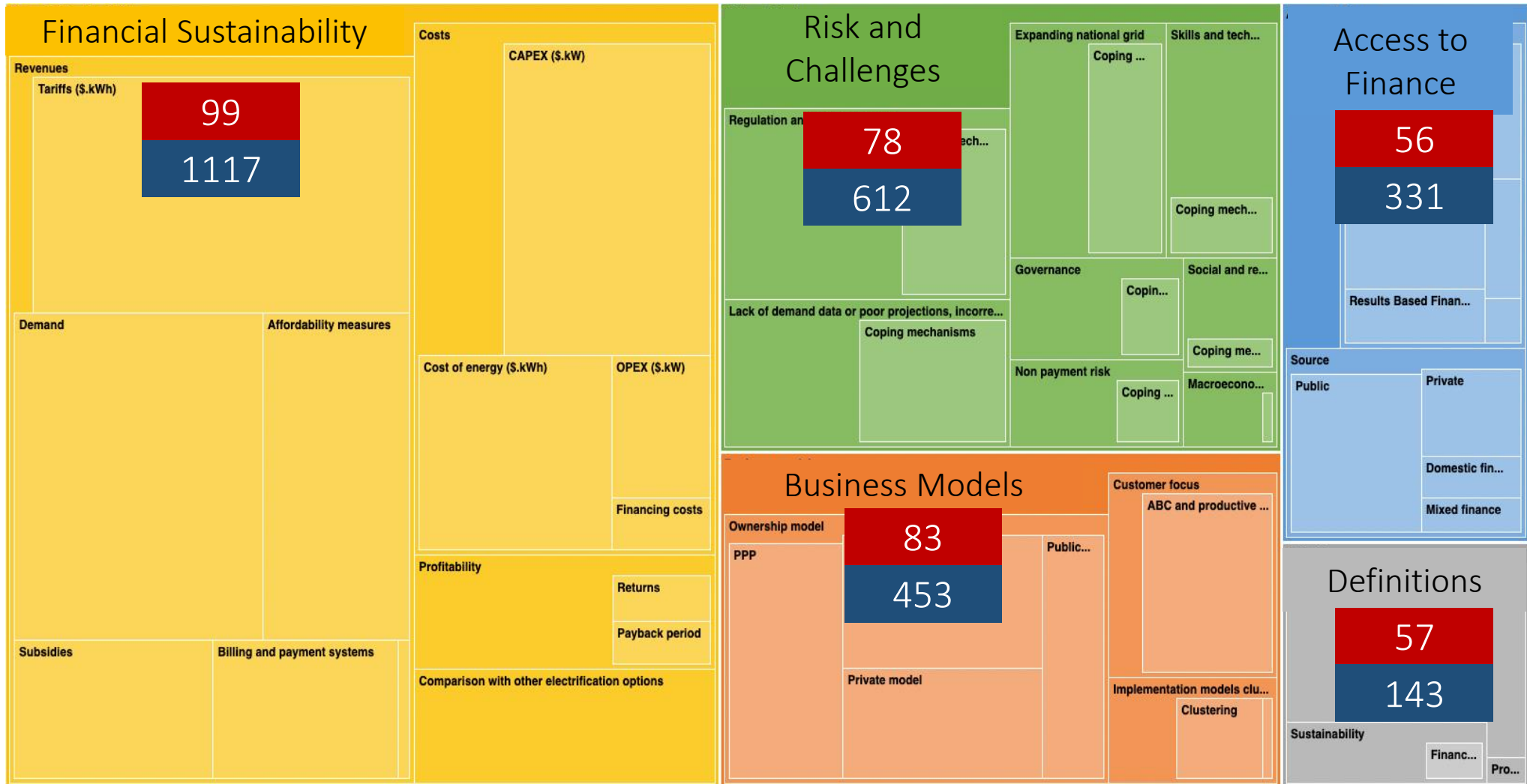
# Methodology

- Sources including: Scopus, Google Scholar, Google search engines, websites of specific institutions supporting mini-grids in Africa, specialised press, and citations in papers selected (snowballing)
- Pre-defined search strings
- First review of titles and abstracts to ensure relevance
- 103 papers reviewed
- Creation of database of selected papers, in Excel, Mendeley and Nvivo
- Database of economic indicators of mini-grids in the literature
- Coding of the literature with Nvivo
- A total of 2,677 references coded!

# Coding scheme

# Files

# References



Definitions

57

143

Sustainability

Financ...

Pro...

# Description of the literature reviewed

We reviewed 103 papers between peer-reviewed academic and grey literature and media, including reports and benchmarks by development and renewable energy institutions.

Figure 1. Literature per type of publication

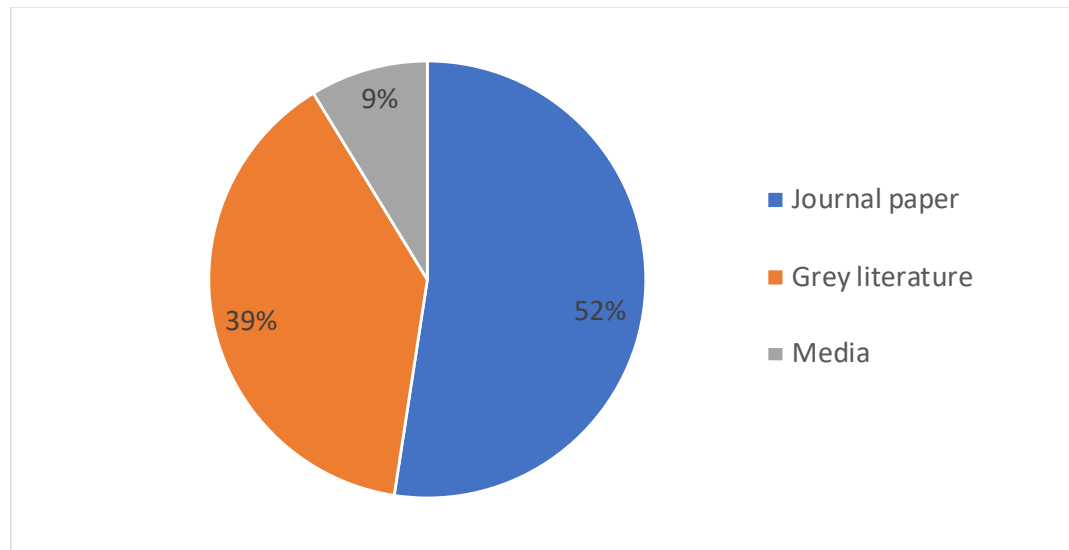
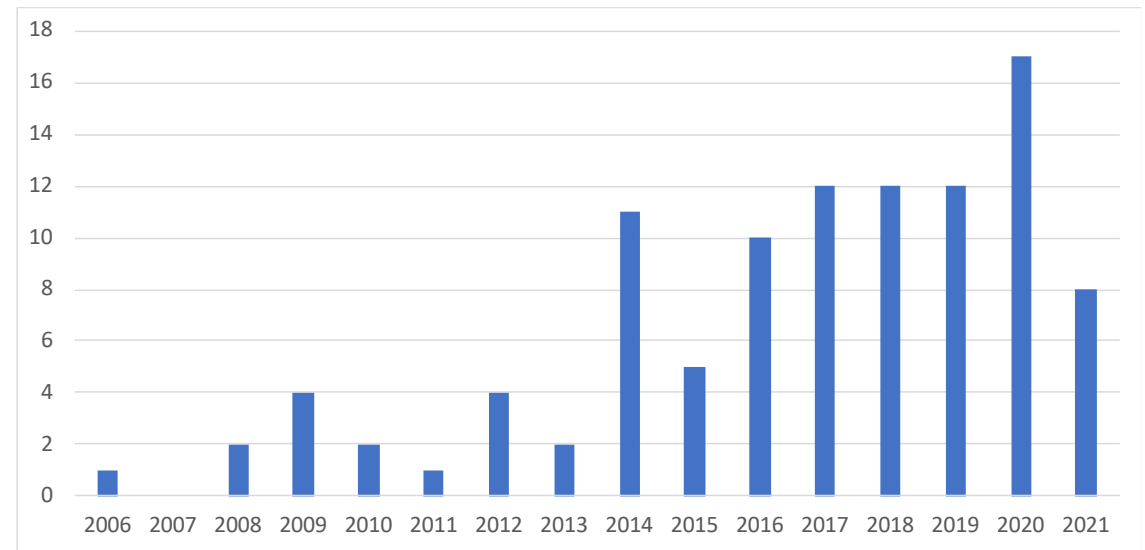


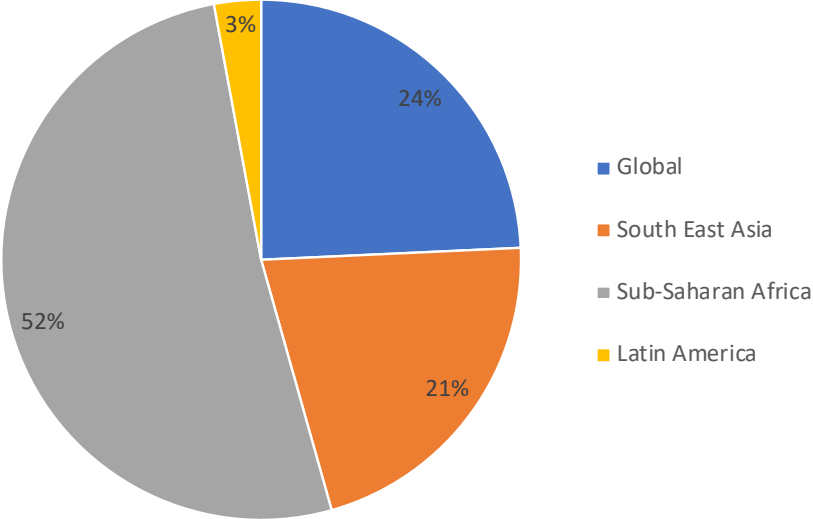
Figure 2. Literature per publication date



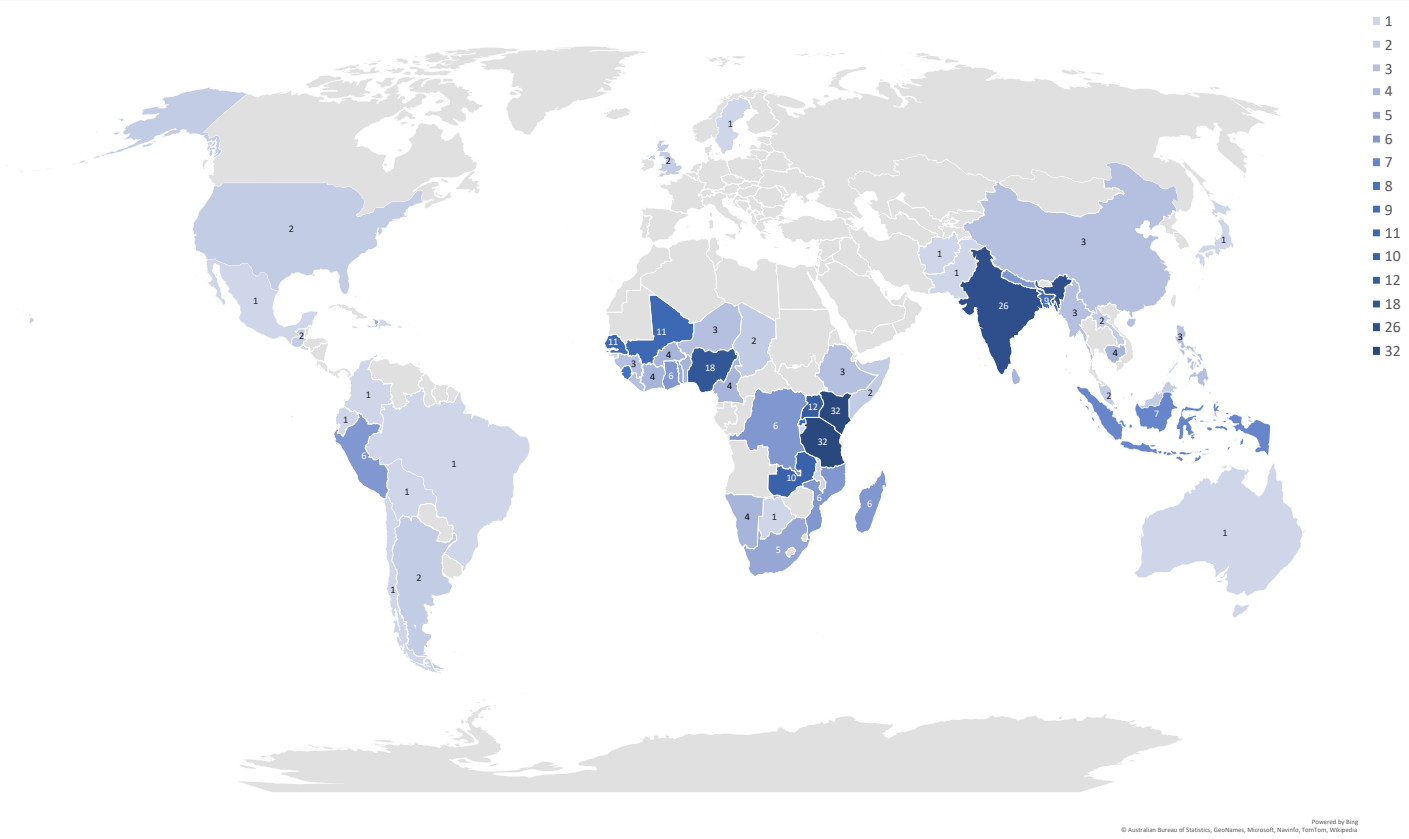
# Description of the literature reviewed

64 countries are covered by the literature reviewed. Per region, most of the publications look at the economic sustainability of mini grids in Sub-Saharan Africa.

**Figure 3.** Percentage of publications covering geographic areas



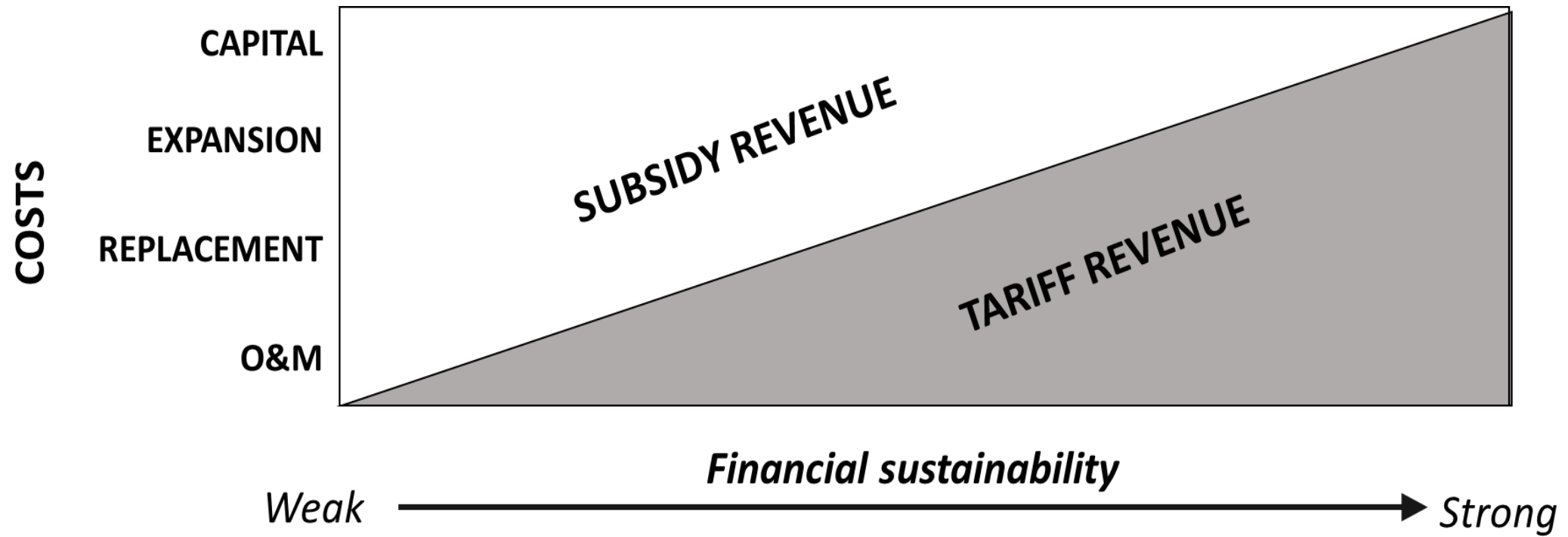
**Figure 4.** Number of publications covering each country





# RQ1. Are mini grids financially sustainable in developing countries, and Sub-Saharan Africa in particular?

- Concerned with the private returns to the investor- Can mini-grids attract investment and be scaled up?
- Financial sustainability as the ability to recover costs incurred through the revenues collected, and in the case of private investors, make a sufficient profit.
- However, there is no agreement on which costs and revenues to consider.
- We define the financial sustainability of mini-grids along a continuum from weak to strong sustainability, according to the costs and revenues included.



# RQ1. Are mini grids financially sustainable in developing countries, and Sub-Saharan Africa in particular?

- Evidence of strong financial sustainability is scarce, with just a handful of examples (i.e., Powerhive in Kenya, private mini-grids in Uttar Pradesh)
- More abundant evidence of financial sustainability when capital costs are subsidized and tariffs cover O&M, replacement and expansion costs (in Cote d'Ivoire, Sierra Leone, Nigeria, Tanzania, Kenya, India, Nepal, Bangladesh, Peru).
- A significant body of literature considers that not only capital costs need to be subsidized, but also replacement and expansion, and part of O&M costs.
- Some literature finds that mini-grids are not financially viable, as they are not able to guarantee enough revenues to cover their costs, whether through tariffs or subsidies, leading to a self-reinforcing cycle of lack of funds and poor quality of supply

# RQ2. Do mini grids provide affordable electricity in developing countries and in Sub-Saharan Africa in particular?

Three different ways to understand affordability:

- **Affordability as ability to pay:** the share of the household budget that is spent on a subsistence level of electricity. Electricity supply is then considered affordable if the share is below a given threshold.
- **Affordability as willingness to pay (WTP):** the maximum amount that an individual indicates that he or she is willing to pay for the energy services provided by the mini-grid. Can be obtained by asking potential users directly about the services they want and how much they are willing to pay for them (“expressed WTP”) or it can be inferred by asking questions about their current expenditure in comparable energy services (“revealed WTP”)
- **Affordability in comparison to other electricity supply alternatives,** mainly comparing to the cost and tariffs of the national grid.

## RQ2. Do mini grids provide affordable electricity in developing countries and in Sub-Saharan Africa in particular?

The different definitions lead to different conclusions on affordability:

- Affordability of mini-grids is **low**, considering customer's ability to pay for its actual costs
- Affordability is **high**, as willingness to pay for the energy services provided, whether through expressed or revealed WTP.
- Affordability is **low** for the individual consumer as compared to the main grid. Grid tariffs are consistently cheaper than mini-grid tariffs, unless they apply a mandated uniform tariff. However, mini-grids can improve the affordability of the electrification effort as a whole, reducing the cost of reaching remote populations, and hence the need of subsidies.
- A strong and consistent conclusion in the literature is that **subsidies are essential** for affordability and equity reasons. The higher the subsidies, the lower the financial sustainability.

## RQ3. Which business models are used, and which ones are deemed successful and on what basis?

The literature defines business models for mini-grids according to four approaches.

- **Ownership models:** defined by who holds and operates the mini-grid assets, including the generation and distribution, between public utility, private sector, community, and hybrid models. Most of the literature employs this definition.
- **Cost recovery models:** describe how the cost is recovered and the capital cost is returned according to for-profit, partially-subsidized, and fully-subsidized structures.
- **Customer focus models:** the target clients differentiate these business models, from a high volume of households to a single anchor customer.
- **Implementation models:** bundling structures driven by the intention to reduce risks and optimize costs, such as franchise, clustering, and portfolio diversification.

# RQ3. Which business models are used, and which ones are deemed successful and on what basis?

Ownership Models	Public utility model	<p><b>+</b> The evidence is strong in suggesting that the role of the utility model is essential to provide electricity access to low-income communities. As a result, state-owned mini-grids are relatively common in SSA.</p> <p><b>-</b> There is inconsistent evidence on the success of this business model. In addition, the insolvency of the public utilities in many SSA countries makes them unable to carry on mini-grid projects effectively.</p>
	Private model	<p><b>+</b> The evidence is strong in suggesting that the role of the private sector is vital for achieving rural electrification. Access to subsidies or grants may able the expansion of this business model. Kenya and Tanzania have incentivized the private sector's participation in off-grid rural electrification.</p> <p><b>-</b> Few initiatives have attained financial sustainability due to the lack of cost-reflective tariffs covering investment and operational costs.</p>
	Community model	<p><b>+</b> The evidence is strong in recognizing the benefits of the community model. This model dominates the development aid electrification projects.</p> <p><b>-</b> The literature is inconsistent on the sustainability of this business model. While some experiences suggest that fully funded projects are the only access to low-income communities, others indicate the significant challenge of donor dependency.</p>
	Hybrid models	<p><b>+</b> The evidence is strong and consistent in proposing the hybrid models as a promising business model. In particular, the PPP structures can overcome the government's budgetary constraints, diversify the project risk between actors, and optimize the expertise and efficiencies of the private sector.</p> <p><b>-</b> The implementation of these models depends on a clear regulatory framework that enables the private sector's participation and guarantees the roles and responsibilities of both parties.</p>

Cost Recovery Models	For-profit	<p><b>-</b> The evidence is weak in providing evidence of the scalability of this business model. In addition, the low payment capacity of rural areas and the inability to apply cost-recovery tariffs challenge the viability of this type of mini-grids.</p>
	Partially subsidized	<p><b>+</b> The evidence is strong and consistent in indicating the need for subsidies to guarantee competitive tariffs that match the utility prices and enduring operations of mini-grids. Approaches that involve the public sector as a stakeholder in mini-grid projects allow implementing cross-subsidized tariffs. In Nigeria, the results-based subsidies like payments to the number of connections.</p>
	Fully subsidized	<p><b>+</b> The evidence is strong in the requirement of subsidies for the financial sustainability of mini-grids.</p> <p><b>-</b> The evidence is inconsistent on the level of assistance required. Moreover, while financial support may allow the application of affordable tariffs, the fully subsidized models challenge the developer's autonomy and set a dependency on the donor.</p>

# RQ3. Which business models are used, and which ones are deemed successful and on what basis?

## Customer Focus Models

Households and small businesses



The evidence is weak to demonstrate that a customer focus on households and small businesses can achieve financial sustainability in the long term. However, many authors suggest integrating productive users into the load to improve the business model's viability.

ABC model



The evidence is strong and consistent in proposing the ABC model as the most promising approach to achieving mini-grids financial sustainability. An anchor client can stabilize the revenue, improve mini-grids viability, and reduce the risk of connecting smaller users. Experiences with telecom and agro-processing industries have shown that the model works.



In SSA, the lack of availability of large businesses in rural areas may limit the scalability of this business model.

## Implementation Models

Clustering approach



The evidence of the viability of the clustering implementation approach is weak and inconsistent. This model establishes opportunities for economies of scale. However, the literature indicates the need for strong managerial and operational skills to succeed, limiting its scalability capacity in SSA.

Operational Bundling



The evidence of the scalability of this business model is weak and inconsistent. None case studies were identified for SSA.

Franchise approach



The evidence of the scalability of this business model is weak and inconsistent. None case studies were identified for SSA.

Portfolio diversification approach



The evidence is strong and consistent in indicating the potential of this approach to improve financial access to mini-grids development.



The lack of examples in the literature limits the ability to conclude on the scalability in SSA.



# Next steps

- Review of the different elements explaining financial sustainability: costs (CAPEX, OPEX, financial) and revenues (demand, tariffs, subsidies). What is the main stumbling block for financial viability?
- Review of access to finance for mini-grids
- Review of the risk profile of mini-grids in SSA and beyond
- Finalisation of working paper- academic paper
- Peer review and contributions by SIGMA colleagues