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Joint EU-AU synthesis report on the business models research

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Summary

Smallholder farmers are for all intensive purposes the breadbasket of sub-Saharan Africa. They are responsible for 80% of the region?s agricultural output. Despite their critically important role, they are largely neglected, often living outside the reach of critical infrastructure. Electricity, which plays a vital role in agricultural productivity, remains especially elusive. 80% of the region?s rural population are smallholder farmers and only 29% of this population has access to electricity. This report proposes a demand-led approach to designing off-grid rural electrification interventions in an effort to facilitate distributed renewable energy (DRE) business models that can accelerate the pace of electrification. It places the smallholder farmer at the centre ? assessing financial viability of acquiring solar water pumps and agro-processing equipment from the perspective of the farmer and determining the suitability of different off-grid DRE technologies (standalone solar and mini-grids) depending on the activity to be electrified.

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Business models for electrification of smallholder agriculture in sub-Saharan Africa

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Key highlights

- Smallholder farmers are for all intensive purposes the breadbasket of sub-Saharan Africa. They are responsible for 80% of the region's agricultural output. Despite their critically important role, they are largely neglected, often living outside the reach of critical infrastructure. Electricity, which plays a vital role in agricultural productivity, remains especially elusive. 80% of the region's rural population are smallholder farmers and only 29% of this population has access to electricity;
- This report proposes a demand-led approach to designing off-grid rural electrification interventions in an effort to facilitate distributed renewable energy (DRE) business models that can accelerate the pace of electrification. It places the smallholder farmer at the centre – assessing financial viability of acquiring solar water pumps and agro-processing equipment from the perspective of the farmer and determining the suitability of different off-grid DRE technologies (standalone solar and mini-grids) depending on the activity to be electrified;
- Results from our techno-economic modelling show that across the key agri value chains in the four case study countries of Nigeria, Rwanda, Zambia and Zimbabwe, the majority of irrigation and agro-processing activities are viable for electrification with DRE technologies. The only activities that are not profitable are those that pertain to cassava, mainly due to relatively low prevailing prices that farmers can ask for these crops. Electrifying irrigation with solar water pumps seems to be especially profitable for all crops considered, except for cassava. The techno-economic model can be downloaded here;
- The report also expands the scope beyond ground-level techno-economics. It adopts a macro approach, also considering factors that influence DRE business model success in the national context. These include DRE regulations, access to finance among DRE companies and state of digital and physical infrastructure. This approach is discussed in this report through the lens of Nigeria, Rwanda, Zambia and Zimbabwe;
- Macro considerations create enabling conditions in these countries to varying degrees. In Nigeria, regulations create a healthy operating environment for organisations that are chiefly tasked with business model implementation: DRE companies. In Rwanda, clear regulations are in place, but the low priority given to the off-grid sector by the government means that the industry remains small. Zambia has a well-crafted mini-grid legislation in place, but its continued draft status stifles growth, while the market in Zimbabwe would benefit from the introduction of regulations. While some countries perform better than others on financing availability, companies across the board generally find it difficult to source suitable financing. Infrastructure such as mobile money performs relatively well in most countries, while physical access to rural areas remains a challenge;
- The contents of this report are intended to open up a discussion for more user-centred business model design. The concepts put forward are not intended to be close-ended. We recommend that the different business models and their associated techniques discussed here (e.g. techno-economic modelling) be tested in a variety of operating environments among a larger proportion of standalone solar and mini-grid companies. These continued practical experiences will add more robustness to concepts introduced here and strengthen the effort towards universal electrification for smallholder farmers in sub-Saharan Africa.

1. Introduction

Energy typically becomes more expensive and less available the further one travels from central, urban areas. The effects of this are particularly evident in the value chains of sectors that span rural and urban economies. Agriculture is one such sector. Low levels of energy access in rural areas limit the ability of rural farmers to irrigate and process their crops.[1] This drives energy-enabled value addition further down the value chain and further away from agriculturally productive, usually lower income rural communities. Despite their important role at the source of these key value chains, rural communities receive a fraction of the total value created between farm and consumer.[2] Instead, value capture is concentrated in large commercial downstream processing facilities. This, in turn, exacerbates the rural/urban divide and keeps rural farmers locked in a cycle of poverty.

Nowhere is this more true than in sub-Saharan Africa. 75% of the world's unelectrified population live in sub-Saharan Africa and the number of people living without access in the region increased from 556 million people in 2010 to 570 million in 2019.[3] The majority of this population live in rural areas – only 28.5% of the rural population had access in 2020.[4] Approximately 70%-80% of the region's rural population is employed in the agricultural sector.[5,6] It is therefore clear that the majority of people without electricity access in rural areas depend on agriculture for their livelihoods. In addition, the majority of this population farm on a small-scale – smallholder farmers account for 80% of the region's agricultural production.[7] As IRENA's Tracking SDG 7 report notes, we are far off from reaching universal electrification in sub-Saharan Africa by 2030, and it is especially rural populations that bear the brunt of this slow progress. **Accelerating the pace of electrification would require a fundamental shift in how electrification interventions, especially those in rural areas, are designed and implemented.**

This report seeks to introduce such a paradigm shift. It compiles extensive research conducted by TFE with support from industry partners as part of the Renewable Energy for African Agriculture (RE4AFAGRI) project of the Long Term Joint EU-AU Research and Innovation Partnership on Renewable Energy. The report introduces the concept of user-led electrification interventions using renewable energy and offers approaches for how these can be designed and implemented in the context of the agri-energy nexus. Agricultural uses of energy form a key focus of this research due to the importance of agriculture in places where electricity access is at its lowest. Improved rural energy access that leads to improved agricultural output offers significant potential for breaking the rural poverty cycle. As such, the agri-energy nexus is the central theme of this research. The user-led component of this study design was adopted from the need to depart from traditional supplier-led models where standard electrification interventions are implemented without consideration of local needs. This limited consideration of local needs, we believe, is a key reason for why many rural electrification interventions fail and why, ultimately, progress towards SDG7 has not met expectations. Adoption of this user-led approach when designing and implementing electrification scenarios could enable the increased pace of SDG7 progress that this region so desperately needs.

TFE identified key agricultural value chains for smallholder farmers in the case study countries of Nigeria, Rwanda, Zambia and Zimbabwe and assessed the techno-economic viability of electrifying each activity in each value chain with renewable energy. We identified the distributed renewable energy (DRE) technologies best suited to power these activities and ultimately compiled best practice demand-led business models to successfully deploy these technologies. We have learnt that appropriate business model design and implementation must be responsive to local, on-ground conditions and requires consideration of macro-factors (factors at the national level), chiefly the following:

 Regulations

 Financing landscape

 Infrastructure

[1] Falchetta, G., Energy access investment, agricultural profitability, and rural development: Time for an integrated approach, 2022 (link)
[2] Lotter, A., Troost, A.P., Fischer, M. & Duby S., Energising Agriculture in Myanmar, 2021 (link)
[3] Blankenship, M. & Golubski, C. Figure of the week: Increasing access to electricity in sub-Saharan Africa, 2021 (link)
[4] World Bank, Access to electricity, rural (% of rural population), 2020 (link)
[5] Amankwah, A. & Gourlay, S., Impact of COVID-19 crisis on agriculture, 2021 (link)
[6] USAID, Agriculture and food security, 2020 (link)
[7] IFAD, Change starts here, 2021 (link)

We start in section 1.1 by introducing the concept of techno-economic viability and how it pertains to value chain electrification. We also discuss the renewable energy technologies best suited to power these value chain activities. In section 2, we look at foundational principles for user-led energy access business models, and we regard smallholder farmers as the key user in this discussion. Section 3 widens the lens by embedding the aforementioned discussion in the context of macro operating environments and what their structure should be to allow for successful business model implementation. While we do cover some country-specific details in section 3, sections 4 to 7 offer a deep dive into the status of the macro operating environment in each case study country (Nigeria, Rwanda, Zambia and Zimbabwe). We close in section 8 with forward-looking conclusions and recommendations.

1.1 Techno-economic viability of value chain electrification

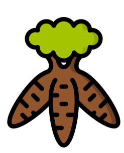
A first step was to identify the agricultural value chains that are the most important for smallholder farmers in Nigeria, Rwanda, Zambia and Zimbabwe. Table 1 presents the top 3 key agricultural value chains in each country for smallholder farmers based on the number of farmers involved with cultivation of the crop in question.

Nigeria	Rwanda	Zambia	Zimbabwe
Maize	Maize	Maize	Maize
Cassava	Cassava	Cassava	Groundnuts
Rice	Beans	Groundnuts	Sorghum

Table 1: Key agricultural value chains for smallholder farmers in case study countries[8,9,10,11]

The main steps involved in the cultivation (e.g. irrigation) and processing (e.g. threshing) were identified for each value chain and the current extent of electrification of each of these steps was identified in the four countries. As would be expected, it was found that the use of electricity in irrigation and processing of these main crops in the four countries is extremely low. For example, 0.9% of farmers in Rwanda use mechanical equipment compared to 1.7% of smallholders in Zambia.[12,13] In Zimbabwe, 7% of smallholder farmers use water pumps and about 2% use mechanical shellers.[14] The majority of these are powered directly with fossil fuels, so the share of electricity use is even lower.

	Maize value chain steps assessed			
	Irrigation	Drying	Shelling	Milling

	Cassava value chain steps assessed				
	Irrigation	Peeling	Grating	Milling	Chipping

	Rice value chain steps assessed			
	Irrigation	Threshing	Drying	Milling

[8] USAID, Agricultural productive use stimulation in Nigeria: Value chain & mini-grid feasibility study, 2020 (link)
[9] National Institute of Statistics of Rwanda, Agricultural Household Survey, 2020 (link)
[10] Indaba Agricultural Policy Research Institute, Rural agricultural livelihoods survey report, 2019 (link)
[11] Zimbabwe Vulnerability Assessment Committee, 2021 Rural livelihoods assessment report, 2021 (link)
[12] National Institute of Statistics of Rwanda, Seasonal Agricultural Survey, 2021 (link)
[13] Indaba Agricultural Policy Research Institute, Rural agricultural livelihoods survey report, 2019 (link)
[14] Zimbabwe National Statistics Agency, Zimbabwe Smallholder Agricultural Productivity Survey Report, 2019 (link)

	Beans value chain steps assessed			
	Irrigation	Drying	Threshing	Grinding

	Groundnuts value chain steps assessed				
	Irrigation	Shelling	Oil pressing	Crushing	Peanut butter

	Sorghum value chain steps assessed			
	Irrigation	Threshing	Dehulling	Milling

As a next step, suitable off-grid technologies for electrification of these activities were identified. The choice between standalone solar or mini-grids depends on whether the activity to be electrified is performed on a farm or in a village. **In most cases, standalone solar is the best suited technology in a farm setting, given the substantial need for irrigation, and given that standalone solar water pumping technology is well established and widely available.** On-farm agro-processing using renewable energy is also technically possible, but these technologies are not widely available yet and improvements are still to be made in terms of efficiency and throughput.[15] Compared to water pumps connected to mini-grids, standalone solar water pumps are also deemed preferable for on-farm irrigation as farms are typically located outside the reach of mini-grids. Mini-grids are always situated at locations where loads are concentrated, e.g. in a village. In Nigeria, for example, croplands are usually situated more than 4 km from the closest village.[16] 41% of smallholder farmers in Nigeria require 15-30 minutes to walk from the closest village to their irrigated fields and 51% more than 30 minutes.[17]

Mini-grids are likely the best suited technology for agro-processing activities which are typically performed in villages. Agro-processing can only be economically viable if the throughput that the machine can process is maximised. This can only be achieved if the machine is operated at a central location (e.g. in a village) where raw produce from multiple smallholder farmers in the surrounding area can be aggregated. Raw produce of one farmer is insufficient to maintain economically viable throughput. Buyers of crops also tend to come to villages, instead of going to each farm on an individual basis.[18]

If solar-powered water pumps and agro-processing machines can be made available in the right locations and at suitable price points, electrification of irrigation and processing activities can be techno-economically viable. The techno-economic model developed as part of this project has found that the only activities that are not viable for electrification are cassava irrigation in Nigeria and Zambia, cassava irrigation and milling in Rwanda and maize milling in Zimbabwe (see Box 1 for more details).

Box 1: Overview of TFE's open-sourced techno-economic model for agri value chain electrification

Initial scoping work for this research has revealed that little is known about methodologies to assess the techno-economic viability of electrifying irrigation and agro-processing in the context of smallholder agriculture. Towards this end, TFE has set out to develop a replicable model that can be used in any geography to assess techno-economic viability in terms of payback period (amount of time it takes a smallholder farmer to pay back the initial capital expense of the machinery), net present value (NPV) and internal rate of return (IRR).

The model's outputs are accurate provided that data inputs are accurate. On the income side, the model considers the marginal revenue enabled by the activity in question, e.g. maize threshing. This is

[15] The World Bank, Off-grid solar market trends report, 2022 (link)
[16] Focus group responses
[17] USAID, Agricultural productive use stimulation in Nigeria: Value chain & mini-grid feasibility study, 2020 (link)
[18] Focus group responses

equal to the difference between the price of maize per kilogram before threshing and after threshing. In the case of irrigation, there is also a price difference between rainfed and irrigated crops given the higher quality of irrigated crops. Annual revenue is dependent on throughput (in the case of agro-processing) or yield increases (in the case of irrigation). On the expenses side, the model considers all costs associated with operation of the water pump or agro-processing machine, including labour, maintenance, electricity and others.

The model considers additional nuances over and above basic income and expense metrics, all of which can be viewed in the open-sourced version of the model, accessible here**.** The model is free to download and open sourced for use by all stakeholders. A user guide for the model is available in annex 1.

Given that standalone solar technologies and mini-grids play equally important roles in the electrification of smallholder agriculture activities in sub-saharan Africa, this report seeks to address the central question of how to design and implement business models that would lead to the broad deployment of these technologies.

2. Business models for the agri-energy nexus

Energy access service providers are increasingly realising that productive uses of electricity are core to financial sustainability. Productive users of electricity perform income-generating activities, which are linked to higher energy consumption and higher ability to pay for electricity. In the case of mini-grids for example, only 20% of the customer base typically consists of productive users, yet they account for 80% of total revenue.[19] As a result, energy access business models are now, more than ever, being designed around productive uses. This has meant that the agri-energy nexus has become a key concept in energy access business model design and implementation. Energy access is at its lowest in rural areas and a significant portion of productive uses in these areas are agriculture-based. **It follows that the ability to effectively design energy access business models around agricultural activities and electrify those activities cost effectively are key in the overall success of rural energy access interventions.** Towards this end, service providers in sub-Saharan Africa have been finding creative ways of stimulating agricultural uses of electricity through, for example, microfinancing of solar water pumps and agro-processing machinery through different payment schemes, acting as a buyer of local agricultural outputs and selling it in economic hubs and others discussed in the remainder of this section.

2.1 Pay-as-you-go or PAYGO

Affordability significantly constrains the uptake of irrigation and agro-processing products. This means that many smallholder farmers find it difficult to pay for water pumps and agro-processing machines upfront. PAYGO arrangements address this issue by allowing the farmer to pay for the use of the system over time instead of buying the system outright.

The PAYGO model leverages mobile technology. Farmers are able to pay for their equipment using mobile money in daily, weekly, or monthly instalments instead of a higher upfront cash payment. The system is typically connected to a remote monitoring and control system which enables the energy provider to monitor usage and system performance and enables remote lockout (automatic switch-off) in case user credit runs out.[20]

PAYGO solar lighting systems for household use are now widely applied across sub-Saharan Africa. The use of PAYGO for solar water pumps and agro-processing equipment, in comparison, is not yet as prevalent. Deploying this deferred payment mechanism in solar water pumps and processing machines is more challenging because these types of equipment have higher costs (requiring larger loan sizes), are more complex (less scope for plug-and-play and needing more customer touchpoints), and are bulkier (making it difficult to distribute to hard-to-reach areas). Given that most PAYGO business models are currently geared towards household solar products, there is a need for an adaptation of existing approaches to account for the differences found in agricultural productive use equipment.

PAYGO can be designed in the form of a “lease-to-own” model. This involves customers paying for the system in small instalments over a period of time and gaining full ownership at the end of the repayment period (see section 2.1.1). “Usage-based” or “service-based” models are nascent but growing. Under this

[19] Lighting Global, The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa, 2019 (link)
[20] Lighting Global, The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa, 2019 (link)

arrangement, users pre-pay for energy or, for example, pumping services but never own the system (see section 2.1.2). Other variations have also been proposed in recent years, such as:

- Pay-as-you-grow: This model has been implemented by some solar water pump distributors and is based on the fact that farmers' income seasonality affects repayment. Flexible repayment terms, i.e. giving time to farmers to sell their produce during harvest seasons, increase affordability and uptake of products;
- Barter sales (non-cash payments): Distributors have also started accepting farmers' produce (crop or livestock) as payments, since the distributors are typically better suited to find an off-taker for crops or livestock in downstream markets.

2.1.1 Lease-to-own

The lease-to-own model operates in the same way as a conventional loan. This service can be offered directly by the supplier of the solar water pump or agro-processing machine, or by involving an external financing partner. Suppliers offering in-house asset financing services need to incorporate some important tools to properly distribute and manage consumer lending. Some of these tools are being adopted from the microfinance sector, while others are being adapted.[21] These include:

- Remote lockout technology that reduces the risk of theft and expands the realm of possibilities for nonpayment contract clauses beyond simple repossession. A remote lockout can also enable flexible financing terms, which adhere more closely to the lumpy income patterns of many informal sector jobs;
- Remote-sensing and location devices that facilitate repossession and mitigate against unauthorised use of an asset;
- Digital payments, automated loan-management software, and well-trained call centres that keep costs low by allowing large portfolios to be serviced by relatively few staff;
- Use of the asset itself as collateral, eliminating the need for borrowers to pledge an existing asset, such as their house or land, which many customers may not own or have a formal title to.[22]

Providing in-house financing services is resource intensive and thus challenging. To avoid expanding financial skills and processes in-house, many suppliers and distributors of equipment prefer to partner with a dedicated financial institution to outsource consumer financing services. These are typically microfinance institutions (MFI), which have extensive knowledge of last-mile consumers and logistics to finance PUE products.[23] MFIs are better able to reach low-income, last-mile borrowers due to their large network of branches and relatively low collateral requirements, can better manage a large number of small-size loans, and can bundle their offerings with other interesting products suited to this clientele (i.e. insurance). Energy access suppliers can benefit from these partnerships through added distribution support, marketing, and expanding sales, while MFIs can expand their loan portfolio with new products at the same time. MFIs charge interest on loans and receive commission from the energy access company if it was also involved with selling or promoting the product. Commission rates range between 10% and 20% depending on the product and country.[24]

The main challenges of MFIs partnering with agri-energy companies to offer consumer financing are related to:

- In areas or countries with limited GSM and mobile money coverage, operating and logistics costs are high, necessitating face-to-face payment collection and customer reminders;
- High cost of capital for MFIs and very high interest rates passed down to borrowers (up to 40%-50% in some cases);[25]
- A mismatch between MFIs' products and customers' needs: Most farmers in sub-Saharan Africa have seasonal incomes, making fixed repayment schedules unappealing or even impossible in some cases.[26]

It is therefore important for MFIs to carefully review the financial product and criteria to meet the needs of the target customer. The loan tenor, size of instalments, and repayment frequency are the most impactful factors in determining the customer's ability to apply for a loan.

Box 2: Practical example of the MFI partnerships in use

[21] Consultative Group to Assist the Poor, Getting Repaid in Asset Finance, 2021 (link)
[22] Consultative Group to Assist the Poor, Getting Repaid in Asset Finance, 2021 (link)
[23] Efficiency for Access, Business Model Innovations Addressing Affordability, Case Studies, 2021 (link)
[24] Power Africa, Microfinance loans for increasing access to off-grid solar products, 2021 (link)
[25] Center for Strategic and International Studies, Supporting Small and Medium Enterprises in Sub-Saharan Africa through Blended Finance, 2021 (link)
[26] Power Africa, Microfinance loans for increasing access to off-grid solar products, 2021 (link)

Natfort Energy in **Zimbabwe** is partnering with an MFI partner that provides farmers with loans to buy PUE products like solar water pumps. This model offers value not only because these products are costly, rendering them difficult to pay for upfront, but also because companies such as Natfort Energy do not always have sufficient in-house skills to educate farmers about the associated credit risk. MFIs are better positioned to do customer vetting, education and follow ups.[27]

2.1.2 Service-based PAYGO models

Under the service-based PAYGO model, customers effectively pay for a service instead of purchasing and owning an appliance themselves. The service provider retains ownership of the appliance being used and assumes responsibility for its installation, operation, and maintenance. Service models are particularly useful for productive appliances that are expensive or used only intermittently. The most prominent agricultural-related service-based models in Africa are solar water pumping for irrigation (water-as-a-service), cooling (cooling-as-a-service), agro-processing (drying, milling, etc), and transportation (mobility-as-a-service).

With cooling-as-a-service (CaaS) models, instead of incurring a large upfront expense to buy a refrigerator, customers pay per amount of refrigerated air or pay a flat service fee, typically for one day of cooling service.[28] Service providers like **ColdHubs** offer centralised, solar-powered walk-in cold storage facilities in which customers can store perishable items in plastic crates.[29]

In water-as-a-service (WaaS) models, companies such as **Aptech** provide WaaS under a fixed monthly fee model. Companies manufacturing and/or distributing agro-processing equipment, or even mini-grid companies would be theoretically well positioned to offer services similar to the WaaS model, avoiding the outright purchase and instead leasing processing equipment or using a fee-for-service model.

Agricultural goods transportation is extremely important to move crops from farms to processing facilities or to reach final markets. Electric mobility as a service emerges as a solution that could potentially be implemented by dedicated companies such as EV company **OX Delivers** in Rwanda charging a fee for transport or by mini-grid developers such as Rubitec Solar partnering with EV companies such as **MAX** in Nigeria offering 2-wheeler transportation services in mini-grid communities.

2.2 Facilitation of services: The Keymaker model

Energy access is the first step towards improved livelihoods for smallholder farmers. Energy access must however be accompanied by additional measures if farmers are to make the most of these opportunities. As a second step, farmers need appropriately-priced irrigation and agro-processing equipment in order to have a practical use of electricity. In many cases, even the addition of this second step may still lead to failure of the overall intervention. Experience and various studies have shown that expanding electricity access, together with financing of irrigation and processing equipment is not a sufficient condition for enabling income growth and employment generation within a rural community.[30] Smallholder farmers are typically located in hard-to-reach rural areas. This means they typically have limited connections with downstream market actors, and transporting crops over long distances and low quality roads is challenging. These barriers reduce the ability of smallholder farmers to find suitable offset points for their crops that are now of higher quality and in larger volumes thanks to irrigation and agro-processing. Consequently, smallholders' crops are typically sold in the local market of the surrounding area. Thus, as a third measure, a service that enables farmers to sell their crops in downstream markets, can improve linkages between the farmer and downstream markets.

The Keymaker model (KMM) is a delivery model in which energy access suppliers act as an agent on behalf of smallholder farmers by selling crops grown and/or processed by local smallholder farmers to an external off-taker. This is done directly by buying unprocessed crops, processing the crops and reselling, or by acting as an intermediate between farmers and processors / off-takers.[31] The GMG facility explains the model according to Figure 1.

[27] Global Distributors Collective, Selling productive use of energy products to last mile-consumers, Lessons Learned, 2022 (link)
[28] Efficiency for Access, Business Model Innovations Addressing Affordability, Case Studies, 2021 (link)
[29] Efficiency for Access, Business Model Innovations Addressing Affordability, Case Studies, 2021 (link)
[30] African, Development Bank, Green Mini-Grid Help Desk, KeyMaker Model Fundamentals, 2019 (link)
[31] African, Development Bank, Green Mini-Grid Help Desk, KeyMaker Model Fundamentals, 2019 (link)

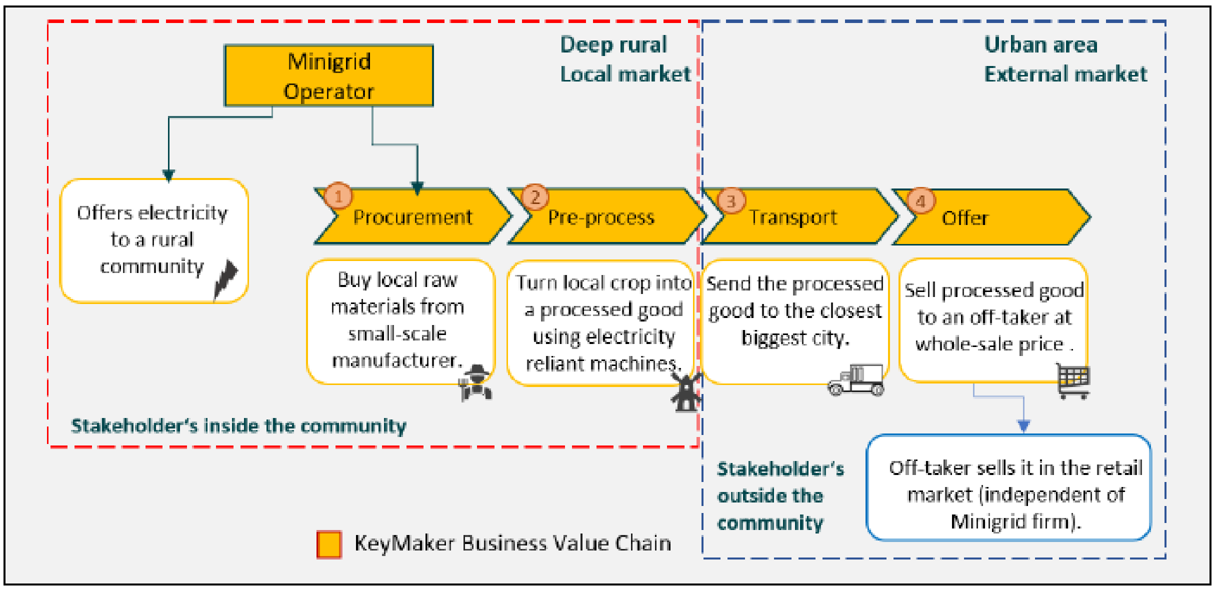


Figure 1: The KeyMaker value chain[32]

The local community is an extremely important stakeholder in the KeyMaker model. Not only is the community a beneficiary, it is also a trade partner at the source of the value chain as well as a customer of electricity.[33] Communities that live in unelectrified areas usually have primary production economies and have developed specialised knowledge around the handling and processing of raw materials. Small-scale farmers, for example, have extensive knowledge of the local conditions, which enables agricultural productivity.

However, smallholder farmers, in general, lack expertise in supply chain management, marketing, information technology and the networks needed to sell crops through multiple distribution channels outside the community.[34] The majority of smallholder farmers sell their crops exclusively to the surrounding community.

The Keymaker model can go beyond connecting farmers with downstream markets to also assist with sourcing quality farming inputs (e.g. seeds) cost-effectively. Both mini-grid developers and standalone product distributors are theoretically able to provide such services to smallholder farmers and/or processors.

Box 3: Practical examples of the Keymaker model in use

The mini-grid company **Zengamina** operates a 700 kW hydro power station in the Zambezi river in **Zambia**. The project supplies over 600 households with electricity and has transformed the standard of service and staffing of district social facilities (hospitals and schools). Most pineapples in Zambia are produced in this district but struggled to reach a market due to bad roads. Zengamina established a pineapple drying factory using excess electricity from the small hydropower station to process, add value and create local jobs. With the support of Musika (NGO), the company Zambezi Pineapples was born. It sources the highest quality pineapples available locally from smallholder farmers and processes them into dried fruit and juice using renewable, mini-grid electricity.

JUMEME, a rural PV mini-grid power supplier in the islands of Lake Victoria, **Tanzania**, collaborates with Tanzanian local communities to collect Tilapia fish on islands in Lake Victoria. It freezes Tilapia on site with mini-grid electricity, reducing postharvest losses and delivers frozen Tilapia to Dar Es Salaam at wholesale prices.[35] Significantly higher prices are reached in Dar es Salaam than in the nearby town of Mwanza and the optimised supply chain reduces overall transport costs.

2.3 Community-centred business models

Energy access interventions can benefit from a balance of responsibilities between the community and the private supplier of electricity (whether in mini-grid or standalone form). Embedding shared responsibility and shared value into business model design offers the following benefits:

[32] African, Development Bank, Green Mini-Grid Help Desk, KeyMaker Model Fundamentals, 2019 (link)
[33] African, Development Bank, Green Mini-Grid Help Desk, KeyMaker Model Fundamentals, 2019 (link)
[34] African, Development Bank, Green Mini-Grid Help Desk, KeyMaker Model Fundamentals, 2019 (link)
[35] African, Development Bank, Green Mini-Grid Help Desk, KeyMaker Model Fundamentals, 2019 (link)

- For the developer, on-site presence of local agents or technicians reduces the site visit travel requirements and associated costs;
- Local community members receive skills training and can be locally employed to conduct paid activities on behalf of the developer, for example troubleshooting of issues that customers are experiencing with their system;
- Local technical upskilling and increased local incomes improve livelihoods and stimulate local economic activity. Increased economic activity may increase energy demand and improve ability to pay, thereby catalysing a virtuous cycle of rural development.

Examples of sharing mechanisms include:
- Profit sharing, where the energy company distributes a portion of their profit to the community, usually to incentivise behaviour such as on-time payment;
- Shared ownership, where assets (e.g. the assets of the local mini-grid) are co-owned and profits distributed accordingly between the supplier and the community. This has several benefits:
    - Incentivising communities to support a project's success;
    - Catalysing local economies, providing livelihood opportunities and additional sources of income which can be recirculated via energy sales;
- Public benefit where an energy company provides street lighting at low or no cost to a community to gain goodwill.[36]

Energy demand estimation, willingness-to-pay assessment and customer acquisition can be supported by trained local representatives. Similarly, on-site activities like collection of payments, technical maintenance and customer care can readily be undertaken by local agents. Local agents, by virtue of their familiarity with local conditions, may also be more effective at facilitating engagement between energy access suppliers and communities. Increases in developer operating costs from agent remuneration could be offset against reduced travel requirements, improved demand estimation and system sizing, better customer risk evaluation, and improved customer acquisition.

Box 4: Practical example of community-centred business models in use

Mobility for Africa (MFA)'s electric vehicle deployment business model in rural areas is based on a shared-use, community-centred service model that relies on off-grid solar installations for charging.[37] MFA manufactures and leases e-tricycles called Hambas to productive groups of up to five people who then share its use. The tricycle is custom designed to meet the driving and transport needs of rural communities.[38] The Hamba device has a maximum load capacity of 400 kg and can cover 50–60 kilometres with a full charge, depending on the load carried. MFA's charging station operates on a 13 kW solar system. Each Hamba vehicle requires approximately six hours to charge.[39]

The Hamba costs $1,500 (without batteries) if paid for upfront. Alternatively, the Hamba can be accessed with a monthly rental fee of $15 (without batteries), making it 30% to 40% more affordable to lease than traditional petrol-fuelled vehicles.[40] MFA retains ownership of the batteries. This PAYGO arrangement is key to the success of the business model, as batteries are the biggest cost component in EVs. Solar charging a single battery costs $0.15. This is sufficient to support a daily commute of 30km.[41] This is much lower than the operating cost of fossil fuel-powered motorcycles, which is estimated at $5.50 for the same distance.

The company's primary target customers include smallholder farmers, workers in associated agriculture sectors (dairy, horticulture, poultry), and goods-trading groups. Small-scale farmers lease the Hamba in order to transport produce such as milk, fruits, tea, or coffee to market aggregators.[42] This leads to less food spoilage, improving the farmers' bargaining power. MFA's business model is presented in Figure 2.

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[36] HPNET, Community Enterprise Hydropower Networks, 2019 (link)
[37] Mobility for Africa, Providing low-cost quality renewable electric three-wheeler vehicles built for a rural environment, 2023 (link)
[38] Mobility for Africa, Providing low-cost quality renewable electric three-wheeler vehicles built for a rural environment, 2023 (link)
[39] Efficiency for Access, Business Model Innovations Addressing Affordability, Case Studies, 2021 (link)
[40] Efficiency for Access, Business Model Innovations Addressing Affordability, Case Studies, 2021 (link)
[41] Efficiency for Access, Business Model Innovations Addressing Affordability, Case Studies, 2021 (link)
[42] Efficiency for Access, Business Model Innovations Addressing Affordability, Case Studies, 2021 (link)

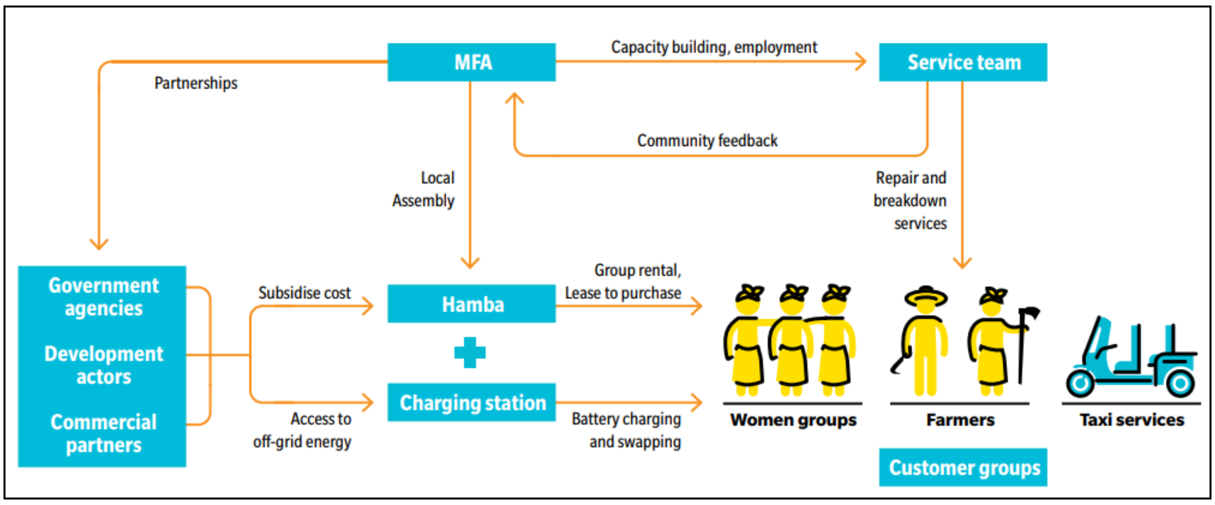

Figure 2: MFA business model[43]

[43] Efficiency for Access, Business Model Innovations Addressing Affordability, Case Studies, 2021 (link)

3. Macro considerations affecting business model implementation

Energy access business models targeting smallholder farmers discussed in section 2 require favourable operating environments to succeed. Regulations should allow for clear operating procedures with limited bureaucracy. Companies should ideally have sufficient access to finance to operate and grow their businesses and the physical and digital infrastructure (for example digital mobile money payments) to implement business models.

3.1 Regulations

Regulations have a significant impact on the favorability of an enabling environment. For example:

- **Licensing and permitting:** Should ideally not be too onerous for energy access companies;
- **Tariffs and price ceilings:** Cost-reflective tariffs and prices should ideally be permitted;
- **Quality standards:** Quality standards should ideally aim for consumer protection, without being set at a level that is too high (which unnecessarily increases the cost base for suppliers);
- **Import duties and other taxes:** Renewable energy components should ideally be exempted from import duties and taxes so as to allow the sector to scale up.

The status of regulations in the case study countries is discussed in detail in sections 4.2.1, 5.2.1, 6.2.1 and 7.2.1.

3.2 Financing

Sub-Saharan Africa has at least 44 million micro, small, and medium enterprises (SMEs), almost all of which are micro.[44] These businesses need access to capital to grow. Of these, 51% require more funding than they can access.[45] Credit constraints are a serious challenge for SMEs. Without reliable sources of working capital, SMEs are unable to make investments needed for growth.

Off-grid solar (household solar home systems and productive use solar) and mini-grid companies across sub-Saharan Africa typically share the common challenges of prohibitively high interest rates charged by commercial banks coupled with short tenors and stringent collateral requirements. These challenges have the most severe effect on the mini-grid industry, where longer-term, infrastructure type financing of more than five years is needed. Commercial banks tend to be reluctant to offer tenors that match this return profile.[46] Local commercial banks especially are unfamiliar with mini-grid investments, which widens the lending gap further. DRE companies, especially smaller ones, typically have limited credit history and limited capacity to perform business and financial planning,[47] which leads to a weaker investment case. The financing gap is exacerbated by the small-scale nature of OGS and mini-grid investments. Borrowing requirements are often perceived by lenders to be too small to warrant the risks and transaction costs. For detailed accounts of funding availability and conditions in the countries of concern, see sections 4.3, 5.3, 6.3 and 7.3.

Figure 3 below describes some of the main indicators measured by the Enterprise survey program by the World Bank, in each of the target countries. Rwanda presents the highest potential in terms of access to finance. It is the country where SMEs have the highest access to loans, the highest level of bank use for working capital financing, and the lowest level of access to finance constraints.

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[44] IFC, MSME finance gap: assessment of the shortfalls and opportunities in financing micro, small and medium enterprises in emerging markets, 2017 (link)
[45] Center for Strategic and International Studies, Supporting Small and Medium Enterprises in Sub-Saharan Africa through Blended Finance, 2021 (link)
[46] USAID, Mini-grid challenges and needs in financing, 2023 (link)
[47] Center for Strategic and International Studies, Supporting Small and Medium Enterprises in Sub-Saharan Africa through Blended Finance, 2021 (link)

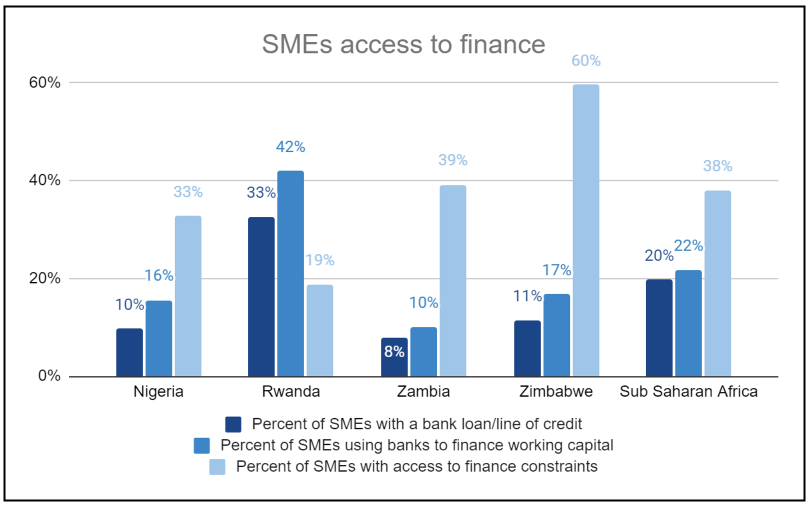

Figure 3: SMEs' access to finance indicators[48]

Financing of energy access companies in sub-Saharan Africa is still predominantly carried out in hard currency, typically US Dollars. While various attempts are being made to increase the share of local currency financing in many countries, local financial institutions are often ill-equipped to understand the investment case of energy access companies, which increases perceived risk and reduces the chances of investment. It means that, in the status quo, hard currency financing will remain the norm. Macroeconomic conditions should ideally allow for easy exchange between local currency and USD. This requires a stable exchange rate between local currency and USD. Figure 4 presents monthly fluctuations between the USD and the Rwandan Franc, Zambian Kwacha, Nigerian Naira and Zimbabwean Dollar. The Rwandan Franc is the most stable currency of the countries under study, with a standard deviation of 0.006. The most volatile currency is the Zimbabwean Dollar with a standard deviation of 0.613, followed by the Zambian Kwacha with 0.199 and the Nigerian Naira with 0.097. Rwanda's relatively stable currency creates favourable conditions for foreign currency investment, which bodes well for investment into energy access companies. Conversely, foreign currency investment into Zimbabwe and, to a lesser degree, Zambia and Nigeria, is hampered by a volatile exchange rate which in turn stifles investment into energy access.

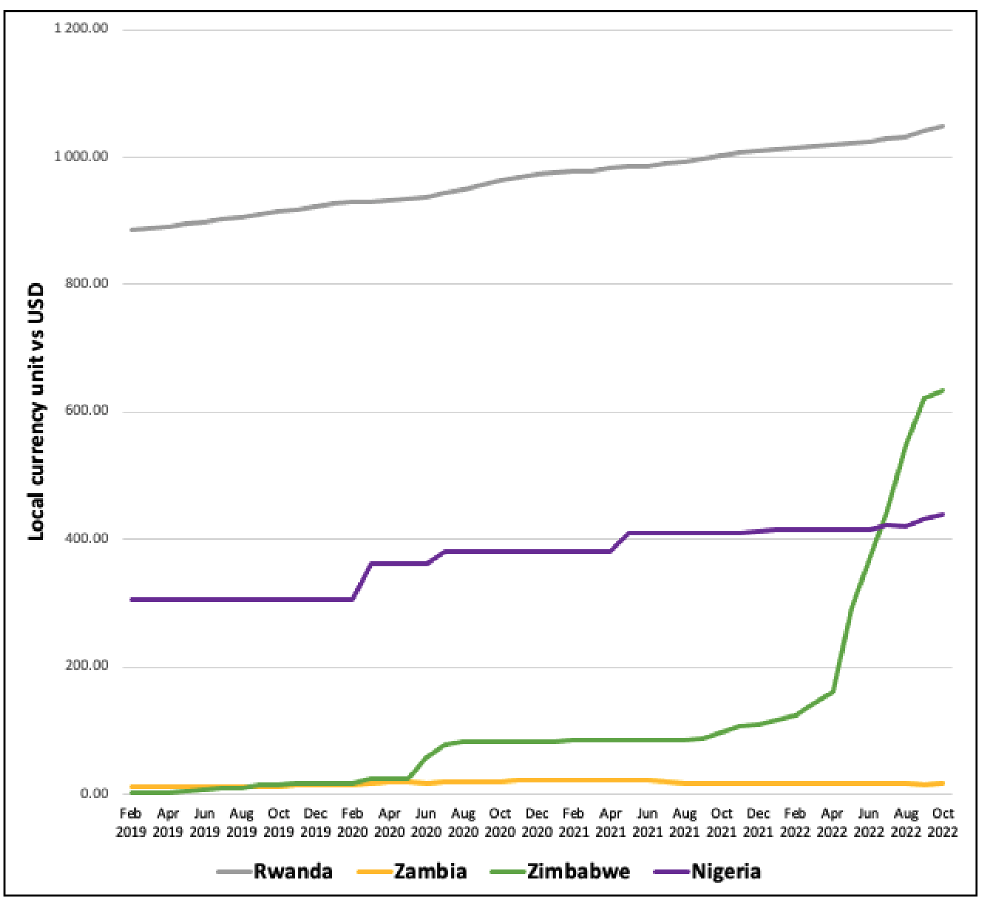

Figure 4: Exchange rate volatility of selected local currencies vs USD[49]

[48] The World Bank, Enterprise Surveys Data, 2023 (link)
[49] TFE analysis based on data from: IMF, International Financial Statistics, 2022 (link)

3.3 Infrastructure

For energy access business models discussed in section 2 to be deployed easily, various types of infrastructure needs to be in place, from national-level physical and digital infrastructure to company-specific internal infrastructure (e.g. digital infrastructure such as risk assessment processes, management information systems, ERPs and systems to analyse repayment capacities of customers).

3.3.1 Digital and mobile infrastructure

Following an unprecedented increase in mobile cellular services across sub-Saharan Africa, many countries across the region are experiencing a rapid increase in the number of people gaining access to the formal economy. Mobile phones have become the gateway for underserved parts of Africa's population to access financial services, connectivity, knowledge, skills, information, goods and services. Farmers can for example receive notifications of crop orders and perform key tasks, such as uploading details of produce for sale. It is also beneficial for farmers to have some experience with formal value chains, understand quality standards and have relatively high productivity, so that they have sufficient produce to sell through the online channel.[50] Mobile devices connected to the internet facilitate this access to information. On the supply side, energy service providers and agricultural equipment suppliers can expand their customer base by reaching a portion of the population that otherwise would not have been reachable without mobile money.

In developing countries, where debit and credit card penetration is relatively low, mobile device ownership and mobile connectivity serve as important enablers of access to financial services through mobile money. Digital payments accelerate the transaction process and avoid the problems associated with cash-on-delivery, such as fraud, delays to the transaction fulfilment, and the time and cost of payment collection or paying suppliers.[51]

Mobile money services are critical for the functioning of PAYGO business models. Smallholder farmers that have access to mobile devices, mobile connectivity and mobile money services can pay for a variety of services on-the-go, instead of incurring high upfront capital expenditures. PAYGO can theoretically operate without mobile money, but this would require paper-based systems, reducing scalability.

Status of mobile infrastructure in-country: The GSMA Mobile Connectivity Index
GSMA developed a mobile connectivity index that measures various indicators that act as enablers for mobile internet connectivity. The indicators measured within this index are:[52]

- **Infrastructure:** Availability of high-performance mobile internet coverage;
- **Affordability:** Availability of mobile services and devices at affordable prices relative to national income levels;
- **Consumer readiness:** Citizens with the awareness and skills required to use the internet;
- **Content and services:** Availability of secure online content accessible to the local population.

Figure 5 shows the comparison of the total mobile connectivity index for the four countries of interest and the average SSA region from 2014 to 2021. Over the past few years, Rwanda, Zambia, and Zimbabwe present an index score relatively similar to each other and to the average of the SSA region (around 42/100 points in 2021), while Nigeria exhibits a score remarkably higher than the rest (56/100 in 2021).[53] This difference comes as a result of Nigeria attaining higher scores for both the "Affordability" and "Content and Services" indicators discussed above.

[50] GSMA, E-commerce in agriculture, new business models for smallholders' inclusion into the formal economy, 2019 (link)
[51] GSMA, E-commerce in agriculture, new business models for smallholders' inclusion into the formal economy, 2019 (link)
[52] GSMA, Mobile Connectivity Index, 2021 (link)
[53] GSMA, Mobile Connectivity Index, 2021 (link)

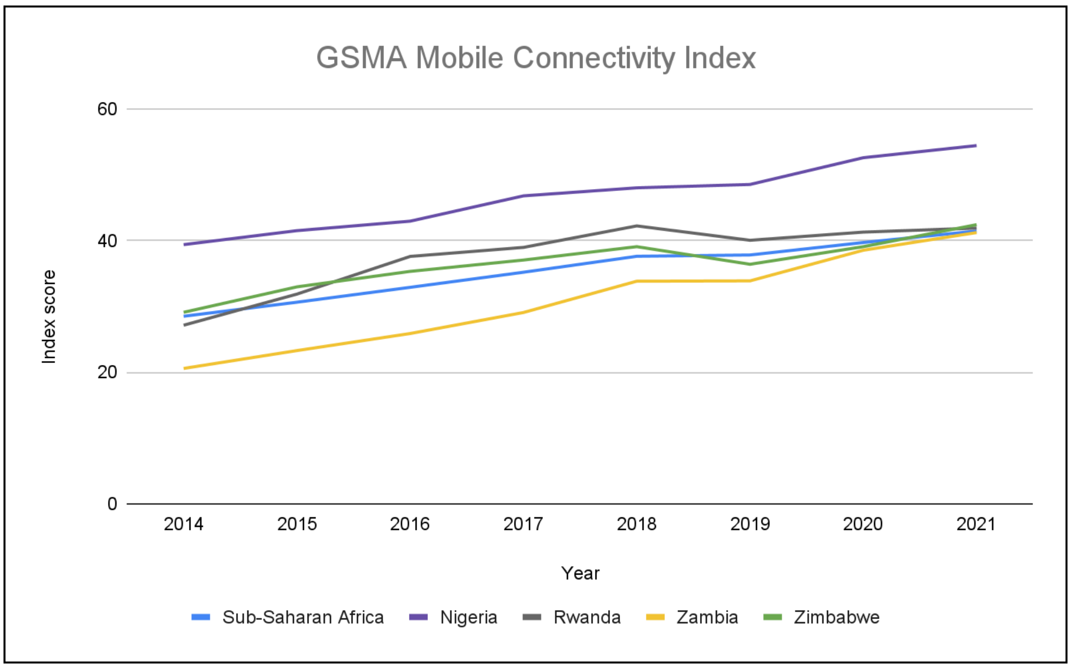

Figure 5: GSMA mobile connectivity index - total

Although all indicators are relevant for the deployment of mobile money payment modalities in modern business models, the “Infrastructure” indicator and the “Mobile ownership” sub-category (under the “Consumer readiness” indicator) result in better-suited parameters to measure current mobile money infrastructure status.

Figure 6 below presents the “Infrastructure” indicator scores for each country and SSA region. In this case, Rwanda has exhibited across the years a higher score than the rest of the countries and the entire region, which indicates that Rwanda has more extensive infrastructure in place to support mobile payment technologies. Nigeria, Zambia, and Zimbabwe have scores similar to the regional average. In all cases a growing trend is observed, indicating the potential of mobile money operations to scale.

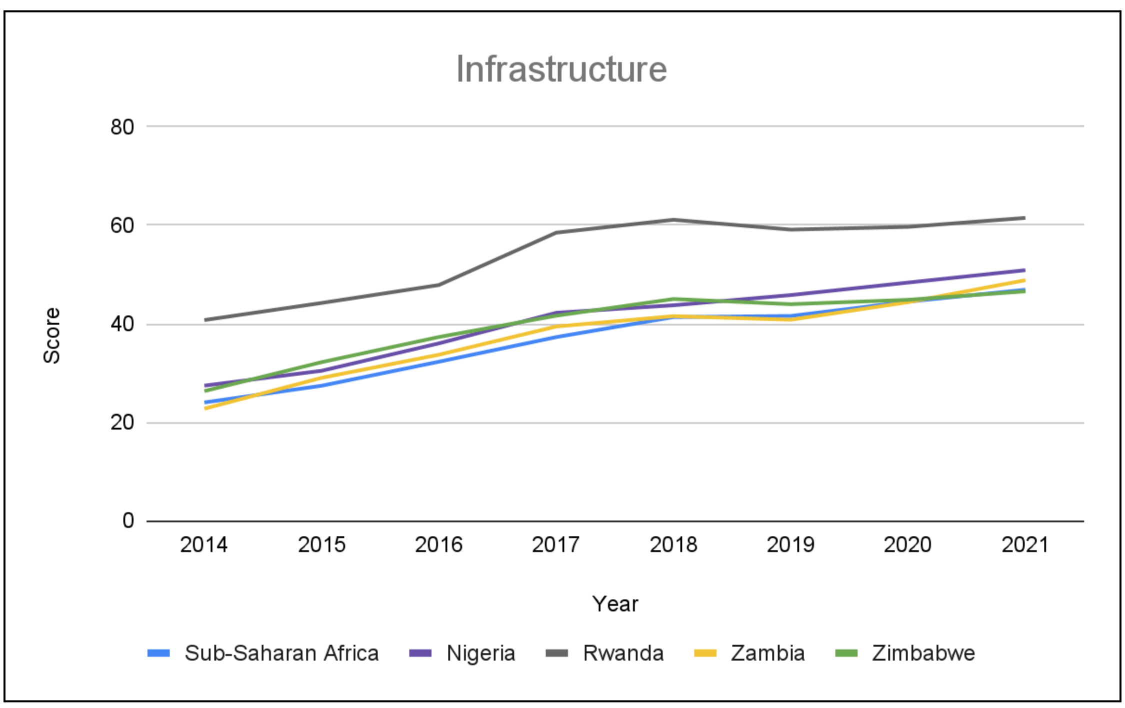

Figure 6: GSMA mobile connectivity index - infrastructure indicator[54]

Figure 7 below identifies the score for mobile ownership in each country. All countries present similar scores and trends under this category, above 50 points and growing.

[54] GSMA, Mobile Connectivity Index, 2021 (link)

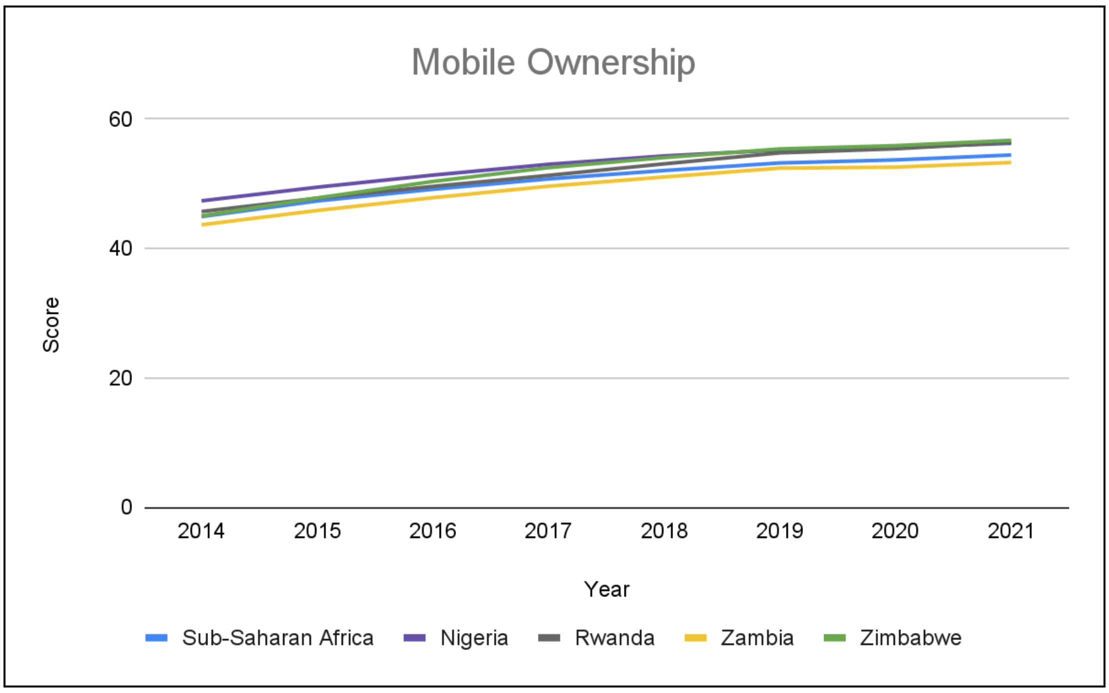

Figure 7: GSMA mobile connectivity index - mobile ownership[55]

The Mobile Money Prevalence Index from GSMA offers a high level overview of the current mobile money usage status. This index measures the number of mobile money accounts per adult, the active accounts in the last 90 days and the number of agents present in the country.[56] According to the mean value between these three dimensions, the target countries are classified as follows:

Country	Category	Mobile Money Prevalence Index
Nigeria	Medium	0.40 - 0.59
Rwanda	Very high	>= 0.80
Zambia	Very high	>= 0.80
Zimbabwe[57]	Very high	>= 0.80

Table 1: MMPI in target countries (2021)

As observed in Table 1 above, with the exception of Nigeria that presents a medium score for mobile money usage, the other three countries exhibit very high scores. This indicates that the adoption of mobile money in Nigeria is still low compared to the other countries, while mobile money is being adopted faster in Rwanda, Zambia, and Zimbabwe. For a detailed account of the current adoption status of mobile money in each country see sections 4.4, 5.4, 6.4 and 7.4.

3.3.2 Roads

Logistics is a critical factor for buying or selling (distributing) any physical product. This includes national infrastructure, such as roads, as well as transport services for first- and last-mile delivery.[58] Markets with a developed logistics infrastructure are better suited to have a higher penetration of companies along the supply chain and thus better connect producers with potential consumers.[59] This is the case for both physical commerce (on-ground food markets) and agri-e-commerce (online markets). Businesses can own their logistics infrastructure, but this can be capital-intensive and could have significant implications for the business model.

The Rural Access Index (RAI) was originally developed as a poverty indicator for rural access. The RAI measures the proportion of the rural population who live within 2 km of an all-season road.[60] It was originally developed and measured by the World Bank in 2006, using the interpretation of existing household questionnaires, and some modelling techniques. This provided a baseline for more than 60 countries, but measurements were not continued. The WB and Research for Community Access

[55] GSMA, Mobile Connectivity Index, 2021 (link)
[56] GSMA, Mobile Money Metrics, 2021 (link)
[57] Zimbabwe MMPI corresponds to year 2020 (no data available for 2021)
[58] GSMA, E-commerce in agriculture, new business models for smallholders' inclusion into the formal economy, 2019 (link)
[59] GSMA, E-commerce in agriculture, new business models for smallholders' inclusion into the formal economy, 2019 (link)
[60] Research for Community Access Partnership, Rural Access Index, 2020 (link)

Partnership (ReCAP) updated this work in 2016 introducing a new geospatial methodology to measure the RAI, which consists of three specific dimensions:

- Urban / rural population distribution;
- Roads and road networks distribution;
- Road conditions - classifying roads as "all-season" considering climate aspects (access during dry and wet seasons) and terrain aspects (flat or mountainous terrain).

Figure 8 below presents the updated Rural Access Index (RAI) for the target countries and for the average SSA region. The values represent the percentage of the rural population that is served by all-season roads. Rwanda exhibits a remarkably high RAI, indicating the well-established road infrastructure in the country. Zambia presents a very low RAI, suggesting the presence of important challenges in the road networks accessing rural areas and thus hampering the presence of last mile distributors and the facilitation of market linkages. Nigeria and Zimbabwe show RAI values above the SSA regional average, but there is still a large gap to be covered. Specifically, Nigeria which, considering the large rural population compared to the other countries, presents around 55 million people living in rural areas without access to all-season roads (the other countries have between 2- and 8 million people not served by all-season roads).

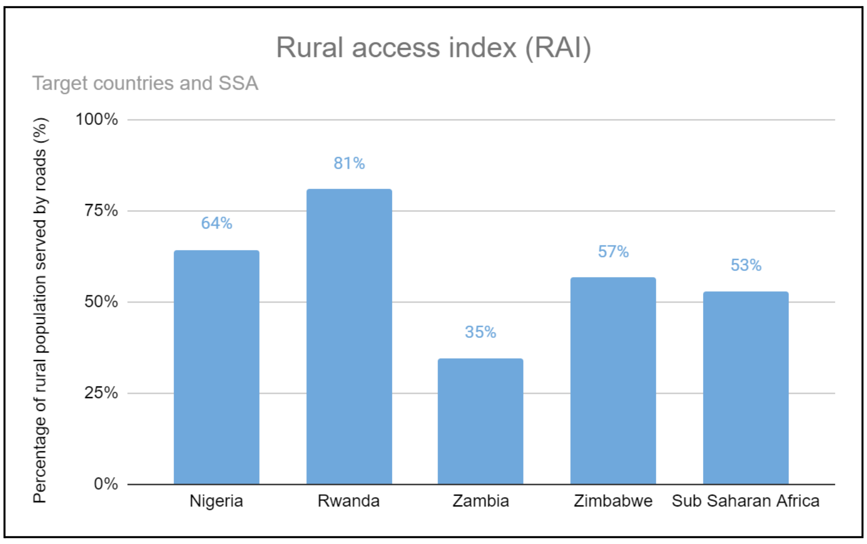

Figure 8: Rural access index (RAI) for target countries and SSA region[61]

[61] The World Bank, Rural Access Index Measurement Tool, 2019 (link)

4. Nigeria

Agriculture accounts for 20% of Nigeria's GDP and employs two thirds of the population.[62] Smallholder farmers represent 88% of the population involved with agriculture in Nigeria, with the average farm size per household at 1.12 hectares.[63] 90% of farmers growing rice and 95% of farmers growing cassava in Nigeria are smallholders.[64,65] The overwhelming majority of these farmers lack access to electricity – the country has a rural electrification rate of only 39%.[66] This has led to extremely low levels of mechanisation in smallholder agricultural practices. The national average rate of mechanisation is only 0.3 horsepower per hectare, compared to the FAO recommendation of 1.5 hp per hectare.[67]

As Section 1.1 shows, standalone solar water pumps are in most cases the preferred electrification technology for on-farm smallholder irrigation. Solar water pumps thus have a critical role to play in Nigeria given that only 2.2% of smallholder farmers have access to irrigation systems.[68] Conversely, as section 1.1 also indicates, small-scale agro-processing is best performed by machines powered by mini-grids located in villages. Electrifying the main Nigerian smallholder agricultural value chains (rice, maize and cassava) holds considerable potential provided that equipment is made available at appropriate price points. As table 2 shows, electrification of all activities across each of these value chains is techno-economically feasible from the perspective of smallholder farmers. All activities except for cassava irrigation have positive payback periods and NPV and IRR values. This analysis considers prevailing cost and income metrics for smallholder farmers in Nigeria (see Box 1 and annex 1 for more details about the model).[69]

	Nigeria												
	Maize				Cassava					Rice			
	Irrigation	Drying	Shelling	Milling	Irrigation	Peeling	Grating	Milling	Chipping	Irrigation	Threshing	Drying	Milling
Annual marginal revenue													
Produce sales	$2441	$1314	$1564	$11732	$289	$4693	$5866	$7625	$3519	$3325	$1304	$971	$3911
Others													
Total revenues	$2441	$1314	$1564	$11732	$289	$4693	$5866	$7625	$3519	$3325	$1304	$971	$3911
Annual marginal cost													
Transport cost to market	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290
Labour	$470	$313	$313	$940	$940	$1880	$1880	$1880	$1880	$392	$313	$313	$627
Maintenance	$33	$15	$50	$50	$33	$94	$94	$94	$94	$33	$24	$8	$80
Electricity	$0	$18	$166	$6781	$0	$497	$2147	$4973	$339	$0	$57	$18	$2260
Grid	$34	$3	$25	$1006	$68	$74	$319	$738	$50	$28	$8	$3	$335
Mini-grid	$228	$18	$166	$6781	$456	$497	$2147	$4973	$339	$190	$57	$18	$2260
Total costs	$793	$636	$819	$8061	$1263	$2761	$4411	$7236	$2603	$715	$684	$629	$3257
Annual marginal profit	$1648	$678	$745	$3671	-$974	$1932	$1455	$389	$917	$2610	$620	$341	$654
Indicators													
Upfront cost	$2361	$1566	$2420	$3000	$2361	$3250	$2000	$285	$2000	$2361	$1473	$3614	$1807
Payback (years)	1.43	2.31	3.25	0.82	-2.42	1.68	1.37	0.73	2.18	0.90	2.38	10.59	2.76
Payback (months)	17.19	27.73	38.97	9.81	-29.09	20.19	16.50	8.78	26.18	10.86	28.52	127.10	33.17
Value added	4.18	21.66	2.60	0.31	-1.24	2.25	0.39	0.05	1.56	7.95	6.34	10.91	0.17
Electricity source	Standalone	Mini-grid	Mini-grid	Mini-grid	Standalone	Mini-grid	Mini-grid	Mini-grid	Mini-grid	Standalone	Mini-grid	Mini-grid	Mini-grid
Location	Farm	Village	Village	Village	Farm	Village	Village	Village	Village	Farm	Farm	Farm	Village
Irrigation second season	Crop rotation				Crop rotation					Crop rotation			

Table 2: Indicative modelling results of value chain electrification in Nigeria[70]

While Nigeria is home to one of the largest markets for standalone solar and mini-grids on the continent, more work needs to be done to ensure that more smallholder farmers can access electricity needed for mechanised irrigation and agro-processing. This requires an assessment of the extent to which the enabling environment is favourable for implementation of the agri-energy nexus DRE business models discussed in section 2. These are mainly macro-considerations such as regulations, funding support and infrastructure.

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62 Agrilinks, Electrifying rural communities in Nigeria, 2020 (link)

63 World Bank, Transforming agribusiness in Nigeria for inclusive recovery, jobs creation and poverty reduction, 2022 (link)

64 Axmann, H., Policy brief: The impact of mechanisation in smallholder rice production in Nigeria, 2021 (link)

65 Global Energy Alliance for People and Planet, Energising agriculture through productive uses of energy, 2020 (link)

66 RIFS Potsdam, The Nigerian Electrification Project – An example of a successful rural electrification design?, 2022 (link)

67 USAID, Agricultural productive use stimulation in Nigeria: Value chain & mini-grid feasibility study, 2020 (link)

68 World Bank, Transforming agribusiness in Nigeria for inclusive recovery, jobs creation and poverty reduction, 2022 (link)

69 The model aims to be as accurate as possible by ingesting prevailing averaged national-level cost and income metrics pertaining to the purchase and operation of solar water pumps and mini-grid connected agro-processing equipment. These results can, however, only be considered as indicative given that input data vary from region to region in a country. The model is open-sourced and guides the user in populating the model with data from their specific local context.

70 TFE, Techno-economic model for agricultural value chain electrification, 2023 (link)

4.1 Mini-grid and off-grid solar market overview

Nigeria's net electricity generation per capita rate is one of the lowest in the world, with an estimated national electrification rate of only 55%.[71] The country has made progress in implementing favourable policies and regulations in the energy sector, as reflected in its overall RISE score of 55 out of 100.[72] Notably, Nigeria has performed well in key RISE indicators related to electricity access, including an impressive mini-grid framework score of 89/100, a perfect score of 100/100 for the framework for off-grid systems, and a score of 100/100 for consumer affordability of electricity.[73] Nigeria plans to reach 100% electrification by 2040, connecting 513,000 households each year from 2020 to 2040.[74] As a part of its 2020 Economic Sustainability Plan, the government has set an ambitious goal to provide 5 million new solar connections by 2023, using solar home systems and mini-grids. This initiative is expected to benefit up to 25 million people.[75]

4.1.1 Mini-grids

An estimated 106 mini-grids have been operating in Nigeria as of 2022.[76] Over the past decade, the installed capacity of mini-grids in the country has increased from 0.06 MWp in 2013 to 11.95 MWp in 2022.[77] In 2023, tariffs ranged between $0.30/kWh (subsidised) and $0.90/kWh (unsubsidised) for systems sizes between 4kW and 100 kW.[78] Average capital expenditure (CAPEX) ranges from $800 to $1,200 per connection.[79]

4.1.2 Standalone solar

GOGLA's semi annual sales report for the second half of 2022 reveals that Nigeria has dominated the standalone solar market globally, ranking among the top 3 in appliance-based sales volumes for TVs, fans, refrigeration units, and solar water pumps. The sale volumes of solar kits for lighting during this period increased by 55%, reaching a total of 722,614 units.[80] Solar agro-processing in Nigeria is underreported,[81] however, a number of companies are now actively selling standalone productive use systems. These include, for example, Sosai Renewables, a company that deploys solar dryers to farming communities in the north of Nigeria and Cold Hubs, a company that distributes large plug-and-play solar-powered cold rooms.[82]

Solar water pumps require high capital investments and this has posed an affordability challenge for smallholder farmers in Nigeria. As such, there has been poor irrigation uptake due to prohibitive installation and operational costs.[83] This is especially true for the large number of smallholder farmers who live below the poverty line of $1.9 per day.[84]

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[71] RIFS Potsdam, The Nigerian Electrification Project – An example of a successful rural electrification design?, 2022 (link)
[72] Regulatory Indicators for Sustainable Energy (RISE), Nigeria, 2020 (link)
[73] Regulatory Indicators for Sustainable Energy (RISE), Nigeria, 2020 (link)
[74] IEA, Rural Electrification Strategy and Implementation Plan of Nigeria, 2017 (link)
[75] Open Capital, Standalone solar investment plan: Nigeria, 2021 (link)
[76] Nigeria SE4All, Mini grids, 2022 (link)
[77] Nigeria SE4All, Mini grids, 2022 (link)
[78] SEforAll, Understanding mini-grid tariffs in Sierra Leone: A quantitative and comparative analysis of price drivers,2023 (link)
[79] USAID, Power Africa Nigeria Power Sector Program, Innovative Financing Model Report, 2022 (link)
[80] GOGLA, Global Off-Grid Solar Market Report, 2022 (link)
[81] Efficiency for Access, Off- and weak grid solar appliance market Nigeria, 2021 (link)
[82] Africa Clean Energy Technical Assistance Facility, Stand Alone Solar (SAS) Market Update: Nigeria, 2021 (link)
[83] USAID, Nigeria Power Sector Program, Productive Use Solar Irrigation Systems in Nigeria, 2022 (link)
[84] USAID, Nigeria Power Sector Program, Productive Use Solar Irrigation Systems in Nigeria, 2022 (link)

4.2 Macro considerations for DRE business models

4.2.1 Regulations affecting mini-grids and off-grid solar

Mini-grids in Nigeria are regulated by the Nigerian Electricity Regulatory Commission (NERC) Regulation for Mini-Grids 2016.[85] Isolated mini-grid regulations are enforced according to the generation capacity of the mini-grid, differentiated between projects smaller than 100 kW and those larger than 100 kW but smaller than 1 MW. The regulations are clear, leading to increased levels of investor confidence, ultimately improving operating conditions for mini-grid companies.

Mini-grids with a generation capacity of less than 100kW:
Isolated mini-grids with a generation capacity of less than 100 kW are required to register with NERC and are not required to have a permit. Isolated mini-grid operators can voluntarily apply for a permit. Registered mini-grid operators are not bound by Nigeria's Technical Codes and Standards, which include the Grid Code, Distribution Code, Metering Code, Health & Safety Code and the Nigerian Electricity Supply and Installation Standards (NESIS) Regulations. Mini-grid tariffs can be determined by the operator using the Multi-Year Tariff Order (MYTO)[86] calculation tool.[87]

Mini-grids with a generation capacity larger than 100 kW but smaller than 1 MW:
Isolated mini-grids that are larger than 100 kW but smaller than 1 MW are required to have a permit. A permit provides protection against grid encroachment. In the instance of the central grid being extended to the site of the mini-grid, a mini-grid developer is paid for the depreciated asset and any operating revenue generated over the previous 12 months. The Nigerian Electricity Management Services Agency (NEMSA) is charged with inspections and certifications of mini-grids, and inspections must take place in order for the NERC to approve a mini-grid permit. The mini-grid permit holder must design, construct, commission, operate, and/or maintain and de-commission its distribution network and related facilities in compliance with the technical codes and standards, terms, and conditions of its permit or tripartite contract.

The billing and tariff model of mini-grids operating under a permit are described in the standardised contract between the mini-grid operator and the customers in the community. Permit holders are required to use the MYTO cost-reflective methodology when determining tariffs, to comply with national technical codes and standards, and conduct an Environmental Impact Assessment (EIA).

Interconnected mini-grids
Interconnected mini-grids are required to submit a tripartite contract between the community, developer, and distribution company (DISCO). The distribution licensee and the mini-grid operator are free to define any usage charge for the distribution grid.

Standalone solar regulations
The standalone solar market in Nigeria is largely free of regulation. SAS products are considered under the National Environmental (Electrical/Electronic Sector) Regulations of 2011. The Government of Nigeria, through the Federal Ministry of Environment (FMEnv), is in the process of developing an e-waste policy.[88] Nigeria is also in the nascent stages of developing "take back" legislation which would legally require manufacturers and importers to finance the take-back and suitable recycling of their products. The relatively light-handed take on SAS regulations in Nigeria has meant that companies are able to operate without unnecessary restrictions.

4.2.2 Taxes affecting mini-grid and off-grid operations

Table 3 presents a summary of the status of taxes in Nigeria with a focus on those that are relevant to the DRE sector. Taxation of DRE is relatively favourable – most technologies are exempt from value added tax (VAT) and import duties. Nigeria's corporate tax rate is also in line with other countries in sub-Saharan Africa.

Corporate Income Tax	Value Added Tax	Withholding Tax	Import duties

[85] Nigerian Electricity Regulatory Commission, Regulation for Mini-Grids, 2016 (link)
[86] The MYTO methodology is based on allowances for three specific costs: Allowed return on capital, depreciation and operating and overhead costs.
[87] Nigerian Electricity Regulatory Commission, Electricity Tariff in Nigerian Electricity Supply Industry, 2023 (link)
[88] Africa Clean Energy-Technical Assistance Facility (ACE TAF), E-Waste Guide for Stand-Alone Solar in Nigeria, 2021, (link)

• Standard corporate tax rate is 30% for large companies (gross turnover of more than NGN 100 million) • 10% if the company has a significant economic purpose (SEP).[89] • Resident companies are subject to corporate income tax (CIT) both locally and internationally, while non-residents are subject to CIT only on Nigerian-sourced income.	• Standard VAT rate is 7.5%. • Renewable energy equipment is exempt from VAT as per the revised VAT (Modification) Order 2021, but implementation of the exemption is inconsistent.	• Dividends, interest, royalties and fees for management, consulting and technical services are liable for WHT of 10%, residents and non-residents included. • Payments to residents in a country with a double tax treaty (DTT) with Nigeria enjoy a reduced rate of 7.5%.[90]	• 20% duty is applicable to solar lanterns, batteries and charge controllers • 5% duty is applicable to solar water pumps • Solar home systems and solar modules are exempt.[91]

Table 3: Taxes affecting DRE operations in Nigeria

4.3 State of financing and its impact on business model implementation

4.3.1 Prevailing interest rates & collateral requirements for mini-grid & solar water pump suppliers

Local currency interest rates offered to OGS and mini-grid companies by Nigerian commercial banks tend to be prohibitively high, ranging from 22% to 28%.[92] Tenors are typically limited to around 3 years, which is generally acceptable for OGS operations, but not for mini-grid operations, as their high costs require longer tenors. Collateral requirements also tend to be ill-suited to the operations of DRE companies, as it often takes the form of fixed assets such as property. DRE is a lean operation and companies rarely have fixed assets that are high in value. As a result, companies often seek foreign investments abroad.

Impact investors and DFIs have been disbursing the majority of funding to DRE companies in Nigeria in the absence of local banks, but this has not been enough to fill the financing gap.[93] DFIs charge interest rates below 10% and are generally able to extend tenors to 8-15 years.[94] DFI financing is often done in hard currency, which is also not without its issues given the strict exchange control rules in place by the Central Bank of Nigeria as per the Foreign Exchange (Monitoring and Miscellaneous Provisions) Act.[95] The relatively high volatility of the Naira versus the US Dollar also means that hedging costs are high.

4.3.2 Status of mini-grid and off-grid solar funding and support programmes

The majority share of climate financing in Nigeria was committed to the energy sector, with on- and off-grid solar receiving the largest share of investment (66% of climate finance in the energy sector) in 2019/20.[96] Nigeria has a relatively healthy financing landscape for off-grid and mini-grid companies. The country is the top investment destination globally for off-grid renewable energy investments, attracting $287 million from 2010 to 2021.[97] The standalone solar market alone attracted $227 million between 2015 and 2020.[98] The growth figures were enabled by a suite of support programmes, such as the National Electrification Program by the Rural Electrification Agency with funding from the World Bank and the African Development Bank. Table 4 presents the main funding and support programmes targeting the mini-grid and OGS sectors in Nigeria as of 2023.

[89] PWC, Worldwide Tax Summaries, Nigeria, 2022 (link)
[90] PWC, Worldwide Tax Summaries, Nigeria, 2022 (link)
[91] GOGLA, Off-grid and VAT and Duty Tracker, 2022 (link)
[92] USAID, Power Africa Nigeria Power Sector Program, Innovative Financing Model Report, 2022 (link)
[93] Some local banks that have made investments in OGS and mini-grid companies include FCMB, Sterling Bank, and the United Bank of Africa.
[94] USAID, Power Africa Nigeria Power Sector Program, Innovative Financing Model Report, 2022 (link)
[95] ENS Africa, Doing Business Nigeria, 2022 (link)
[96] Landscape of climate finance in Nigeria, 2022 (link)
[97] Global landscape of renewable energy finance, 2023 (link)
[98] Stand-alone solar investment map Nigeria, 2021 (link)

FUNDING & SUPPORT PROGRAMME	FUNDING	Outcomes	TIMELINE
The Africa Mini-grids Programme (AMP) Nigeria window[99] under the Global Environment Facility (GEF)	$150 million in project preparation grant from the GET Trust Fund.	The Rural Electrification Agency (REA) launched AMP on the 29th September 2022, with the goal of improving access to clean energy. It aims to achieve this by enhancing the financial sustainability of renewable energy mini-grids and promoting increased commercial investment. It focuses on utilising cost reduction strategies and innovative business models. ● In 2021, co-financing of $12.1 million was approved to promote an innovative approach for switching to clean energy technologies and solutions in small and medium enterprises (SMEs) and startups through a strengthened cleantech ecosystem in Nigeria.[100]	2020- ongoing
Solar Power Naija (SPN) programme	$24 million was provided by The Nigeria Sovereign Investment Authority (NSIA) for the programme.	As part of the Economic Sustainability Plan (ESP), the government launched the Solar Power Naija (SPN) programme in December 2020.[101] The program aims to serve as an anchor for job creation and local content integration in the rapidly expanding off-grid sector by incentivising local manufacturing and distribution of components and off-grid solutions. Through the Central Bank of Nigeria, SPN made two forms of low-cost local currency debt available to eligible participants: Working capital loans and term loans. Companies can apply for an SPN loan through their preferred commercial bank. As of 2021, two companies had achieved financial close through the assistance of SPN.[102]	2020 - 2030
Rural Electrification Fund (REF)	● Solar hybrid mini-grids ($213m) ● SHS ($75m); ● Energising education programme ($250m); ● Energy efficient equipment and productive use of appliances ($20m); ● Technical assistance ($37m)	The Rural Electrification Fund provides support for the development of the on- and off-grid sectors through capital grants up to 75% of project costs. ● As of March 2023, the Rural Electrification Agency (REA) through the REF's third grant, plans to build over 1,000 mini-grids in off-grid communities. The Solar Hybrid Mini Grid component of the NEP also provides additional support for the development of private sector mini-grids in unserved and underserved areas with high economic growth potential. ● Direct outcomes of the REF project include the creation of 19,310 home systems, the connection of 138,000 homes and the completion of 16 mini-grids.	Ongoing

[99] Global Environment Facility,National child project under the GEF Africa Mini-grids Program Nigeria, 2021 (link)
[100] Global Environment Facility, Work Program, 2022 (link)
[101] REA, Solar Power Naija Programme, 2020 (link)
[102] SPN, Solar Power Naija: Enabling 5 Million Solar Connections Downstream Participants Workshop, 2021 (link)

Standalone Solar Home Systems Output Based Fund (SHS OBF)	The OBF is a $60 million grant funding with fixed incentive grants of up to 60% of the costs of the system to the grantees for each eligible system installed and verified. 20% of the grant received will be used to reduce the cost of the end-user product price.	The Standalone Solar Home Systems Output Based Fund (SHS OBF) targets unserved and underserved Nigerian households and micro, small, and medium enterprises (MSMEs) access better energy services at an affordable cost, via standalone solar systems and private sector companies.[103] The programme forms part of the Nigeria Electrification Project. ● The SHS OBF programme has deployed over 995,000 SHS in rural communities across Nigeria through the NEP, impacting nearly 5 million people. ● As of March 2022, the NEP signed Grant Agreement Addendums with six (6) existing qualified companies under the Output Based Fund (OBF). Companies include: Engie Energy Access Nigeria Limited, A4&T Power Solutions Limited, Wavelength Integrated Power Services Limited, Morton78 Limited, Lemi Renewable Energy Limited and Greenlight Planet.	Ongoing
Nigeria Electrification Project (NEP)	Total funding t was $1.215 billion[104] from the African Development Bank (AfDB), the World Bank, Africa Growing Together Fund (AGTF), counterpart funding from the Government of Nigeria and commercial funding from the private sector. ● $150 Million for the mini-grid component. ● $60 million for the SHS sub component. ● $19 million for the results based financing for productive use appliances sub-component. ● $105 million for phase II and $123 million for phase III of the energizing education programme sub-component	The Rural Electrification Agency of Nigeria implemented NEP, with the objective of providing over 500,000 people with access to affordable electricity.[105] The project has four components: Solar hybrid mini-grid development, standalone solar systems for households and MSMEs, results based financing for productive use appliances and equipment, energising education and technical assistance.[106] As of 2023, results are as follows: ● 3.8 Million people, 681,563 households and 4,795 MSMEs have been connected to electricity. ● The mini grid performance based grant connected 160,403 households and MSMEs to electricity through mini grids 54 mini grids were completed under this component. ● 340,000 households and MSMEs were connected using solar home systems. ● 22,962 households and MSMEs were provided with productive use equipment.[107]	2018 - Ongoing

[103] Rural Electrification Agency, Standalone Solar Home Systems Output Based Fund, 2022 (link)
[104] AfDB, Nigeria Electrification Project: Appraisal report, 2013 (link)
[105] AfDB, Nigeria - Nigeria Electrification Project, 2018 (link)
[106] REA, National Electrification Project, 2023 (link)
[107] REA, Key performance indicators, 2023 (link)

UNDP: De-Risking Interconnected Solar Mini-grid Investment	€9.3 million	The project is coordinated by the Rural Electrification Agency (REA) with support from the European Union and the German government through the Nigerian Energy Support Programme (NESP).[108] The programme is currently in its second phase (NESP II). The programme focus is to extend electricity access to 15,000 customers across Nigeria, including residential, public, commercial, and productive users. • As of Feb 2022, 8 solar mini-grid developers have been granted funding to develop 23 mini-grids across 11 States of the federation. The companies Include: Acob Lighting Technology Limited, GVE Projects, Nayo Tropical Technology Limited, Rubitec Nigeria Limited, Darway Coast Nigeria Limited, Havenhill Synergy Limited, Sosa-Protergia Joint Development Company Limited, and A4&T Power Solutions Limited.	Ongoing
The Universal Energy Facility (UEF)[109]	$500 million facility funded by Shell Foundation, The Rockefeller Foundation, IKEA Foundation, Power Africa, Good Energies, FCDO, Carbon Trust, Germany's Federal Ministry for Economic Cooperation and Development, GIZ, and the Africa Mini-grid Developers Association (AMDA)	UEF is a multi-donor results-based financing facility managed by Sustainable Energy for All. The UEF is providing grants to select companies that will begin construction on their proposed standalone solar projects, which aim to connect approximately 3,500 businesses, markets, shopping malls, cold-storage facilities, clinics, schools, and other productive uses of energy.	2023-2024
Regional Off-Grid Electricity Access Project (ROGEAP)	Total project funding is $338.7 million. The project is funded by the World Bank, Clean Technology Fund and Netherlands Cooperation (DGIS).	The ROGEAP project aims to increase access to sustainable energy for households, businesses, public hospitals, and schools in the 15 ECOWAS member states.[110] In Nigeria, the project was officially launched in July 2022, with the project's objectives being; 1. Improve the institutional framework of Nigeria's power sector by integrating legal provisions and incentives for off-grid electricity; 2. Introduction of quality standards to protect the off-grid energy market; 3. Capacity building of human capital and support for local industry development; 4. Access to funding for the private sector in the form of reduced interest rates on loans.	2017-ongoing

[108] UNDP Derisking Interconnected Solar Mini-Grid Investments in Nigeria, 2021 (link)
[109] Sustainable Energy for All, News and Events, Companies to receive finance for projects connecting businesses with clean energy as part of programme designed to support Nigeria Energy Transition Plan, 2023 (link)
[110] Lighting Africa, Regional Off-Grid Electricity Access Project (ROGEAP), 2021 (link)

Renewable Energy Performance Platform (REPP)	£46 Million in co-financing.	REPP works to mobilise private sector development activity and investment in small and medium sized projects. It has 38 contracted projects covering a wide range of technologies, from solar home systems to grid-connected solar farms and run-of-river hydropower plants. It provides: ● Development phase capital and support; ● Access to risk mitigation instruments; ● Gap financing; and ● Access to long-term lending.[111] In 2016, REPP provided $288,000 in development capital to GVE projects Ltd for the construction of mini-grids in 72 villages across several states in Nigeria.[112] In 2019, REPP provided a loan of $ 2.24 Million and $1.6 Million in equity to PAS solar, to assist them in providing off-grid energy solutions using energy-as-a-service business models.[113]	2015 - ongoing

Table 4: DRE funding programmes in Nigeria

[111] REPP, About REPP, 2020 (link)
[112] REPP, GVE Nigeria, 2022 (link)
[113] REPP, PAS Solar, 2022 (link)

4.4 Infrastructure affecting business model implementation

4.4.1 Mobile infrastructure

Mobile cellular subscriptions in Nigeria experienced a steady increase from 2017 to 2020, increasing from 75 subscriptions per 100 people to 98 subscriptions per 100 people.[114] Subscriptions declined to 91 subscriptions per 100 people in 2021.[115] This exceeds the sub-Saharan African average of 84 subscriptions.

Mobile money transactions grew from 47 million in 2017 to 1.2 billion in 2020.[116] This trend follows the same trend in West Africa as a region – the region surpassed East Africa as the fastest growing region for mobile money in the world in 2022.[117] Despite the fast growth of mobile money in Nigeria, the market is still significantly smaller than the global average. In 2021, there were 192 registered accounts per 1,000 people, compared to the global average of 924 accounts.[118] This can greatly hamper the success of PAYGO business models. Companies looking to sell solar water pumps, agro-processing equipment and mini-grids would, as a consequence, be well advised to closely assess the status of mobile money usage in the particular area of concern.

Due to cash shortages in the country and the country's youthful and tech-savvy population, there is reason to believe that the market will rapidly catch up to the global average. The value of all mobile money transactions carried out between January and September 2022 in Nigeria was N12.8 trillion (approximately $2.8 billion), which is already double the amount recorded over the same period in 2021 and also exceeds the entire transaction value for 2020.[119] Figure 9 illustrates Nigeria's mobile money transaction growth from 2017 to 2021.

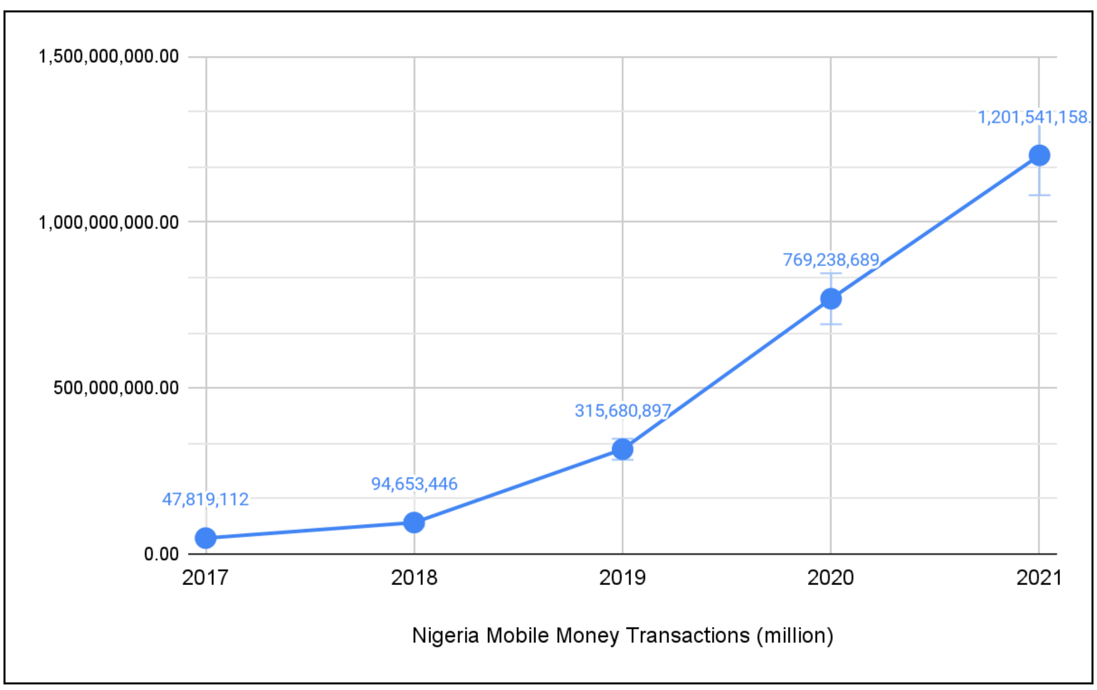

Figure 9: Growth in mobile money transactions[120]

4.4.2 State of the general business operating environment

Investors and international organisations intending to operate their business in Nigeria must adhere to the following processes:[121]

- All companies' premises must be registered with the relevant state government and a levy is payable to the revenue service of the relevant state;
- All businesses with foreign investor involvement must register with the Nigerian Investment Promotion Commission (NIPC) before commencing operations;
- All companies must obtain a permit from the Federal Ministry of the Interior;

[114] World Bank, Mobile Cellular Prescriptions Nigeria, 2021 (link)
[115] World Bank, Mobile Cellular Prescriptions Nigeria, 2021 (link)
[116] International Monetary Fund, Macroeconomic and Financial Data Nigeria, 2022 (link)
[117] GSMA, The state of the industry report on mobile money, 2023 (link)
[118] IMF, Number of registered mobile money accounts per 1,000 adults, 2021 (link)
[119] Oyekanmi, S., Mobile transactions in Nigeria double to N12.8 trillion in 9 months, 2022 (link)
[120] IMF, macroeconomic and Financial Data, 2021 (link)
[121] ENSAfrica, Doing business in Nigeria, 2022 (link)

- All taxpayers must register with the Federal Inland Revenue Service for corporate tax and VAT;
- Companies with five or more employees or a turnover exceeding N50 million are required to make contributions to the Industrial Training Fund;
- All employers must register with the Employees' Compensation Scheme, which covers compensation for employee injury, disability or death;
- Companies with more than three employees must make pension contributions on behalf of employees;
- Investors are required to apply for an expatriate quota if employees are foreign nationals. The quota allocates work permits depending on the nature and size of the business;
- Approval from and registration with National Office for Technology Acquisition and Promotion (NOTAP) is required for any cross-border contract regarding the use of intellectual property or the supply of technical expertise, machinery and operating staff or managerial assistance.

5. Rwanda

76% of Rwanda's working population is involved in agriculture, a sector that constitutes approximately one third of the country's economy and that delivers 63% of the country's exports by value.[122] 75% of Rwanda's agricultural produce is grown by smallholder farmers.[123] Rwanda is the most densely populated country in Africa, which partly contributes to the country's average farm size of only 0.72 hectares per household.[124]

The pronounced need for affordable and reliable electricity in rural areas is reflected in the low levels of mechanisation in agriculture in Rwanda: Only 0.9% of farmers have access to mechanical equipment.[125] Provisional results from TFE's agri-energy nexus techno-economic model show that deployment of solar water pumps and mini-grids for agri-processing can be financially viable. This, in turn, is likely to lead to increased levels of mechanisation in Rwanda's main agricultural value chains. Table 5 presents indicative results pertaining to electrification of the main steps of the maize, cassava and beans value chains in Rwanda.

Rwanda										
Maize					Cassava		Beans			
Irrigation	Drying	Shelling	Dehulling	Milling	Irrigation	Milling	Irrigation	Drying	Threshing	Grinding
$4024	$1850	$4667	$3500	$3500	$211	$1657	$4548	$994	$3314	$1657
$4024	$1850	$4667	$3500	$3500	$211	$1657	$4548	$994	$3314	$1657
$290	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290
$397	$397	$397	$1192	$1192	$1192	$2383	$298	$397	$397	$397
$33	$15	$25	$45	$25	$33	$94	$33	$8	$34	$34
$0	$82	$513	$1027	$411	$0	$903	$0	$16	$411	$164
$20	$36	$225	$450	$180	$60	$396	$15	$7	$180	$72
$46	$82	$513	$1027	$411	$138	$903	$34	$16	$411	$164
$720	$784	$1226	$2553	$1917	$1515	$3671	$621	$712	$1131	$885
$3304	$1066	$3441	$947	$1583	-$1304	-$2014	$3927	$283	$2183	$772
$738	$1660	$2500	$2662	$1597	$738	$885	$738	$1200	$2263	$879
0.22	1.56	0.73	2.81	1.01	-0.57	-0.44	0.19	4.25	1.04	1.14
2.68	18.69	8.72	33.75	12.11	-6.79	-5.27	2.26	50.96	12.44	13.66
37.72	6.82	3.52	0.48	2.02	-4.96	-1.17	59.78	9.03	2.79	2.47
Standalone	Mini-grid	Mini-grid	Mini-grid	Mini-grid	Standalone	Mini-grid	Standalone	Mini-grid	Mini-grid	Mini-grid
Farm	Village	Village	Village	Village	Farm	Village	Farm	Village	Village	Village
Crop rotation					Crop rotation		Crop rotation			

Table 5: Indicative modelling results of value chain electrification in Rwanda[126]

Rwanda has made significant strides in enhancing its connectivity rates, with 61% of the population having access to electricity, as of 2022. This includes 47% of connections to the national grid, and 14% of connections achieved through off-grid systems.[127] Despite the relatively large share of the population having access to off-grid systems, an improved enabling environment is needed to further increase this penetration and, in turn, ensure that farmers can access electricity needed for mechanised irrigation and agro-processing. Section 5.2 discusses this matter.

5.1 Mini-grid and off-grid market overview

Current electricity access targets aim for universal electrification by 2024.[128] 90% of connections are planned to be grid-based and 10% will be off-grid.[129] This represents a significant de-prioritisation of off-grid systems compared to the previous iteration of the NEP, mainly due to the country's impressive grid extension progress. Despite this progress, high levels of investment will need to be deployed rapidly to fund the remaining grid extension areas before the 2024 deadline.
On-grid electrification carries a higher absolute cost than off-grid DRE deployment. As such, allowing private mini-grid operators and standalone solar companies to raise their own funds and assist with

[122] Weatherspoon, D.D., Miller, S.R., Niyitanga, F., Weatherspoon L.J. & Oehmke, J.F., Rwanda's commercialization of smallholder agriculture: Implications for rural food production and household food choices, 2021 (link)
[123] Mugisha, I.R., The smallholder farmers feeding the long food supply chain in Rwanda, 2022 (link)
[124] Ngango, J. & Hong, S., Assessing production efficiency by farm size in Rwanda: A zero-inefficiency stochastic frontier approach, 2022 (link)
[125] National Institute of Statistics of Rwanda, Seasonal agricultural survey, 2023 (link)
[126] TFE, Techno-economic model for agricultural value chain electrification, 2023 (link)
[127] Rwanda Energy Group (REG), Electricity access, 2022 (link)
[128] Rwanda Energy Group (REG), Electricity access, 2022 (link)
[129] EDCL, National Electrification Plan Revision, 2021 (link)

electrifying a portion of the population earmarked for grid electrification (in addition to the portion already earmarked to mini-grids and OGS) could be a more cost effective and rapid pathway towards the country's goal of universal energy access by 2024. This will also assist in accelerating progress towards the Energy Sector Strategic Plan's target of 100% electrification for productive users by 2024.[130]

5.1.1 Mini-grids

As of 2019, 84 mini-grids have been operating in Rwanda, with a combined capacity of 250 kW serving 3,582 households.[131] By 2020, the market had grown significantly, with 11 companies reporting to the Energy Development Corporation Limited (EDCL) and a total installed capacity of 463 kW. One year later, in 2021, 6,500 households were accessing electricity from mini-grids.[132] Individualised cost-based tariff methodologies are used for mini-grid tariff setting,[133] which points to an effective willing buyer-willing seller model. The future for mini-grids in Rwanda is, however, less bright than its past, with the latest NEP iteration only allocating a total of 182 villages in the country for mini-grid electrification. This implies that the total future market size is limited to only 98 new projects, given that 84 projects are already operating.

5.1.2 Standalone solar

In 2018, 253,181 households had access to solar home systems in Rwanda, served by 27 companies.[134] By the end of 2021, about 500,000 households across the country had access to electricity through solar home systems.[135] GOGLA's semi-annual report for the second half of 2022 indicates that sales volumes of solar energy kits reached 108,608 units.[136] This represents a decline of 31% compared to the first half of 2022.

The market for standalone solar systems in agriculture and other productive sectors is still nascent, however, there are an increasing number of companies supplying and offering services for solar water pumping, cold storage and solar cooling. These include Davis and Shirtliff, Ignite Power, Futurepump and Bunga Energy. Prices for solar irrigation systems in Rwanda range between RWF800,000-2,000,000 ($826-$2,066).[137] In a study conducted with 1,200 SWP customers in Rwanda and other countries, 90% reported higher earnings and 96% had an increase in farm productivity.[138] The potential market for all types of standalone solar systems is however limited, as the 2021 NEP only plans for 8.9% of the yet-to-be electrified population to be served by these systems.

5.2 Macro considerations for DRE business models

5.2.1 Regulations affecting mini-grids and off-grid solar

Mini-grids

Any activity involving generation, transmission, trading or distribution of electricity is required to have a licence from the Rwanda Utilities Regulatory Authority (RURA). Mini-grids in Rwanda are regulated through the RURA's Minimum Technical Requirements for Mini-grids 2019.[139] All mini-grids in Rwanda must generate at least 50% of consumed energy on an annual kWh basis from renewable energy. Mini-grid project developers are responsible for on-site warranty, ensuring that failed components are repaired or replaced in case such a claim is required.[140] Any mini-grid that connects or intends to be connected to the national grid shall be in compliance with the Rwanda Grid Code.

Mini-grid operators intending to operate an isolated grid are required to apply to the RURA for end-user tariff approval prior to starting construction and installation of the isolated grid. The tariff methodology sets out the isolated grid electricity end-user tariffs that are charged to all isolated grid consumers.[141]

All energy projects must undergo an environmental impact assessment reviewed and cleared by the Rwanda Development Board (RDB) and where applicable, have an Environmental Impact Assessment

[130] Ministry of Infrastructure Rwanda, Energy sector strategic plan: 2018/19 - 2023/24, 2018 (link)
[131] REG, Off-grid electricity access expansion programs in Rwanda, 2019 (link)
[132] Energy Private Developers Rwanda, Off-grid solutions and clean cooking market sales report, 2021 (link)
[133] USAID-NARUC, Exploring Africa's mini-grid tariff methodologies, 2020 (link)
[134] REG, Off-grid electricity access expansion programs in Rwanda, 2019 (link)
[135] EPD,Off-Grid Solutions and Clean Cooking Market Sales Report 2021 (link)
[136] GOGLA, Global off-grid Solar Market Report, 2022 (link)
[137] Africa Clean Energy Technical Assistance Facility, Stand Alone Solar (SAS) Market Update Rwanda, 2021 (link)
[138] The World Bank, Off-grid Solar Market Trends Report, 2022 (link)
[139] Rwanda Utilities Regulatory Authority (RURA), Minimum Technical Requirements for Mini-grids 2019 (link)
[140] Rwanda Utilities Regulatory Authority (RURA), Minimum Technical Requirements for Mini-grids 2019 (link)
[141] Rwanda Utilities Regulatory Authority (RURA), Draft Tariff Methodology for Isolated Grid in Rwanda, 2020 (link)

(EIA) Certificate. All mini-grid project developments must comply with the Rwanda Environment Management Authority (REMA) environmental policy.[142]

Standalone Solar (SAS)
SAS systems are regulated by the Ministerial Guidelines on Minimum Standard Requirements for Solar Home Systems 2022.[143] The guidelines define the minimum service level energy requirements applicable to off-grid solar home systems considered under rural electrification in Rwanda. This is an update to a previous iteration that enforced standards that were high to the extent where the cost base of SAS increased to levels above the affordability of customers. The revised guidelines is a step in the right direction, where consumers are protected with sufficient standards, while suppliers are able to still achieve a lower cost base. Guidelines on solar water pumps specifically are not specified as the market is still in its infancy. Single-light off-grid solar systems are not considered to be SHS, while crystalline solar PV panels are the only panels accepted for importation.

Systems must be capable of supplying enough electricity power to at least:

a) 3 lamps of at least 120 lumens each, operating for a minimum of 4 hours per day;
b) A mobile phone charge supply for at least two hours per day;
c) A radio charge supply for at least 5 hours per night;
d) Supply the above loads for at least one day without input from the solar module/ when there is no sunshine;

End users are to be provided with a 3-year minimum warranty and after-sales contract that commits to the availability of spare parts and technical service for a minimum period of 5 years after the system installation.

5.2.2 Taxes affecting mini-grid and off-grid operations

In Rwanda, solar products qualify for import duty and VAT exemptions. As part of the East African Community (EAC), Rwanda has adopted the common agreement among EAC countries to exempt specialised equipment for the development and generation of solar and wind energy.[144]

Under the Rwanda Investment Code, the country has several investment tax incentives for its priority sectors which include energy generation, transmission, and distribution, and electric mobility, namely:

a) Reduced corporate income tax rates applying for a period of five years to newly listed companies;
b) Income tax concessions available to an international company which has its headquarters or regional office in Rwanda;
c) A seven-year tax holiday and a reduced corporate income tax rate of 15% available to registered investors in priority sectors;
d) A five-year tax holiday available to microfinance institutions and specialised industrial and innovation parks developers;
e) Customs duties exemption for a registered investor investing in products used in export processing zones (EPZs).[145]

Corporate Income Tax (CIT)	Value Added Tax (VAT)	Withholding Tax (WHT)	Import Duties
• 30%, and a reduced rate of 15%. This is applicable to renewable energy companies and other priority sectors. • A 7-year tax holiday is also enjoyed by priority sectors.[146]	• Standard rate of 18% applies to goods and services that are neither exempt from VAT or zero-rated. • All solar products are exempt.	• Standard rate of 15% on interest, dividends and royalties. • A reduced rate of 5% is levied on government securities and dividends paid by listed companies to EAC resident beneficiaries. • 5% is applicable on goods imported for commercial use.	• 25% duty is applicable to batteries • 10% duty is applicable to solar lanterns, • Other solar products are exempt.[147]

Table 6: Taxes affecting DRE operations in Rwanda

[142] Republic of Rwanda, Rwanda Environment Management Authority Environmental Policy, 2023 (link)
[143] Republic of Rwanda, Ministry of Infrastructure,Ministerial Guidelines on Minimum Standard Requirements for solar home systems, 2022 (link)
[144] PWC, Worldwide Tax Summary, Nigeria, 2022 (link)
[145] Rwanda Development Board, Investment Code, 2021 (link)
[146] ENSAfrica, Doing business in Rwanda, 2021 (link)
[147] BDO East Africa Advisory Services, The East African Regional Handbook on Solar Taxation, 2022 (link)

5.3 State of financing and its impact on business model implementation

5.3.1 Prevailing interest rates & collateral requirements for mini-grid & solar water pump suppliers

Mini-grid developers across Nigeria, Rwanda, and Zambia all share the common challenges of prohibitively high-interest rates charged by commercial banks, coupled with short tenors and collateral requirements. These challenges are a hindrance to scaling mini-grid projects. Mini-grids require longer-term financing that most commercial banks are not able or reluctant to provide.[148] Local commercial banks are also unfamiliar with mini-grid markets, technologies, and business models, which makes lending to mini-grid developers a high risk.

The Rwandan mini-grid market is expected to have a compound annual growth rate (CAGR) of over 20% in the five years between 2021 and 2026, however, mini-grid developers have been faced with the challenge of gaining access to upfront capital, high-interest rates, access to loan guarantees and concessional finance, as well as the limitations posed through collateral requirements.[149] Companies in Rwanda source local currency debt at rates of 10% to 17% on average and hard currency at 6% to 10% (concessional debt at the lower end and commercial debt at the higher end).[150] The difference in local and foreign currency interest rates is a result of perceived exchange rate risk. Local loan terms are often short, at about 24 months loan and collateral requirements can be extensive. High-interest rates and short loan terms are generally incompatible with the needs of many DRE business models and has forced many businesses to raise capital abroad and take on exchange rate risk. On the positive side, the Rwandan Franc is fairly stable (see section 3.2) and the government does not impose any foreign exchange controls.

5.3.2 Status of mini-grid and off-grid solar funding and support programmes

Between 2010 and 2021 Rwanda ranked among the top three recipient countries for off-grid investments in East Africa, alongside Tanzania and Kenya. Together, these countries received 43% of the total investment amounting to $2.2 billion.[151] Mini-grids have mainly depended on concessional capital (mainly grants) as commercial capital has largely been absent. Mini-grid operators in Rwanda use grants to finance approximately 40% to 70% of upfront CAPEX.[152]

The Rwanda off-grid sector has several programmes and funding that have been implemented with the aim of developing both on-grid and off-grid electrification as part of Rwanda's economic development targets. Listed below are some of the programmes currently underway in Rwanda relating to off-grid electrification.

148 USAID, Mini-grid challenges and needs in financing, 2023 (link)
149 Energy Private Developers (EPD), Rwanda, 2021 (link)
150 TFE surveys
151 IRENA, Global landscape of renewable energy finance, 2023 (link)
152 TRAIDE Rwanda, Investment Opportunities in the Rwandan Energy Sector, 2020 (link)

FUNDING & SUPPORT PROGRAMME	FUNDING	OUTCOMES	TIMELINE
Renewable Energy Fund (REF)	Funding for REF is set up as a financial intermediary loan. Funds are transferred from the SREP World Bank programme to REF (managed by the Development Bank of Rwanda), which in turn disburses funds to companies. The total REF project funding is $48.9 million.	The project's focus is to increase electricity access in Rwanda through off-grid technologies and facilitate private sector participation in off-grid electrification. REF has 5 financing windows: 1) Window 1: On-lending through SACCOs to households and micro-enterprises; 2) Window 2: On-lending through banks (commercial and microfinance) to households and smaller businesses; 3) Window 3: Direct financing of mini-grid developers (no funding dispersed by 2023); 4) Window 4: Direct financing of OGS companies (only activated in March 2019); 5) Window 5: Results-based financing (RBF) for off-grid access (added in 2020 by the project implementation unit (PIU) after restructuring).[153] By November 2021; ● 340,704 people and 1,309 enterprises had been provided with new or improved electricity services though solar home systems in window 5. A little more than half of these beneficiaries are women. Window 5 has also provided $1,333,707 in result-based grant financing to end-users. ● The project had trained 68 savings and credit cooperatives (SACCOs), and lended to 56 SACCOs. Between them, the SACCOs have drawn down $1,576,880 from window 1 and on-lent $317,317 to households and enterprises, by 2021. ● Under window 2, the project has lent $ 2,722,104 to two commercial banks and two microfinance institutions (MFIs), which have, in turn on-lent $201,215 to households and enterprises. ● Under window 4, the project has on-lent $3,344,923 to off-grid solar companies.[154]	REF commenced in 2017 and will conclude by September 2023.[155]
The Rwanda Agricultural Board (RAB) Small-Scale Irrigation Technology (SSIT)	RAB provides a 50% subsidy when implementing SSIT.	The programme is primarily successful through diesel-powered systems as solar irrigation systems require higher upfront costs. Prices for solar irrigation systems range between RWF800,000-2,000,000 ($826-$2,066).[156]	

[153] Climate Investment Funds, Rwanda Renewable Energy Fund Project, 2022 (link)
[154] Climate Investment Funds, Rwanda Renewable Energy Fund Project, 2022 (link)
[155] The World Bank, Rwanda Renewable Energy Fund Project, 2017 (link)
[156] African Clean Energy, Stand Alone Solar (SAS) Market Update Rwanda, 2021 (link)

EnDev Rwanda Mini-grid results-based financing project (Mini-grid RBF)[157]	€31,075,600	Energising development (EnDev) initially supported the biogas and micro-hydro power sector. In 2014, the project started to support private solar companies and mini-grid developers through DFID-funded results based financing. The second iteration of this programme is a pro-poor RBF ran from 2019-2021, aimed at addressing the affordability gap. In 2019-2020, SNV implemented EnDev's cooking activities in Rwanda. The project's objective, as of December 2022, is to transform markets to provide access to affordable, reliable,sustainable, and modern energy as a means to deliver social, economic, and environmental change. Until December 2022; ● The clean cooking initiative (ReCIC) supported 5 cooperatives and 14 medium companies. 93,318 Improved cook stoves were sold and 98,600 t COe were avoided. ● The mini grid RBF provided 10,000 people with access to electricity, through 22 solar DC nano-grids, 2 solar AC and 1 hydro mini-grid. 97 entrepreneurs were supported in PUE. ● The solar lighting RBF provided more than 630,000 people with access to energy through solar lighting products. ● The hydro power initiative supported the installation of four hydro power plants providing electricity to 45,000 people, with a total capacity of 2,874 kW. ● Through grid densification, 14,800 poor households connected to the grid.[158]	2006 - 2024
Renewable Energy Performance Platform (REPP)	£46 Million in co-financing.	REPP works to mobilise private sector development activity and investment in small and medium sized projects. It has 38 contracted projects covering a wide range of technologies, from solar homes systems to grid-connected solar farms and run-of-river hydropower plants. It provides ● Development phase capital and support, ● Access to risk mitigation instruments, ● Gap financing, and ● Access to long-term lending[159] In 2019 and 2020, ARC power Rwanda secured a combined £900,000 in convertible loans from REPP to build a portfolio of mini-grids in Rwanda.[160]	2015 - ongoing

Table 7: DRE funding programmes in Rwanda

[157] REG, Off Grid Electricity Access Expansion Programs in Rwanda, 2019 (link)
[158] GIZ (Energising development), EnDev Rwanda, 2022 (link)
[159] REPP, About REPP, 2023 (link)
[160] REPP projects, ARC power rwanda, 2023 (link)

5.4 Infrastructure affecting business model implementation

5.4.1 Mobile infrastructure

Mobile cellular subscriptions in Rwanda grew at an annual rate of 31% between 2001 and 2020.[161] This translated to 81 subscriptions per 100 people in 2021 and compares well with the sub-Saharan African average of 84 subscriptions per 100 people.[162] The total number of registered mobile subscribers in 2021 was 15.3 million.[163]

Access to mobile money has been an important enabler for financial inclusion in Rwanda. The mobile money penetration rate increased to 60% (around 3 in every 5 adults were using a mobile money account) in 2020 from 39% in 2016.[164] This was largely influenced by the offering of electronic services (e-wallet services) by 85% of mobile money operators and 94% of commercial banks.[165] In 2021, the country had 1,904 registered accounts per 1,000 adults, which is more than double the global average of 924 accounts.[166] In the same year, a total of 914.9 million transactions were processed, up from only 251 million in 2017 (see Figure 10).[167] Rwanda's healthy mobile money market has enabled the provision of a range of financial products and services which have helped to increase the scalability of PAYGO systems.

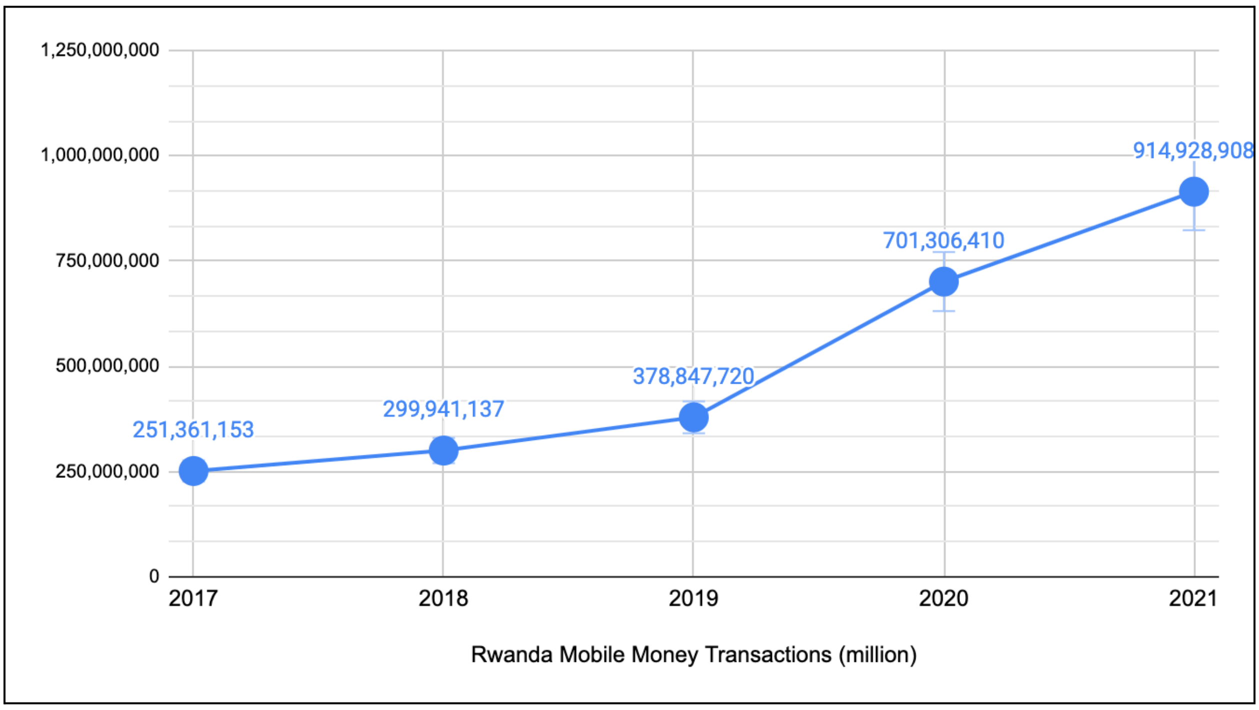

Figure 10: Changes in mobile money transactions[168]

The expansion of the mobile money market has helped to reduce the accessibility gap of financial services (particularly in rural areas). Digital records (information that is captured through software or a computer) are providing more transparent and efficient ways to monitor growth within the mobile money market.[169] The mobile money market in Rwanda continues to grow, but there remains a need to address the barriers of low financial literacy, the accessibility of financial access points, and internet access in hard-to-reach areas.

5.4.2 State of general business operating environment

Business registration in Rwanda can be done online and be processed within 24 hours. Overall, Rwanda has one of the most attractive business climates on the continent, considered to be the fourth-best African investment destination in 2021.[170] All investors or multinational companies wishing to open a business in Rwanda need to adhere to the following processes regarding applications for licences and registrations:

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[161] World Bank, Mobile Cellular Prescriptions Rwanda, 2020 (link)
[162] World Bank, Mobile Cellular Prescriptions Rwanda, 2020 (link)
[163] National Bank of Rwanda, Mobile payment statistics, 2021 (link)
[164] National Bank of Rwanda, Finscope report, 2020 (link)
[165] AFR, FinScope Digital financial Services Thematic Report, Rwanda, 2021 (link)
[166] IMF, Number of registered mobile money accounts per 1,000 adults, 2021 (link)
[167] International Monetary Fund, Macroeconomic and Financial Data Rwanda, 2022 (link)
[168] International Monetary Fund, Macroeconomic and Financial Data Rwanda, 2022 (link)
[169] National Bank of Rwanda, Finscope report, 2020 (link)
[170] RMB, Where to Invest in Africa, 2021 (link)

- Foreign companies must register with the Rwanda Development Board (RDB) to benefit from incentives available in priority sectors (e.g. energy generation). Registration is not mandatory;
- The RDB operates a one-stop shop for business registration, where investors can apply for company incorporation and obtain a tax identification number;
- At least one director of a private company must be a resident of Rwanda, but does not need to be a Rwandan citizen;
- All taxpayers must register with the RRA;
- Every company must register for a trading licence.

6. Zambia

Agriculture is a key sector in Zambia's economy, accounting for 60% of the workforce, the majority of which are smallholder farmers.[171] There are 1.6 million smallholder farmers in Zambia.[172] Agriculture's contribution to the economy has however declined in recent years, from 24% of GDP in 2000 to 2.6% of GDP in 2019.[173] This is mainly a result of the growth of Zambia's mining sector and poor infrastructure, lack of finance and declining investments in research and development in the agriculture sector.[174]

In the rural areas of Zambia, 89% of households are engaged in agriculture, yet 77% of the entire rural population lives below the poverty line.[175] With a rural electrification rate of only 14% in 2020,[176] It is estimated that the vast majority of smallholder farmers living below the poverty line also live without electricity. In parallel to government interventions to kickstart a resurgence in agricultural productivity (such as zero-rating VAT on agricultural equipment and concessional financing schemes for irrigation), rural electrification with standalone solar systems and mini-grids can greatly aid in enhancing agricultural productivity for smallholders and in turn breaking the rural cycle of poverty. As Table 8 shows, financially viable electrification of the main steps in the maize, cassava and groundnuts value chains is possible in Zambia. The assessment considers the increased farmer revenue enabled by the use of mechanised processes and the costs involved with those processes. For more details about TFE's techno-economic model, see box 1 and annex 1.

	Zambia														
	Maize				Cassava					Groundnuts					
	Irrigation	Shelling	Dehulling	Milling	Irrigation	Peeling	Grating	Milling	Chipping	Irrigation	Shelling	Oil pressing	Crushing	Peanut butter
Annual marginal revenue														
Produce sales	$4158	$782	$1408	$2346	$322	$2737	$7821	$6257	$3128	$4152	$1043	$8655	$1564	$6789
Others														
Total revenues	$4158	$782	$1408	$2346	$322	$2737	$7821	$6257	$3128	$4152	$1043	$8655	$1564	$6789
Annual marginal cost														
Transport cost to market	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290
Labour	$395	$113	$339	$339	$678	$1355	$1355	$1355	$1355	$339	$113	$904	$904	$904
Maintenance	$33	$25	$35	$45	$33	$75	$94	$103	$56	$33	$89	$103	$43	$43
Electricity	$0	$43	$293	$440	$0	$469	$1760	$1760	$352	$0	$59	$860	$313	$469
Grid	$10	$9	$63	$94	$17	$100	$375	$375	$75	$8	$13	$184	$67	$100
Mini-grid	$46	$43	$293	$440	$79	$469	$1760	$1760	$352	$39	$59	$860	$313	$469
Total costs	$718	$471	$957	$1114	$1001	$2190	$3499	$3508	$2054	$662	$551	$2157	$1549	$1706
Annual marginal profit	$3440	$311	$451	$1233	-$679	$548	$4322	$2748	$1075	$3490	$492	$6498	$15	$5083
Indicators														
Upfront cost	$738	$1118	$894	$1888	$738	$2329	$4550	$1888	$2329	$738	$1778	$2059	$900	$2000
Payback (years)	0.21	3.59	1.98	1.53	-1.09	4.25	1.05	0.69	2.17	0.21	3.61	0.32	60.78	0.39
Payback (months)	2.57	43.12	23.81	18.38	-13.05	51.04	12.63	8.24	26.00	2.54	43.35	3.80	729.41	4.72
Value added	2.69	4.77	2.30	6.30	-0.31	0.70	5.53	3.51	1.37	3.19	7.55	12.46	0.03	9.75
Electricity source	Standalone	Mini-grid	Mini-grid	Mini-grid	Standalone	Mini-grid	Mini-grid	Mini-grid	Mini-grid	Standalone	Mini-grid	Mini-grid	Mini-grid	Mini-grid
Location	Farm	Village	Village	Village	Farm	Village	Village	Village	Village	Farm	Village	Village	Village	Village
Irrigation second season	Crop rotation				Crop rotation					Crop rotation				

Table 8: Indicative modelling results of value chain electrification in Zambia[177]

6.1 Mini-grid and off-grid market overview

The electricity access rate in Zambia was a mere 42.4% in 2019, 37.7% of which was grid-based and 4.7% off-grid.[178] These statistics may be attributed, in part, to policies and regulations that govern the sector. Zambia's overall RISE score is 46 out of 100, with the mini-grid framework scoring 68/100, the off-grid systems framework scoring 60/100, and the consumer affordability of electricity scoring 73/100.[179]

The Rural Electrification Master Plan (REMP) for the period 2008-2030 aims to electrify 1,217 rural growth centres across the country through grid extension, mini-hydro power stations, or solar home systems. In alignment with Zambia's Vision 2030, REMP also seeks to raise urban electrification rates to 90% and rural access rates to 51% by 2030.[180]

Specific targets towards standalone electrification have been outlined in the National Energy Policy of 2019. The policy outlines a strategy that aims to distribute 500,000 solar home systems (SHS) and install 350,000 solar water heaters by 2030.[181] A total investment of around $1.1 bn is needed to achieve

[171] Fusillier, J.L., Sutherland, A., Villani, R. & Chapoto, A., Maize value chain analysis in Zambia, 2021 (link)
[172] African Farming, Zambia's smallholder farmers and the complexities of government support, 2023 (link)
[173] Sonoda, H., Working with smallholders to tackle food insecurity in Zambia, 2022 (link)
[174] Phiri, J., Malec, K., Majune, S.K., Appiah-Kubi, S.N.K., Gebeltová, Z., Maitah, M., Maitah, K & Abdullahi, K.T., Agriculture as a determinant of Zambian economic sustainability, 2020 (link)
[175] Pirttila, J. & Kangasniemi, M., Direct support to small scale farmers reduces poverty - what Zambia is doing right, 2023 (link)
[176] The World Bank, Access to electricity, rural (% of rural population), 2020 (link)
[177] TFE, Techno-economic model for agricultural value chain electrification, 2023 (link)
[178] Signify foundation, Mapping the off-grid solar market in Zambia, 2019 (link)
[179] Regulatory Indicators for Sustainable Energy (RISE), Zambia, 2023 (link)
[180] Rural electrification Master Plan for Zambia 2008 - 2030, 2009 (link)
[181] Leary, J., Serenje, N., Mwila F. et al., eCooking Zambia national policy & markets review, 2019 (link)

REMP's targets which equates to a required annual investment of roughly $50 million per year between 2008 and 2030.[182]

6.1.2 Mini-grids

The mini-grid sector in Zambia is still fairly nascent with an estimated total operating base of 30 projects. Companies active in this industry include Standard Microgrid, Solera, Muhanya Solar, PowerCorner, Sigora Energy and Zengamina Power Company. A handful of sites are owned by the Rural Electrification Authority. A 2021 study by the Increased Access to Electricity and Renewable Energy Production (IAEREP) project estimates that about 2 million people would be best served by mini-grids,[183] which suggests that the sector still has substantial ground to cover. For some of the existing and under-development mini-grids, 100% CAPEX subsidised tariffs range from $0.08 per kWh to $0.26 per kWh and fixed charges range from $4.00 to $10.00 per month.[184]

6.1.3 Standalone solar

According to an assessment done in 2018, the estimated market size for solar home systems is 4.2 million people.[185] Sales of solar energy kits in Zambia reached 290,228 units in the second half of 2022; a 34% increase from the first half of 2022.[186] Zambia's solar irrigation market is becoming relatively developed as more SWP distributors enter the market, such as Solar Mac Energy, Vitalite, Muhanya Solar and Suntech.[187] Upfront costs for solar water pumps in Zambia range from $500 to $1590, depending on the capacity and manufacturer.[188] Solar Mac Energy, for example, provides a range of solar water pumps priced between ZMW 21,680 and 32,040 ($1,074–$1,590).[189] In a study conducted with 1,200 SWP customers in Zambia and other countries, 90% reported higher earnings and 96% had an increase in farm productivity.[190] Solar agro-processing is a small market in comparison. Agsol, one example of a supplier in Zambia, offers standalone solar hammer mills.[191] The mill is predominantly used for maize milling. Upfront costs for agro-processing equipment, the most common being the solar powered-grain mill, are between $660-$1,310.[192]

6.2 Macro considerations for DRE business models

6.2.1 Regulations affecting mini-grids and off-grid solar

Mini-grids

The regulatory framework for mini-grids in Zambia was approved by the Energy Regulation Board (ERB) in 2019, but as of 2023 these regulations have still not been gazetted and remain in draft form. While this set of regulations is widely regarded as favourable for private mini-grid operations,[193] the continued draft status of the law creates uncertainty for developers and investors and in turn stifles the growth of the sector. The framework consists of three documents:[194]

1. Licensing framework
2. Rules on Tariffs Applicable to Mini-Grids in Zambia
3. Technical Requirements for Mini-Grids in Zambia

The licensing framework specifies that all mini-grids must be licensed and must be studied in parallel to the Rules on Tariffs Applicable to Mini-grids in Zambia. Both of these documents classify mini-grids into the following three categories:

- Category 1 mini-grids: Mini-grids with an installed capacity of up to 100 kW. These are exempt from tariff regulation and can apply tariffs that reasonably recover the costs of providing service to

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[182] Japan International Cooperation Agency, The Study for Development of the Rural Electrification Master Plan in Zambia, 2008 (link)
[183] Bumbarger, S., Powering small-scale renewable electrification in rural Zambia, 2021 (link)
[184] REA, Off-grid initiatives to accelerate rural electrification in Zambia, 2023 (link)
[185] Carbon Trust, Mini-Grid Market Opportunity Assessment: Zambia, 2018 (link)
[186] GOGLA, Global Off-Grid Solar Market Report, 2022 (link)
[187] Africa Clean Energy Technical Assistance Facility, Stand Alone Solar (SAS) Market Update Zambia, 2021 (link)
[188] Annex xx, Solar pump upfront selling costs: Zambia, 2023 (link)
[189] Solar Mac Energy, Get solar finance for office or home power systems, solar pump systems, 2023 (link)
[190] The World Bank, Off-grid Solar Market Trends Report, 2022 (link)
[191] EEP Africa, Agsol - Solar mills: powering rural productivity, 2019 (link)
[192] The World Bank, Off-grid Solar Market Trends Report, 2022 (link)
[193] Mambwe, C., Schröder, K., Kügel, L. & Jain, P., Benchmarking and comparing effectiveness of mini-grid encroachment regulations of 24 African countries, 2022 (link)
[194] ERB Zambia, Summary of approved regulatory framework for mini-grids in Zambia, 2018 (link)

customers, including a reasonable profit and must adjust their tariffs downwards to reflect any one-off capital or recurrent subsidies.
- Category 2 mini-grids are mini-grids with an installed capacity above 100kW and up to 1 MW, requiring upfront tariff approval by the ERB. ERB must be provided with the proposed tariff design, tariff levels, and escalation rates, along with an explanation of how they contribute to the recovery of reasonable costs.
- Category 3 mini-grids are mini-grids with an installed capacity above 1 MW. Category 3 mini-grids are required to apply tariffs approved by ERB based on Allowed Costs (costs that regulated mini-grids are allowed to recover through regulated tariffs). Tariffs are regulated in 5-year regulatory periods during periodic reviews.[195]

Zambia's mini-grid technical requirements differ with respect to the generation technology and installed capacity of the mini-grid. The technical requirements draft law classifies mini-grids into the following clusters:

- Cluster 1 mini-grids: Any mini-grid powered by hydro
- Cluster 2 mini-grids are any mini-grids powered by solar, wind or biomass with a generation capacity greater than 10 kW, but less than or equal to 100 kW. Cluster 2 mini-grids can also be mini-grids powered by solar, wind, or biomass with a generation capacity equal to or greater than 100 kW.
- Cluster 3 mini-grids are any mini-grids powered by solar, wind, or biomass with a generation capacity equal to or less than 10 kW.

The technical requirements draft law also covers matters pertaining to grid encroachment. The following possible courses of action are applicable in the case of grid encroachment on the site of a mini-grid:

1. The main grid acquires the client base and builds a completely new distribution network, while the mini-grid operator abandons all assets and removes them from the area;
2. The main grid acquires the client base and the complete distribution network, generation and storage assets of the mini-grid;
3. The mini-grid operator can become a small power distributor for the main grid, and discontinue the operation of its generation and storage assets. The mini-grid operator can resell only energy from the main grid as a retailer and retains their customer base.
4. The mini-grid operator and the main grid conclude a contract for net-metering. In case of excess energy from the mini-grid, the mini-grid operator has the right to sell the excess energy to the main grid. In case of an energy deficit, the main grid delivers the requested energy to the mini-grid operator. The prices of selling and buying are subject to a net-metering agreement.

Standalone solar

Regulations for Zambia's standalone solar sector are still in the nascent stages. The National Renewable Energy Strategy looks to generate 100 MW from solar by 2030, distribute 500,000 SHS and the installation of 350,000 solar water heaters.[196]

The Zambian Bureau of Standards (ZABS) and Zambia Information and Communications Technology Authority (ZICTA) are leading the adoption of e-waste standards. Guidelines on solar water pumps are not specified as the market is still in its infancy.[197]

6.2.2 Taxes affecting mini-grid and off-grid operations

Table 9 presents a summary of the status of taxes in Zambia with a focus on those that are relevant to the DRE sector. Taxation of DRE is very favourable – most technologies are exempt from value added tax (VAT) and all are exempt from import duties. Zambia's corporate tax rate is slightly higher than the average corporate tax rate in sub-Saharan Africa of 28%.

Corporate Income Tax (CIT)	Value Added Tax (VAT)	Withholding Tax (WHT)	Import Duty

[195] USAID, Exploring Africa's mini-grid Tariff Methodologies, 2020 (link)
[196] Africa Clean Energy Technical Assistance Facility, Stand Alone Solar Market Update Zambia, 2021 (link)
[197] Africa Clean Energy Technical Assistance Facility, Stand Alone Solar Market Update Zambia, 2021 (link)

• Standard tax rate is 35%. • For companies with an annual turnover of not exceeding ZMW 800,000 a monthly turnover tax is applied. Zambia has six different turnover tax bands with a fixed base amount and a monthly rate of 3% on the balance.	• VAT is 16% for standard-rated supplies. • Solar panels and SHS are zero rated. • Batteries are charged at 16%[198]	• Residents pay 15% on dividends, interest, royalties and management and technical service fees. • Non-residents pay 20% except if stipulated otherwise in a double taxation treaty.[199]	• Solar lanterns, batteries, solar home systems and solar modules are exempt.[200]

Table 9: Taxes affecting DRE operations in Zambia

All potential companies in Zambia are required to be registered with the Patents and Companies Registration Agency (PACRA), and all companies, local or foreign, must register with Zambia Revenue Authority (ZRA) for corporate income tax, Pay as You Earn (PAYE) income tax on employment earnings and possibly Value Added Tax (VAT), depending on the scope and scale of the business.[201]

6.3 State of financing and its impact on business model implementation

6.3.1 Prevailing interest rates & collateral requirements for mini-grid & solar water pump suppliers

Mini-grid developers across Nigeria, Rwanda, and Zambia all share the common challenges of prohibitively high-interest rates charged by commercial banks, coupled with short tenors and collateral requirements. These challenges are a hindrance to scaling mini-grid projects. Mini-grids require longer-term financing that most commercial banks are not able or reluctant to provide.[202] Local commercial banks are also unfamiliar with mini-grid markets, technologies, and business models, which makes lending to mini-grid developers a high risk.

Availability of domestic funding from local commercial banks to mini-grid developers in Zambia is limited. This comes as a result of the mini-grid sector being relatively unknown to local banks, and preference is reserved for conventional investments that yield higher returns and carry lower risk. Local commercial banks charge an interest of 25% for local currency loans with significant collateral requirements (no specifications as to the collateral requirements).[203] Foreign currency investments are facilitated by the fact that Zambia does not impose any exchange control restrictions and investors are free to repatriate any funds, whether or not they are generated from a source in Zambia. However, as section 3.2 has shown, the Kwacha is relatively volatile against the USD, which increases foreign exchange risk and reduces the likelihood of international investment.

The Development Bank of Zambia (DBZ) does provide more favourable lending conditions compared to local commercial banks. DBZ has a project finance facility that permits loans of up to 10 years in both foreign and local currency with a minimum loan size of $200,000. Interest rates are the base rate plus/up to 5% on foreign currency, and local currency interest rates are offered at the Bank of Zambia base rate which was 9.5% in 2020,[204] with an additional 9% margin. Anecdotal evidence from reports suggest that DBZ's collateral requirements are, however, substantial.[205] DBZ provides separate credit lines up to $100,000 to small to medium enterprises (SMEs) and is additionally receiving support from the African Development Bank (AfDB) for business development and SME on-lending. The African Development Bank (AfDB) is in the process of capacitating Zambia's local commercial banks to invest in both mini-grid and off-grid renewable energy projects.

Mini-grids financed by DBZ
Through funding from UNEP/GEF, DBZ has provided soft loans for the ZESCO Shiwangandu 1 MW hydro mini-grid (ZESCO operates the electricity grid, and is responsible for much of the country's power generation), and the REA 60 kW solar mini-grid.

[198] Africa Clean Energy, Customs handbook For Solar PV Products in Zambia, 2022 (link)
[199] ENSAfrica, Doing business in Zambia, 2022 (link)
[200] Africa Clean Energy, Customs handbook For Solar PV Products in Zambia, 2022 (link)
[201] GET.invest Market Insights, Zambia: Solar PV and Hydro Mini-Grids, 2019 (link)
[202] USAID, Mini-grid challenges and needs in financing, 2023 (link)
[203] GET.invest Market Insights, Zambia Solar PV and Hydro Mini-Grids, 2019 (link)
[204] The World Bank, Lending interest rate (%) Zambia, 2020 (link)
[205] GET.invest Market Insights, Zambia Solar PV and Hydro Mini-Grids, 2019 (link)

6.3.2 Status of mini-grid and off-grid solar funding and support programmes

FUNDING & SUPPORT PROGRAMME	FUNDING	OUTCOMES	TIMELINE
Increase Access to Electricity and Renewable Energy Production (IAEREP)	€25 million in funding was provided by the EU. The indicative allocation of funds by lot is: Lot 1: Demonstration of projects in partnership with the REA - €3 Million Lot 2: Renewable-energy powered mini-grid demonstration with the private sector - €18 Million Lot 3: Energy efficiency demonstration projects - €4 Million	The programme aims at increasing access to clean, reliable and affordable energy through promotion of use of renewable energy and energy efficiency technologies. It is implemented through three parallel lines of action: 1. Support to public institutions to develop and/or revise the legal and regulatory framework; 2. Build capacity of both public and private organisations and, 3. Providing early stage seed finance in the form of grant funding. As of May 2023; ● The project had supported the commissioning of a Strategic Environmental Assessment (SEA) for the energy sector in Zambia,[206] ● A capacity building programme was launched. 28 participants from 12 institutions representing both the private and public sector participated in the training;[207] ● The project has also supported the launch of vocational training in renewable energy and energy efficiency[208], the certified training of energy auditors,[209] as well as the training of young technicians through TEVETA-Zambia.[210] ● The project funded the creation of an NGO platform that houses the database of Zambian NGOs. 20 Zambian NGOs have received training on the technical aspects of Renewable energy and energy efficiency, and the utilisation of the NGO platform.[211]	2016-2022

206 Global gateway, IAEREP TA1 Assists MoE in SEA, 2023 (link)
207 Global gateway, Successful implementation of the first capacity building training, 2023 (link)
208 Global gateway, IAEREP launches vocational training in renewable energy and energy efficiency, 2022 (link)
209 Global gateway, EU-trained energy auditors save power in Zambia, 2022 (link)
210 Global gateway, EU-IAEREP supports training of youth through TEVETA (IAEREP - TA1), 2022 (link).
211 Global gateway, IAEREP organises training on Zambia NGO platform implementation, 2023 (link)

Electricity Services Access Project (ESAP)	$36.8 million in funding provided by the World Bank. The project's components are: Component A: On-grid Electricity Access Expansion - $23.7 Million Component B: Off-grid Electricity Expansion - $5.9 Million Component C: Capacity Building and Project Implementation - $7.2 Million	The objective of ESAP is to increase electricity access in Zambia's targeted rural areas. There are 3 components to the project. The first component is on-grid electricity access expansion, the second is off-grid electricity access expansion and the third is capacity building and project implementation. ● By June 2022, a population of 234,807 had been provided with off- and on-grid access to electricity. 8,455 MSEs were provided with on-grid access to electricity. ● By June 2022, 109 people were trained in sector policy and technical aspects.[212]	2018 - 2023.
Beyond the Grid Fund for Africa (BGFA) in Zambia	$20 Million in results-based social impact procurement fund.[213]	BFGA is funded by the Nordic Environment Finance Corporation (Nefco) in partnership with Renewable Energy and Energy Efficiency Partnership (REEEP) and Power Africa. Rather than a distinct physical asset or service, the BGFZ aims for social impact by procuring the delivery of an energy service subscription (ESS) on behalf of end-users. The three pillars of its approach are calls for proposals as a financing mechanism, the provision of platforms for market change and market intelligence on the deployment of their energy services subscriptions. ● In March 2022, BGFA announced the signing of its first agreements in Zambia with RDG collective Limited, Zengamina Power Limited and Vitalite Zambia Ltd. The total value of these contracts was €5.9 Million.[214] ● In June 2022, Power Corner Zambia Limited and Engie Energy Access Zambia were signed with BGFA. Along with 2 other companies, the total value for the contracts was €8 Million.[215] ● By December 2022, Vitalite had 113,400 ESS, RDG Collective had 25,697, Zengamina Power had 2,600, Power Corner Zambia had 3,212 and Engie Energy Access Zambia had 295,668.[216] ● As of March 2023, d.light Zambia Limited and another company based in Uganda received a total of €3.9 million from BGFA. With the financing, d.light Zambia Limited aims to support the scale-up of its solar homes systems business.[217]	2017- 2026

[212] The World Bank, Electricity Service Access Project, 2022 (link)
[213] Power Africa,Beyond the Grid Fund for Zambia (link)
[214] BGFA, Beyond the Grid Fund for Africa signs its first projects with off-grid energy service companies in Zambia, 2022 (link)
[215] BGFA, Beyond the Grid Fund for Africa has signed further projects with off-grid energy service companies in Burkina Faso, Liberia and Zambia, 2022 (link)
[216] BFGA, Beyond the Grid Fund for Africa Impact report, 2022 (link)
[217] BFGA, The Beyond the Grid Fund for Africa programme signs further projects in Uganda and Zambia, 2023 (link)

EDFI ElectriFI Zambia country window	€40 million	The EDFI project is an EU-based facility with the objective of deploying solar home systems and productive-use appliances in rural Zambia.[218] ● As of 2022, $2 Million had been provided to RDG collective to boost its solar home system operations.[219] ● In March 2023, EDFI committed to providing a $1.5 million convertible note to Vitalite, that will be automatically converted into an equity stake in the company upon the next qualified equity raise by the company.[220]	2018 - Ongoing
Zambia - Zambia Renewable Energy Financing Framework[221]	$154 Million debt financing by AfDB and co-financed by the Green Climate Fund.	Project focus is on catalysing private investment for small-scale renewable energy projects. The project will be implemented by REA through contracts for consulting services for mini-grid and off-grid project preparation, feasibility studies, and regulatory design. Financing is intended for selected GETFiT projects. (Global Energy Transfer Feed-in Tariffs: GETFiT)	2018-2025
Powering renewable energy opportunities (PREO)	Up to €300,000 grant funding	PREO is a demand-led, productive use of energy (PUE) programme stimulating partnerships, innovation and learning to address the needs and improve the livelihoods of sub-Saharan African communities. In 2022, Good Nature Agro (GNA), a social enterprise with the majority of its farmers based in parts of Zambia, was provided with €160,000 in grant funding by PREO to support the introduction of solar powered borehole and irrigation systems that allow farmers to diversify their crop portfolio.[222]	2019 - Present
Nordic Development Fund's Energy and Environment Partnerships Trust (EEP Africa)	€200,000 - €1,000,000 non-repayable and repayable grants	The program provides financing to private companies, start-ups and social enterprises. ● EEP Africa awarded €208,680 to Solarworx in 2021 to fund the distribution of 300 solar home systems/ connection points to rural households, and entrepreneurs.[223] ● In 2019, EEP Africa awarded €787,192 to Agsol. With the financing, Agsol plans to develop new markets and distribute mills through local partners in Zambia, among other countries.[224]	2010 - Ongoing

[218] EDFI, Electrification Financing Initiative, 2023 (link)
[219] Afrik 21, Zambia: EDFI invests $2m in RDG collective's solar home systems, 2022 (link)
[220] EDFI, Vitalite Zambia secures $ 1,5 million from EDFI ElectriFI to support its growth, 2023 (link)
[221] African Development Bank, Green Climate Fund, Zambia - Zambia Renewable Energy Financing Framework, 2022 (link)
[222] PREO, Good Nature Agro receive PREO funding to transform the livelihoods of small-scale Zambian farmers with irrigation-based contract farming, 2022 (link)
[223] EEP Africa, Solar smart grid, 2023 (link)
[224] EEP Africa, Solar mills: powering rural productivity, 2023 (link)

Water and Energy for Food (WE4F)	$40,000 - $250,000 in grant funding	WE4F, through its regional innovation hubs, provides financial support, technical assistance, and investment facilitation to water-food, energy-food, and water-energy-food innovations. • In March 2023, WEF announced the winners of the second S/CA RIH Call for Innovations. The Zambia based awardees include: Zircon Energy Solutions who sell solar-powered water pumps to farmers through a pay-as-you-go business model and Ndkay who provide farmers with solar cold rooms that extend product shelf life and reduce post-harvest losses.[225] • In July 2022, the first S/CA call for innovation winners included Zambian based companies such as: Solar Village who sell Micron's highly water-efficient sprayers and the Solar Village Battery Stick to rural smallholder farmers.[226]	Ongoing

Table 10: DRE funding programmes in Zambia

[225] Water and Energy for Food, WE4F Southern and Central Africa Regional Innovation Hub Announces Winners of the Second Call for Innovations, 2023 (link)
[226] Water and Energy for Food, WE4F Southern and Central Africa Regional Innovation Hub Announces Winners of the First Call for Innovations, 2022 (link)

6.4 Infrastructure affecting business model implementation

6.4.1 Mobile infrastructure

Penetration of mobile cellular subscriptions in Zambia improved from 78 subscriptions per 100 people in 2017 to 104 subscriptions per 100 people in 2021.[227] This improvement compares favourably to the 2021 sub-Saharan average of 84 subscriptions per 100 people.[228] Active mobile cellular subscriptions increased from 3 million to 9.8 million between 2017 and 2021.[229]

The increase in mobile penetration and growing investments in the telecommunications sector is enabling more access and adoption of mobile money. Between 2017 and 2021 the number of mobile money transactions in Zambia cumulatively increased from 11 million to 834 million (see Figure 11).[230] Compared to global standards, Zambia also has a thriving mobile money industry. In 2021, the country had 1,804 mobile money accounts registered per 1,000 adults compared to the global average of 924 accounts.[231] This means that from an infrastructural point of view, there is a heightened likelihood of successful adoption of PAYGO-enabled products and services in Zambia.

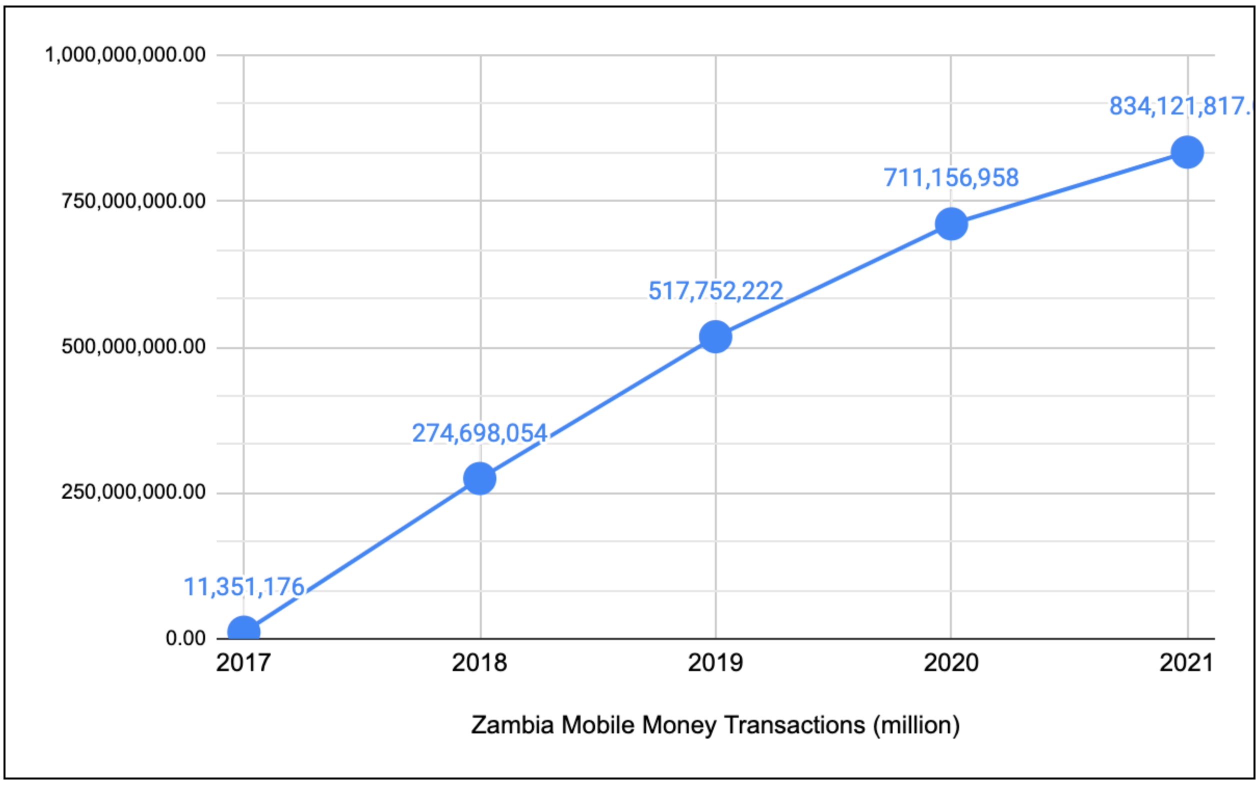

Figure 11: Growth in mobile money transactions[232]

6.4.2 State of general business operating environment

Companies are registered with the Patents and Companies Registration Agency, and it takes one week to complete registration once all the required documents have been submitted.[233] Companies must have a minimum of two shareholders and a maximum of 50. No requirements for local shareholding are in place. Investors and international companies looking to open a business in Zambia are subject to the following processes:[234]

- Investors must register with the Zambia Development Agency to obtain an investment certificate in order to qualify for incentives. However, registration is not compulsory. One notable example of an incentive is accelerated depreciation based on the cost of equipment for companies operating in the farming, agro-processing, mineral processing, tourism, electricity generation and asset leasing sectors;
- All companies must hold a valid general trading licence and pay levies to the local government council in the area where the company operates;

[227] World Bank, Mobile cellular subscriptions, Zambia, 2021 (link)
[228] World Bank, Mobile cellular subscriptions, Sub-Saharan Africa, 2021 (link)
[229] Bank of Zambia, National Payment Systems in Zambia Annual Report, 2021 (link)
[230] International Monetary Fund, Macroeconomic and Financial Data Zambia, 2022 (link)
[231] IMF, Number of registered mobile money accounts per 1,000 adults, 2021 (link)
[232] International Monetary Fund, Macroeconomic and Financial Data Zambia, 2022 (link)
[233] ENS Africa, Doing Business Zambia, 2022 (link)
[234] ENS Africa, Doing Business Zambia, 2022 (link)

- A private company must have a minimum of two directors, one of which must be a Zambian resident. An expatriate that holds a work permit is regarded as a resident;
- All taxpayers must register with the Zambia Revenue Authority;
- All employers must register with the National Pension Scheme Authority and each employee must have a social security number;
- All companies must register with the Workers' Compensation Fund Control Board;
- All employers must register their employees with the National Health Insurance Management Authority.

7. Zimbabwe

Agriculture represents 40% of Zimbabwe's total export income and 17% of the country's GDP.[235] The sector provides employment to approximately 70% of Zimbabwe's population and the country is home to an estimated 1.3 million smallholder farmers – a group that occupies approximately 70% of agricultural land.[236] Despite the fact that smallholder farmers form such an integral part of Zimbabwe's agricultural landscape, living and working conditions are difficult. Only 7% of smallholder farmers have access to water pumps and about 2% use mechanical shellers.[237] Key to these low levels of mechanisation is the lack of electricity access. In 2020, the country's rural electrification rate stood at only 37%.[238] As is the case with most countries that experience low electrification levels, off-grid systems can play a key role in closing the gap. In the agricultural sector in Zimbabwe and further afield, they can cost-effectively power increased levels of mechanisation, which will lead to higher income levels for farmers. Horticulture farmers in Zimbabwe have, for example, experienced yield increases of 2.5-fold to 3.2-fold after adopting irrigation systems.[239] Table 11 presents indicative results from TFE's techno-economic modelling of electrification of key steps in the maize, groundnuts and sorghum value chains in Zimbabwe. Barring groundnut milling, electrification of all activities are estimated to be economically feasible. As with other countries in this report, this assumes that irrigation is powered with solar water pumps and agro-processing machinery with mini-grids.

	Zimbabwe												
	Maize				Groundnuts					Sorghum			
	Irrigation	Shelling	Dehulling	Milling	Irrigation	Shelling	De-skinning	Roasting	Peanut butter	Irrigation	Threshing	Dehulling	Milling
Annual marginal revenue													
Produce sales	$2660	$1517	$2845	$683	$2652	$2998	$1499	$5396	$8679	$2646	$3950	$4937	$1382
Others													
Total revenues	$2660	$1517	$2845	$683	$2652	$2998	$1499	$5396	$8679	$2646	$3950	$4937	$1382
Annual marginal cost													
Transport cost to market	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290	$290
Labour	$677	$193	$580	$580	$773	$193	$193	$1547	$1547	$677	$193	$580	$580
Maintenance	$33	$25	$30	$25	$33	$89	$45	$125	$30	$33	$25	$30	$25
Electricity	$0	$29	$196	$59	$0	$39	$26	$574	$417	$0	$29	$235	$59
Grid	$101	$17	$117	$35	$116	$23	$16	$344	$250	$101	$17	$141	$35
Mini-grid	$169	$29	$196	$59	$193	$39	$26	$574	$417	$169	$29	$235	$59
Total costs	$1000	$537	$1096	$954	$1097	$611	$554	$2536	$2284	$1000	$537	$1135	$954
Annual marginal profit	$1660	$980	$1749	-$271	$1555	$2387	$945	$2861	$6395	$1646	$3413	$3802	$429
Indicators													
Upfront cost	$690	$1880	$2400	$285	$690	$1675	$900	$2500	$2000	$690	$1880	$2000	$285
Payback (years)	0.42	1.92	1.37	-1.05	0.44	0.70	0.95	0.87	0.31	0.42	0.55	0.53	0.67
Payback (months)	4.99	23.02	16.46	-12.62	5.32	8.42	11.43	10.49	3.75	5.03	6.61	6.31	7.98
Value added	1.30	15.04	8.95	-1.39	1.07	36.62	14.49	5.49	12.27	1.29	52.36	19.45	2.19
Electricity source	Standalone	Mini-grid	Mini-grid	Mini-grid	Standalone	Mini-grid	Mini-grid	Mini-grid	Mini-grid	Standalone	Mini-grid	Mini-grid	Mini-grid
Location	Farm	Village	Village	Village	Farm	Village	Village	Village	Village	Farm	Village	Village	Village
Irrigation second season	Crop rotation				Crop rotation					Crop rotation			

Table 11: Indicative modelling results of value chain electrification in Zimbabwe[240]

Unlocking this potential however requires accelerated adoption of irrigation and agro-processing, which can only be facilitated by the availability of solar water pumps and mini-grid energy services in rural areas. This requires a favourable operating environment for suppliers of solar water pumps, mini-grids and agro-processing machinery.

7.1 Mini-grid and off-grid market overview

As of 2020, Zimbabwe's nationwide access to electricity stood at 52.7%.[241] Regulatory performance is below average according to the ESMAP RISE Index, with an overall score of 38 out of 100. This includes low scores in key electricity access indicators, such as the mini-grid framework which is 30/100, the off-grid system framework at 65/100, and the consumer affordability of electricity at 44/100.[242]

In 2019, the government launched the Rural Electrification Master Plan, which aims to connect 1,000 rural growth points and 6,700 rural business centres with electricity through a combination of mini-grids and off-grid solutions by 2030.[243] The plan also details the connection of 250,000 rural households with off-grid solar home systems by 2023. Additionally, the government has set a target of installing 500,000 solar water heaters in households and institutions by 2030 as part of its efforts to promote renewable energy.

[235] FAO, Zimbabwe at a glance, 2023 (link)
[236] International Fund for Agricultural Development, Zimbabwe smallholder agriculture cluster project, 2021 (link)
[237] Zimbabwe National Statistics Agency, Zimbabwe Smallholder Agricultural Productivity Survey Report, 2019 (link)
[238] World Bank, Access to electricity (% of population) - Zimbabwe, 2020 (link)
[239] Lighting Global, The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa, 2019 (link)
[240] TFE, Techno-economic model for agricultural value chain electrification, 2023 (link)
[241] World Bank, Access to electricity (% of population) - Zimbabwe, 2020 (link)
[242] Regulatory Indicators for Sustainable Energy, Zimbabwe, 2021 (link)
[243] Rural electrification Authority (REA), Rural Electrification Master Plan: Zimbabwe, 2019 (link)

Zimbabwe has targeted a contribution of USD 3 billion towards off-grid solar solutions as part of the NDC.[244]

7.1.1 Mini-grids

Zimbabwe's mini-grid sector is relatively nascent. Existing mini-grids are mainly developed by NGOs and are donor funded. These include six projects with a total installed capacity of 145 kWp that were developed as part of the ACP-EU Energy Facility programme between 1990 and 2013. More recently, SNV developed the 99 kW Mashaba solar mini-grid.[245] Practical Action is also active in the country having developed the 80 kW Himalaya hydro mini-grid. Eight mini-hydro plants have been installed by IPPs, ranging from 30 kW to 15 MW each.[246] Companies such as Distributed Power Africa are also active in the industry, yet with a focus on urban mini-grids. The Rural Electrification Fund has ambitious plans to deploy 56 community mini-grids and 184 institutional mini-grids by 2025.[247] The addressable market for mini-grids in the country is estimated at 14.4 million people (approximately 10% of the population).[248]

The Zimbabwe Energy Regulatory Authority (ZERA) sets the tariffs for electricity in Zimbabwe, including those for mini-grids. As of 2018, the average mini-grid tariff in Zimbabwe was around $0.28 per kWh.[249] However, this varies depending on the provider, the size of the mini-grid and the service tier level, since ZERA has limited interference with tariff models for mini-grids that are less than 100kW in size.

7.1.2 Standalone solar

As is the case with mini-grids, the market for standalone solar in Zimbabwe is relatively small compared to other countries. Approximately 14 companies are involved in the supply of solar home systems on a variety of business models from PAYGO to cash sales, while about 11 sell solar productive use systems including solar water pumps.[250] The estimated addressable market for solar home systems is 2.2 million people, making up 13% of the unelectrified population as of 2018.[251] GOGLA's sales report has indicated solar energy kits sales reaching 31,886 units in the second half of 2022 in Zimbabwe. This represents an increase of 282% compared to the first half of the year,[252] which indicates that the market is recovering well after the COVID-19 pandemic.

Zimbabwean NGOs are the main stakeholders that implement solar irrigation schemes in rural areas.[253] Solar-powered processing equipment, such as solar mills, shows little to no activity, with the market dominated by grid and diesel solutions.[254] Despite this, solar threshers have been identified as a potential solution that could be cheaper than diesel-powered alternatives and provide more efficient threshing services to remote producers.[255] The upfront costs of solar water pumps and agricultural processing machines in Zimbabwe vary depending on the size, capacity, and type of equipment. The cost of a solar water pump in Zimbabwe can range from $200 to $1500,[256] depending on the capacity and manufacturer (see Annex 3 for detailed costs).

7.2 Macro considerations for DRE business models

7.2.1 Regulations affecting mini-grids and off-grid solar

General energy sector regulations

The Electricity Solar Photovoltaic System Regulations 2020 are applicable to manufacturers, importers, vendors, technicians, contractors and owners of all kinds of solar installations.[257] Solar technicians are required to have a licence from the regulatory authority before designing, installing, commissioning, and maintaining solar systems. Licences issued under these regulations are valid for a period of three years. Licences are divided into different classes as discussed below.

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[244] The Global Development Policy (GDP) centre, Expanding renewable energy for access and development, 2020 (link)
[245] SNV, Sustainable Energy for Rural Communities/Mashaba Solar Mini-grid, 2023 (link)
[246] Carbon trust, Mini-Grid Market Opportunity Assessment: Zimbabwe, 2018 (link)
[247] Makumbinde, F., Zimbabwe Rural Electrification Fund, 2022 (link)
[248] ESMAP, Mini-grids for half a billion people, 2022 (link)
[249] Carbon trust, Mini-Grid Market Opportunity Assessment: Zimbabwe, 2018 (link)
[250] Africa Clean Energy Technical Assistance Facility, Stand Alone Solar Market Update Zimbabwe, 2021 (link)
[251] Carbon trust, Mini-Grid Market Opportunity Assessment: Zimbabwe, 2018 (link)
[252] GOGLA, Global Off-Grid Solar Market Report H2, 2022 (link)
[253] Africa Clean Energy Technical Assistance Facility, Stand Alone Solar Market Update Zimbabwe, 2021 (link)
[254] Clasp - Milling solar appliance technology brief, 2021 (link)
[255] Lighting Global, The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa, 2019 (link)
[256] See Annex 3 for detailed costs
[257] Zimbabwe Electricity Solar Photovoltaic System Regulations, 2020 (link)

- Licence for technicians:
    - **Class ST1:** For work on solar systems with a single inverter, single charge controller, single or multiple solar modules not more than 400 watts.
    - **Class ST2:** For work on solar systems not more than 2 kW, a single inverter/charger connected to a grid or a backup generator, a charge controller of up to 70 amperes, and multiple batteries.
    - **Class ST3:** For work on grid-tied solar systems of a capacity not more than 50 kW, and single-phase hybrid systems not more than 10 kW direct current coupled with a single battery inverter and they may connect multiple batteries.
    - **Class ST4:** For work on grid-tied or hybrid, or solar water pumping systems of any capacity.
- Licences for contractors and manufacturers:
    - **Class SC1:** Contractors can import and sell solar components not exceeding 400W. Contractors can work on solar systems with a single inverter charge controller, and single or multiple solar PV modules not more than 400 watts.
    - **Class SC2:** Contractors can import and sell solar components not exceeding 2 kW. Contractors can work on solar systems of not more than 2 kW, a single inverter/charger connected to the grid or a backup generator, a charge controller of up to 70 amperes and multiple batteries.
    - **Class SC3:** Contractors can import and sell solar systems and components and solar water pumping systems not exceeding 50 kW. Contractors can work on grid-tied solar systems of not more than 50 kW or single phase, hybrid systems not more than 10 kW or direct current coupled with a single battery inverter.
    - **Class SC4:** Contractors can manufacture, import or sell solar products and design, install, and commission grid-tied, hybrid or solar water pumping systems of any capacity. Contractors are required to be, or to have in their employment a class ST4 technician.
    - **Class SM:** Contractors can import parts necessary for the manufacturing of solar components, and manufacture and sell solar components and systems.

All renewable energy projects need to undergo the EIA process prior to implementation as per provisions in the Environmental Management Act, 2002, and Statutory Instrument 7 of 2007 Environmental Impact Assessment and Ecosystems Protection Regulations.[258] Projects less than 5 MW enjoy relaxed requirements.

Mini-grids

All mini-grid projects in Zimbabwe are required to obtain a licence, yet there are no specific mini-grid regulations in place. Regulations are recommended to assist the industry to scale up in the country. Licensing fees are waived for mini-grids smaller than 1 MW.[259] Projects require the approval of at least a two-thirds majority of the local population before beginning work on the project. Developers are allowed to charge cost-reflective tariffs, but have to take into consideration the paying capacity of the consumer when setting the tariffs. Mini-grids must also obtain approval from the Environmental Management Agency and the Zimbabwe National Water Authority. Fees have been noted to be prohibitively high, which has since been lowered.[260]

Standalone solar

Zimbabwe adopted the International Electrotechnical Commission (IEC) standards for standalone solar systems in 2020. The Zimbabwe Energy Regulatory Authority (ZERA), the Ministry of Industry and Commerce (MoIC) and Bureau Veritas carry out verification and assessment of conformity of imported solar goods.[261] Zimbabwe has no specific regulations on e-waste in place.

7.2.2 Taxes affecting mini-grid and off-grid operations

The National Renewable Energy Policy 2019 specifies guidelines on tax exemptions for renewable energy.[262] For community-funded or NGO-sponsored off-grid projects, all duties on the import of equipment and all taxes related to consumption of electricity are waived as provided in the respective legislation and amendments (Finance Act, Income Tax Act, Value Added Tax Act and Value Added Tax Regulations, Customs, and Excise Duty Act and Customs and Excise General Regulations).[263]

258 SADC, Zimbabwe Environmental Management Act, 2019 (link)
259 Ministry of energy and power development, Zimbabwe National Renewable Energy Policy, 2019 (link)
260 ESMAP, Mini-grids for half a billion people, 2022 (link)
261 Africa Clean Energy Technical Assistance Facility, Stand Alone Solar Market Update Zimbabwe, 2021 (link)
262 ZERA, Zimbabwe National Renewable Energy Policy, 2019 (link)
263 ZERA, Zimbabwe National Renewable Energy Policy, 2019 (link)

Table 12 presents the status of taxes as they pertain to renewable energy. These are relatively favourable for the sector. Most solar energy generation equipment enjoy duty-free imports. Renewable energy developers can also benefit from a 10-year income tax holiday provided that certain requirements are met. This is offered to investors in the energy, water and sanitation, and transport sectors. Accelerated and full tax deductible depreciation allowances are also planned for solar equipment.

Corporate Income Tax (CIT)	Value Added Tax (VAT)	Withholding Tax (WHT)	Import Duty
• The standard corporate tax rate is 24.72%.	• The standard VAT rate is 15% • Exemptions are granted for: solar panels, inverters, solar lights, energy saving light bulbs and electricity generators.[264]	• Residents: ○ 10% on dividends, ○ 5% on interest from fixed deposits ○ 15% on other interest ○ Royalties and fees for management, consulting and technical services are exempt. • Non-residents: ○ 15% on dividends ○ 10% on dividends from listed securities ○ Interest payments are exempt ○ 15% on royalties and fees for management, consulting and technical services[265]	• 23% duty is applicable to solar lanterns, • 20% duty is applicable to batteries • 5% duty is applicable to solar water pumps • Solar home systems and solar modules are exempt.[266]

Table 12: DRE-related taxes in Zimbabwe

7.3 State of financing and its impact on business model implementation

7.3.1 Prevailing interest rates & collateral requirements for mini-grid & solar water pump suppliers

Commercial financing is still absent from the mini-grid sector, chiefly due to the underdeveloped status of the sector. Mini-grids require longer-term financing that most commercial banks are not able or reluctant to provide.[267] Local commercial banks are also unfamiliar with mini-grid markets, technologies, and business models, which makes lending to mini-grid developers a high risk. Some local commercial banks such as the African Banking Corporation, Steward Bank and ZimBank have however been involved with financing standalone solar systems and other solar projects.[268] It is likely that interest rates and collateral requirements will be fairly high considering the limited track record for renewable energy investments in Zimbabwe, high inflation and high volatility of the local currency.

Investors may, without restriction or delay, in a freely convertible currency, transfer funds as specified under the ZIDA Act, into and out of Zimbabwe. Cross-border transactions must be made through a commercial bank (authorised dealer). Authorised dealers can process external loans and/or trade credits of up to $20 million without prior approval from the RBZ's External Loans Coordinating Committee (ELCC). All applications for external loans in excess of this stipulated threshold must be submitted to the RBZ for the ELCC's approval.[269] The Zimbabwean Dollar is however very volatile (see section 3.2), which increases foreign exchange risk and stifles investment into energy access companies in the country.

7.3.2 Status of mini-grid and off-grid solar funding and support programmes

Finance flows from DFIs to the larger renewable energy sector in Zimbabwe from 2007 to 2018 amounted to $487 million.[270] Only a small share of this funding is estimated to have been deployed in the mini-grid and standalone solar sectors. The government, through the National Renewable Energy Policy 2019, has

[264] Matrix Tax School, A call for government to incentivize solar projects, 2023 (link)
[265] ENSAfrica, Doing business in Zimbabwe, 2023 (link)
[266] GOGLA, Off-grid and VAT and Duty Tracker, 2022 (link)
[267] USAID, Mini-grid challenges and needs in financing, 2023 (link)
[268] Africa Clean Energy Technical Assistance Facility, Stand Alone Solar Market Update Zimbabwe, 2021 (link)
[269] Reserve Bank of Zimbabwe, Foreign exchange guidelines, 2009 (link)
[270] Global Development Policy, Expanding renewable energy for access and development, 2020 (link)

outlined support and financing structures for the development of off-grid technologies and other clean energy projects.[271] Table 13 shows the current status of financing programmes in Zimbabwe.

[271] Ministry of Energy and Power Development, National Renewable Energy Policy, 2019 (link)

FUNDING & SUPPORT PROGRAMME	FUNDING	OUTCOMES	TIMELINE
Rural Electrification Fund (REF)[272]	Government grants; Loans (no specification as to the amount)	REF was set up by the government of Zimbabwe to support rural electrification programs, including the development of mini-grids. The fund provides grants and loans to communities and private sector players to finance the construction and operation of mini-grids. ● REF commissioned a 60 kW Bemba mini-grid solar project, as of November 2022.[273] ● 27 households have been connected and REF has installed a 10,000L tank for water storage as well as irrigation and provision of piped water to the cattle drinking trough; ● In 2021, community solar mini-grids started being built. 1 is complete, 7 were in progress in 2022, and 56 were to be constructed by 2025. ● 424 Institutions connected to mini grids and 434 mobile solar units were distributed. 24 mini-grids in progress.[274]	Ongoing (initial implementation of REF was in acted in 2002)
UNDP Zimbabwe[275]	$1.5 million catalytic funding	The funding aims to accelerate access to sustainable, affordable, and clean energy in Zimbabwe. UNDP is working with the Ministry of Energy and Power Development, the Rural Electrification Fund, and the Zimbabwe Energy Regulatory Agency in the implementation of this project. The intervention is hinged on the Viability Gap Funding Framework. Investment is directed towards: 1. Supporting two solar mini-grids and offers up to 50% subsidy for renewable energy projects CAPEX as Viability Gap Funding; 2. supporting the pre-feasibility studies and 5 full feasibility studies of solar mini-grid project sites identified and prioritised by the Government of Zimbabwe.	2022- ongoing (no indication if project has commenced)

272 The Rural Electrification Authority Zimbabwe, Solar energy, 2023 (link)
273 REF Zimbabwe, Bemba Mini-grid Solar System, 2022 (link)
274 Africa Energy Forum, Country Focus, Zimbabwe Rural Electrification Fund, 2022 (link)
275 UNDP, Energy Offer for Zimbabwe, 2022 (link)

The Sustainable Energy for Rural Communities (SE4RC): The Mashaba Solar Mini-grid project.[276,277]	The project was jointly funded by the European Union (EU-ACP), the OPEC Fund for International Development (OFID), and the Global Environmental Facility (GEF).	The aim of the project was to promote universal access to modern energy services for 10,000 rural men and women in 2,800 households in Gwanda South. • A 99KW solar mini-grid system, two energy centres, and two stand-alone power units. • The mini-grid powers three irrigation schemes, five business centres, a clinic, a school, and a study centre; • The mini-grid uses a three-tier tariff structure with a prepaid metering system for all customers; • The energy centre supports economic activities such as cold rooms, agro-processing, welding, and similar activities that require substantial energy. • A resource/study centre with facilities that include ICT provision, e-learning, internet, TV, after-hours study, and community information; • Energy kiosks for household energy requirements such as lighting, communication/mobile phone charging, entertainment (televisions and radios), and battery charging among other low-energy uses.	2016 (completed)
Econet: Ugesi Energy Re-Imagine Rural Initiative	$100 million	The project aims to build solar mini-grids at 100 sites in rural areas across the country. • In 2020, A 100 kW mini-grid which supports 70 businesses was commissioned in Ndolwane. 10 more mini-grids have been planned under the programme.[278]	2019-ongoing
Renewable Energy and Adaptation and Climate Technologies Program for Sub-Saharan Africa (REACT SSA) by the Africa Enterprise Challenge Fund (AECF).[279]	$6.5 million committed by the Sweden International Development Cooperation Agency (SIDA)	The programme aims to provide funding to promote the implementation of renewable energy projects by the private sector. The fund matches funding on a 1:2 basis. • In a second round of funding, and by 2021, 14 companies in Zimbabwe were shortlisted of which 9 were targeted to be funded.[280]	2020-2021

[276] African Development Bank, Mini-Grid Market Opportunity Assessment, Zimbabwe, Green Mini-Grid Market Development Programme, 2018 (link)
[277] SNV, Sustainable Energy for Rural Communities, Mashaba Solar Mini-grid, 2023 (link)
[278] Pressreader, Ndolwane community reaps solar project benefits, 2020 (link)
[279] African Development Bank, Mini-Grid Market Opportunity Assessment, Zimbabwe, Green Mini-Grid Market Development Programme, 2018 (link)
[280] African Development Bank, Mini-Grid Market Opportunity Assessment, Zimbabwe, Green Mini-Grid Market Development Programme, 2018 (link)

African Development Bank (AfDB) Rural Electrification Support Program (RESP)	tbc	The program provides financing to private sector players and communities to develop and operate mini-grids in rural areas	tbc
Nordic Development Fund's Energy and Environment Partnerships Trust (EEP Africa)	€200,000 - €1,000,000 non-repayable and repayable grants	The program provides financing to private companies, start-ups and social enterprises from any of their country focuses, including Zimbabwe. In 2019, EEP Africa provided €210,000 in funding to Celfre Energy for the distribution of 570 solar water pumps to smallholder farmers.[281]	2010 - ongoing
Water and Energy for Food (WE4F)	$40,000 - $250,000 in grant funding	WE4F, through its regional innovation hubs, provides financial support, technical assistance, and investment facilitation to water-food, energy-food, and water-energy-food innovations. • In July 2022, the first S/CA call for innovation winners included Zimbabwe based companies such as: Zonful Energy who sell solar water pumps using PAYGO and FarmHut Africa who provide a digital marketplace and logistic service to farmers, helping reduce their energy consumption.[282]	Ongoing

Table 13: DRE funding programmes in Zimbabwe

[281] EEP Africa, Celfre Energy, 2019 (link)
[282] Water and Energy for Food, WE4F Southern and Central Africa Regional Innovation Hub Announces Winners of the First Call for Innovations, 2022 (link)

7.4 Infrastructure affecting business model implementation

7.4.1 Mobile infrastructure

Mobile cellular subscriptions in Zimbabwe have experienced fluctuations from 2017 to 2021. Subscriptions stood at 96 subscriptions per 100 people in 2017, decreasing to 89 subscriptions per 100 people in 2021 – slightly higher than the global average of 84 subscriptions.[283] The mobile device penetration rate stood at 84.8% of the total population in urban areas in 2021. However, the rate remains lower in rural areas due to low connectivity and limited distribution of 3G and LTE coverage.[284]

The mobile money market in Zimbabwe experienced a downturn from 2019 to 2021, decreasing from 1.9 billion to 1.2 billion.[285] The downturn was largely influenced by the introduction of the Real Time Gross Settlement Dollar (RTGS Dollar) as the country's interim currency in 2019 which led to de-dollarisation.[286] The RTGS Dollar is an electronic currency that is available in the form of RTGS balances, digital money, which is accessible through a mobile money wallet.[287] For individuals who do not have mobile money wallets, the RTGS dollar is available in the form of Zimbabwe bond notes (physical currency).

The interchangeable use between the RTGS dollar, US dollar and Zimbabwe bond notes has resulted in inconsistencies in the exchange rate due to daily fluctuations, increased inflation, and loss of value in digitally stored currency. In addition, the lack of interoperability among mobile money operators and high transaction fees[288] limit the ability to accurately monitor the prevalence of mobile money transactions in the country. The number of active mobile money subscribers decreased to 6.9 million in 2022, from 7.2 million the previous year (see Figure 12).[289]

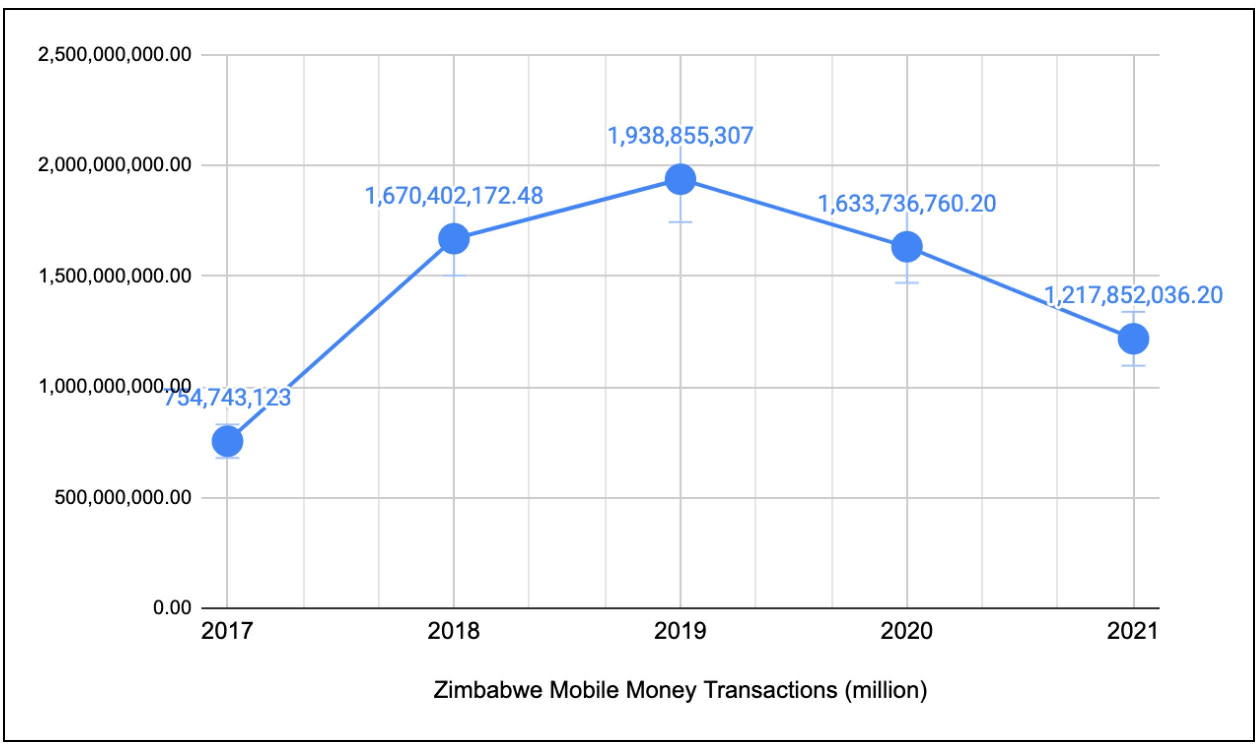

Figure 12: Changes in mobile money transactions.[290]

Despite this, Zimbabwe is still one of the leading African countries in terms of mobile money usage. Out of a total population of 15 million people, 7.1 million people use a mobile money wallet.[291] The digital payments infrastructure in the country is well-developed with 96% of all transactions being made digitally. Per 1,000 adults, Zimbabwe remains above the global average of 924 registered accounts, at 1460 accounts.[292]

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283 World Bank, Mobile Cellular Subscriptions, Zimbabwe, 2021 (link)
284 World Bank, Mobile Cellular Subscriptions, Zimbabwe, 2021 (link)
285 International Monetary Fund, Macroeconomic and Financial Data Zimbabwe, 2022 (link)
286 World Bank, Digital Economy for Zimbabwe Country Diagnostic Report, 2021 (link)
287 Reserve Bank of Zimbabwe, Statutory Instrument 33, 2019 (link)
288 World Bank, Digital Economy for Zimbabwe Country Diagnostic Report, 2021 (link)
289 Reserve Bank of Zimbabwe, National Payments Systems, Second Quarter Highlights Report, 2022 (link)
290 International Monetary Fund, Macroeconomic and Financial Data Zimbabwe, 2022 (link)
291 World Bank, Digital Economy for Zimbabwe Country Diagnostic Report, 2021 (link)
292 IMF, Number of registered mobile money accounts per 1,000 adults, 2021 (link)

Zimbabwe has one of the most expensive telecommunications markets in Africa due to macroeconomic conditions and underinvestment in market infrastructure.[293] The Postal and Telecommunications Regulatory Authority of Zimbabwe (POTRAZ) approved a third consecutive increase in voice, data, and SMS tariffs by 55.6% in 2020, and TelOne increased its broadband tariffs by 199% in 2019.[294] This makes it difficult for low-income households and individuals in rural areas to afford broadband and data services.

In spite of fluctuations across the mobile market, the increased adoption and use of mobile services (cellular subscriptions, mobile money subscribers and transactions, and internet use) will continue to be a key avenue of growth in the use of PAYGO services. However, policies in the telecommunications sector need to be revisited in order to provide more affordable options and accessibility to the mobile money market within low-income and rural communities.

7.4.2 State of general business operating environment

Companies in Zimbabwe must have a trading licence from the local government authority. The One Stop Investment Services Centre (OSISC) has been established as a one-stop shop to provide investment services, including company registration, tax registration and clearance, and licensing procedures. Foreign investors looking to operate in Zimbabwe must register with the following departmental representatives at the OSISC:[295]

- The Office for the Registration of Companies and Other Business Entities;
- All taxpayers must register with the Zimbabwe Revenue Authority (ZIMRA). If a company's turnover exceeds the VAT registration threshold, VAT registration becomes mandatory;
- Every employer must register with the National Social Security Authority (NSSA) for processing of social security contributions;
- The Immigration Department;
- The Reserve Bank of Zimbabwe.

In addition, each employer must register with the Zimbabwe Manpower Development Fund for payments of training levies.

[293] World Bank, Digital Economy for Zimbabwe Country Diagnostic Report, 2021 (link)
[294] World Bank, Digital Economy for Zimbabwe Country Diagnostic Report, 2021 (link)
[295] ENS Africa, Doing Business Zimbabwe, 2022 (link)

8. Conclusions

The business case for value chain electrification in sub-Saharan Africa is, in many cases, positive, as evidenced by the techno-economic study conducted for select countries in this project. The ingredients to successful deployment are universal: With agro-processing, ensure that throughput is maximised. This is the single most impactful way to improve the economics of agro-processing. With irrigation, support smallholder farmers to practise crop rotation techniques between staples and cash crops enable faster recovery of capital expenditure.

The off-grid renewable energy technologies to deliver electricity to value chain activities are proven. Focus on positioning agro-processing equipment facilities in villages and power them with alternating current electricity from mini-grids. Educate smallholder farmers on the use of standalone solar water pumps on-farm, to save costs that would otherwise have been incurred to extend mini-grid power lines to pumps on farms.

The foundational principles of successful agri-energy nexus business models are clear. PAYGO models improve affordability by avoiding high upfront capital expenditures, Keymaker models connect smallholder farmers with downstream markets which facilitate higher profit margins for their crops and community-centred business models ensure longevity as a result of community buy-in.

The ingredients for favourable macro operating environments are known. Regulations and taxes should not impede energy access operations unnecessarily, financing should be readily available and infrastructure should allow for efficient operations. In Nigeria, regulations create a healthy operating environment. In Rwanda, clear regulations are in place, but the low priority given to the off-grid sector by the government means that the industry remains small. Zambia has a well-crafted legislation in place, but its continued draft status stifles growth, while the market in Zimbabwe would benefit from the introduction of regulations. While some countries perform better than others on financing availability, companies across the board generally find it difficult to source suitable financing. Infrastructure such as mobile money performs relatively well in most countries, while physical access to rural areas remains a challenge.

What remains is the need for more practical experience with these business models in a variety of macro operating environments among a larger proportion of off-grid and mini-grid companies. This report has showcased examples of the key agri-energy business models used by companies to adequately serve smallholder farmers. Key to disseminating best practices discussed in this report is the open sourcing of techniques such as the techno-economic model (downloadable here**)** and facilitating experiments with companies on the use of the demand-led business models discussed in this report.

Annex 1: User guide for techno-economic model

TFE's agro-processing and irrigation techno-economic model is designed to measure the financial viability of purchasing and operating solar water pumps and agro-processing machinery among smallholder farmers. The model is replicable, meaning that it can ingest data from the local context of any user anywhere in the world. The model is designed to be highly accurate given that it considers data points from a wide variety of considerations that influence the business case, from smallholder profit margins, to nuances such as whether the farmer only grows staple crops or cash crops as well. Data inputs are, as a result, a critical success factor for the model. If input data are inaccurate and do not reflect reality, outputs will also be inaccurate.

Sheet 1: Main inputs

The first sheet, main inputs, is where users populate the model with input data. This data is automatically used by the model to calculate the outputs. The sheet is structured to ingest data of three staple crop value chains and one horticulture value chain in up to four countries. As an example, the figure below shows a pre-populated version of the inputs sheet for the maize value chain in Nigeria.

Insert country name below: Nigeria		Insert staple crop 1 below: Maize			
User to answer questions in blue:	Unit	Irrigation	Drying	Shelling	Milling
General questions:					
How many hours per day will the equipment be operational?	h/day	6	6	5	5
Across how many months per year will the equipment be used?	months/year	6	2	2	6
If the equipment will be connected to the grid, what is the tariff?	USD/kWh	0.086	0.086	0.086	0.086
If the equipment will be connected to a mini-grid, what is the tariff?	USD/kWh	0.578	0.578	0.578	0.578
What is the current price per litre of diesel?	USD/L	2.048	2.048	2.048	2.048
What is the distance from the farm to the market and back?	km	50	50	50	50
What is the fuel consumption of the vehicle that delivers crops to market?	l/km	0.059	0.059	0.059	0.059
How much do you expect to spend on maintenance per year?	USD/year	33	15	50	50
What is the monthly salary in USD that the equipment operator will earn?	$156.63				
Irrigation-specific questions (additional inputs on irrigation sheet):					
What is the upfront cost of the relevant solar water pump?	USD	$2361			
What the the power rating of the pump?	kW	0.36			
Agro-processing specific questions:					
What is the upfront cost of the relevant processing machine?	USD		$1566	$2420	$3000
What is the maximum possible throughput that the machine can deliver?	kg/hour		83	400	1000
What is the power rating of the processing machine?	kW		0.20	2.20	30.00
Automatic answers, feeding into results sheets:					
Capacity utilization	%	12.50%	1.79%	1.49%	4.46%
Operating hours	h/year	1095	156	130	391
Portion of salary (1 worker) attributed to operation of the equipment	USD/year	$469.88	$313.25	$313.25	$939.76
Realistic machinery throughput	kg/h		83	200	500
Annual energy consumption	kWh/year	394	31	287	11732
Power rating reverse calculation	kW	0.36	0.2	2.2	30.0

Colour coded cells are those that users can edit. For example, users are requested to modify the number of hours that the equipment will be operational, the number of months per year that it will be operational and so forth. Cells that are white are automatic calculations that, in turn, automatically feed into the output sheets. All modifiable cells must be accurately populated by the user to ensure accurate outputs in the respective output sheets (e.g. sheets 3 and 4).

Sheet 2: Price margin inputs

The price margin input sheet collects information about the price margin that the smallholder farmer experiences as a result of operating the solar water pump (in the case of irrigation), dryer (in the case of drying) and so forth. Users can populate this data in one of two ways: Either by subtracting the crop price per kilogram without operation of a pump or agro-processing machine from the crop price **with** access to the pump or machine, or by skipping this calculation and directly inserting the margin. In the figure below, the milling margin is directly inserted, while irrigation, drying and shelling follows the calculation mentioned above. The price margin serves as an input into the annual marginal revenue calculations in the payback period results sheet.

Nigeria		Maize			
Parameter	Unit	Irrigation	Drying	Shelling	Milling
Crop price without activity	USD/kg	0.40	0.40	0.50	
Crop price with activity	USD/kg	0.52	0.50	0.60	
Price margin	USD/kg	0.12	0.10	0.06	0.06

Sheet 3: Payback period results

Sheet 3 presents payback period results. “Payback (months)” (row 27) expresses the number of months it would take the smallholder farmer to recover the cost of the equipment. For agro-processing activities, the user can select whether the equipment is powered by a mini-grid or by the grid (row 30). Selecting the grid as a power source would typically lead to a more profitable scenario due to its lower tariffs compared to those of mini-grids. A scenario where the main grid powers agro-processing equipment is however unlikely in rural areas, as they are typically not within reach of the grid. As this report explained, standalone solar agro-processing is still nascent, so selection of “standalone” as an electricity source for agro-processing activities will lead to an error message. In the case of irrigation, only “standalone” is regarded by the model as a valid input, due to this being the preferable power source for irrigation (see section 1.1 for an explanation).

There is one level of nuance to irrigation in this sheet that is not applicable to non-irrigation activities. In row 32, the user is asked to select an irrigation scenario. Users are presented with four options as follows:

1. **No:** No second season irrigation. Thus only irrigation during rainy season
2. **Mono-cultivation:** Two seasons of staple crop cultivation enabled by year-round access to irrigation.
3. **Crop rotation:** Again year-round irrigation, but diversifying through one season with staple crop and the other with horticulture (tomato used as test case)
4. **Year-round horticulture**: Again year-round irrigation, but no cultivation of staple crops, only horticulture (year-round horticulture only selectable in horticulture columns - P, AB, AQ & BE).

As would be expected, the most lucrative scenario for the smallholder farmer is year-round horticulture as these crops fetch the highest price and in turn the payback period reduces, while the NPV and IRR increases. The most realistic scenario, however, is the crop rotation scenario, where the smallholder farmer grows a staple crop for one season in the year and a cash crop such as tomatoes in the second season in the same year. It is uncommon for smallholder farmers to not grow any staple crops at all, which is why the crop rotation scenario is the preferable scenario.

Sheet 4: IRR results

Sheet 4 runs in parallel to sheet 3 and serves as an output sheet. The sheet calculates the NPV and IRR from the initial capital outlay and the subsequent income year-on-year for 10 years. If the NPV is positive, the investment is regarded as profitable.

	Nigeria								
	Maize				Cassava				
	Irrigation	Drying	Shelling	Milling	Irrigation	Peeling	Grating	Milling	Chipping
Year 0	-$2361	-$1566	-$2420	-$3000	-$2361	-$3250	-$2000	-$285	-$2000
Year 1	$1648	$678	$745	$3671	-$974	$1932	$1455	$389	$917
Year 2	$1648	$678	$745	$3671	-$974	$1932	$1455	$389	$917
Year 3	$1648	$678	$745	$3671	-$974	$1932	$1455	$389	$917
Year 4	$1648	$678	$745	$3671	-$974	$1932	$1455	$389	$917
Year 5	$1648	$678	$745	$3671	-$974	$1932	$1455	$389	$917
Year 6	$1648	$678	$745	$3671	-$974	$1932	$1455	$389	$917
Year 7	$1648	$678	$745	$3671	-$974	$1932	$1455	$389	$917
Year 8	$1648	$678	$745	$3671	-$974	$1932	$1455	$389	$917
Year 9	$1648	$678	$745	$3671	-$974	$1932	$1455	$389	$917
Year 10	$1648	$678	$745	$3671	-$974	$1932	$1455	$389	$917
NPV	$7764.61	$2597.37	$2158.75	$19556.15	-$8344.95	$8620.07	$6940.05	$2107.33	$3633.75
IRR	69%	42%	28%	122%	#NUM!	59%	72%	137%	45%
Conclusion	Profitable	Profitable	Profitable	Profitable	Loss-making	Profitable	Profitable	Profitable	Profitable

Sheets 5-8: Irrigation inputs for each country

These sheets are dedicated to inputs pertaining to irrigation. The first table on the sheet is for information only, where users can insert data pertaining to technical specifications and other details about the solar water pump being modelled (see figure below).

Water pumping requirements (information only):				
Input category	**Unit**		**Source**	**Notes**
Required flow rate (maize)	m3/hour	5	USAID Solar irrigation report	
Required flow rate (Cassava)	m3/hour	5	USAID Solar irrigation report	
Required flow rate (Rice)	m3/hour	19	USAID Solar irrigation report	
Brand and model name of selected pump	Bennie Agro Surface water pump			
Power rating of selected pump	kW	0.36		
Max flow rate of selected pump	m3/hour	40		
Total head	m	15	https://upcommc	

The next section automatically calculates yield increases in staple crops as a result of irrigation, drawing on user inputs pertaining to how many months in the year the farmer uses the pump in the mono-cultivation and crop rotation scenarios respectively, whether there is only one season or two seasons in the year during which irrigation is carried out, estimated differences between rainfed yield and irrigated yield, and so forth.

Calculation of **yield** increases in **staple** crops as a result of irrigation (serves as an input for revenue calculations below):			
	Maize	**Cassava**	**Rice**
Utilization of irrigation (h/day)	6	6	6
		User to input:	
Utilization of irrigation - mono-cropping (month/year)	7	12	4
Utilization of irrigation - crop rotation (month/year)	6	12	5
Seasons rainfed (per year)	1	1	1
Seasons irrigated (per year)	2	1	2
AVG yield - rainfed (kg/ha)	1704	5541	2300
Rainfed yield (tonnes per hectare)	5.2	14	2.3
Irrigated yield (tonnes per hectare)	6	22	5
Factors used to calculate irrigation yield from rainfed yield	1.1538	1.5714	2.1739
		Auto-calculation:	
AVG yield - irrigated (kg/ha)	**1966**	**8707**	**5000**

The sheet then displays auto-calculations towards generating outputs for the marginal annual revenue that the smallholder farmer will experience as a result of irrigation in each irrigation scenario: No second season, mono-cultivation, crop rotation and year-round irrigated horticulture. Users are only required to insert the average yield and price of irrigated crop in the horticulture scenario, seeing that data for these indicators in the other three scenarios are already inserted one step earlier.

Auto-calculation: Increased revenues as a result of irrigation Scenarios 1 and 2: Mono-cultivation (1 season & 2 seasons, with staple crop)					
	Maize	**Cassava**	**Rice**		
Price rainfed	$0.40	$0.05	$0.29		
Price irrigation	$0.52	$0.07	$0.38	USD/kg	
Annual revenue rainfed only (without irrigation)	$682	$277	$671		
Annual revenue with irrigation for same crop (mono-c)	$2045	$566	$3790	USD/year	
Marginal annual revenue in mono-cultivation scenario, 1 season	**$341**	**$289**	**$1225**		
Marginal annual revenue in mono-cultivation scenario, 2 seasons	**$1363**	**$289**	**$3120**		
Auto-calculation: Increased revenues as a result of irrigation Scenario 3: Crop rotation (Dry season horticulture & second season staple)					
	Maize	**Cassava**	**Rice**	**Tomato**	
AVG yield - irrigated horticulture				8750	kg/ha
Price irrigation horticulture				$0.24	USD/kg
Annual revenue irrigation (1 season horticulture, 1 season staple)	$3122	$566	$3995		USD/year
Marginal annual revenue in crop rotation scenario	**$2441**	**$289**	**$3325**		
Calculation: Increased revenues as a result of irrigation (user inputs needed) Scenario 4: Year-round irrigated horticulture					
	Tomato				
AVG yield - irrigated horticulture	8750	<--User to input	kg/ha		
Price irrigation horticulture	$0.24	<--User to input	USD/kg		
Annual revenue irrigation	$4200		USD/year		
Marginal annual revenue	**$3518**		USD/year		

Annex 2: Case study examples of business models in use

Nigeria

Solarworx's systems are sold in Nigeria and Zambia and are PAYGO enabled. It gives distributors the flexibility to offer the Solego water kit on a consumer loan.[296] Users can easily pay their instalments via mobile money. Therefore, all systems can be seamlessly integrated into all the common last-mile management platforms. Tokens can be sent to the customers' mobile phones or directly to the systems with GPRS.[297]

Besides their traditional lease-to-own model, **Koolboks** also offers an innovative cooling-as-a-service (CaaS) model. The main target groups of the CaaS model include small businesses and health centres. The refrigerators range in capacity between 158 and 540 litres and can last without a supply of power for up to three days. Depending on the size of the system, they are powered by up to two 150-watt solar panels.[298]

Ownership of the system stays with the service provider. The service provider also remains responsible for installing, operating, and maintaining the appliance. The service provider pays for the electricity used by the appliance. Customers only pay for the amount of chilled or refrigerated air or cooling capacity actually used. Depending on the contractual model, they can purchase cooling services on the basis of periodic quarterly, monthly, weekly, or even daily payments. Fees can be as low as USD 10 per month for the 158-litre fridges.

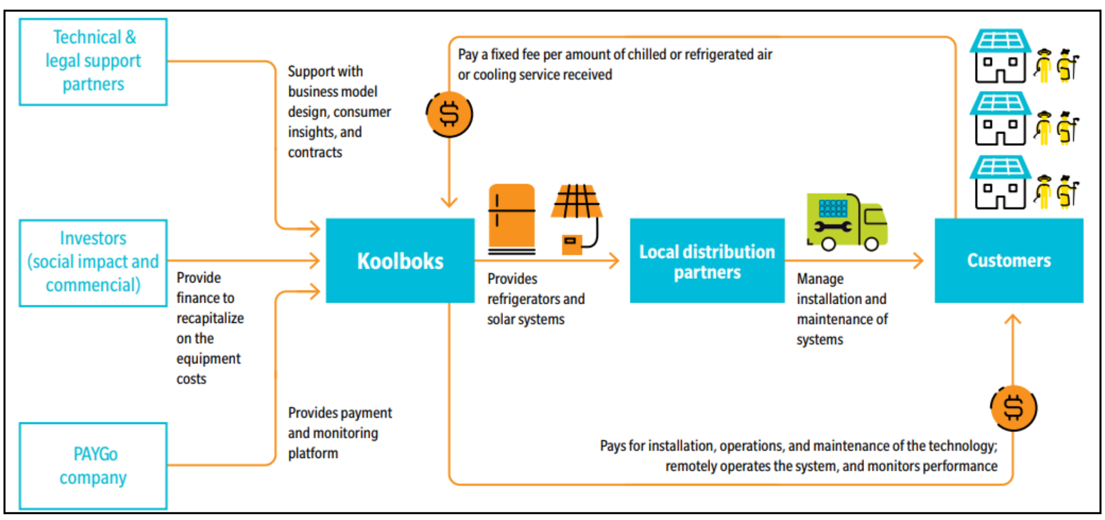

Figure 13: Koolboks business model

ColdHubs in Nigeria operates solar-powered cool rooms where retailers can rent space to store their produce near markets. This allows retailers to extend the freshness of their goods from around 2 days to 21 days, with a post-harvest loss-reduction of 80%.[299]

Rubitec Solar (mini-grid developer) and **MAX** (e-mobility company) piloted a mobility-as-a-service model in an existing mini-grid site in Nigeria. MAX offered daily E2W leases to trained local drivers.[300] The pilot offered charging via a battery swap model, and the fleet's battery-to-vehicle ratio was 1.5. MAX staff members based in Gbamu Gbamu (mini-grid community) were on call if drivers experienced issues, and routine maintenance was performed on-site. All vehicle charging was conducted at a centralised charging depot powered by Rubitec's solar-hybrid mini-grid which rented the charging depot building and charging infrastructure to MAX for $40.00 (15,000 naira) per month. Rubitec created a special $0.34/kWh (130 Naira/kWh) tariff for EV charging, which is a discount over the tariff of $0.46/kWh (175 Naira/kWh) offered to most other mini-grid customers.[301]

[296] Solego water kit includes 2 x 50W solar PV panels, battery, 4 lamps and a submersible water pump
[297] Solarworx, Solego Water Kit, 2023 (link)
[298] Efficiency for Access Coalition, Business Model Innovations Addressing Affordability, Case Studies, 2021 (link)
[299] GET.transform, Energy for Rural Industrialisation Productive Use of Energy 2.0, 2022 (link)
[300] RMI, Powering Small-Format Electric Vehicles with Minigrids, 2022 (link)
[301] RMI, Powering Small-Format Electric Vehicles with Minigrids, 2022 (link)

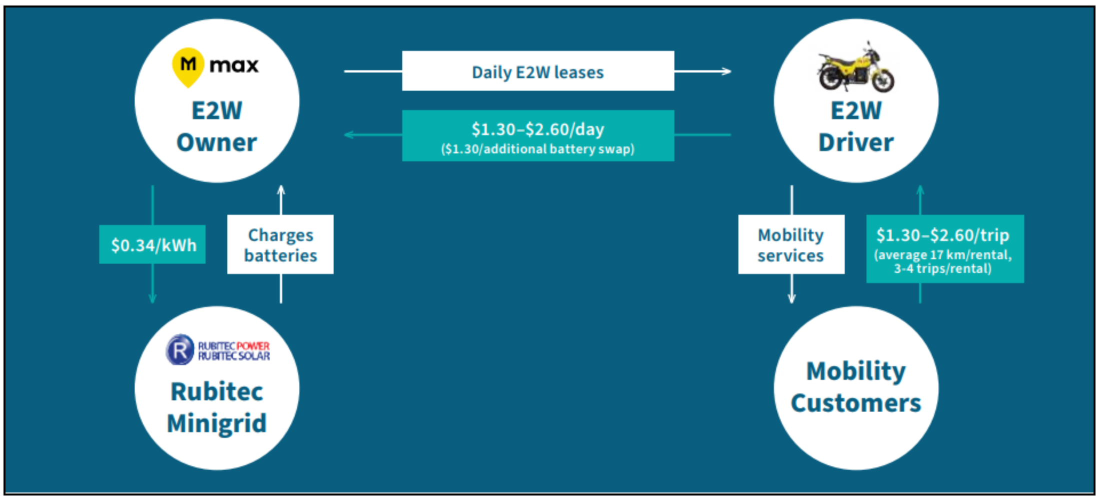

Figure 13: Rubitec Solar and MAX mobility-as-a-service business model[302]

Sosai Renewable Energies in Nigeria has set up a 'drying for sale' model with the INNOTECH solar dryer product. Eight hubs with 22 dryers have been set up, managed by 80 women. The company owns the solar dryers perpetually and the women who manage the dryers pay a flat fee per month. They do packaging as well as drying, which is more lucrative, and means they generate revenue outside of season. Furthermore, they started producing products of their own, like carrot and sweet potato flour. Sosai also focuses on finding ways to get the dried products to the market to ensure revenues for the women working in the drying hubs.[303]

Husk Power Systems is a mini-grid developer operating in Nigeria and Tanzania. The model used by Husk is similar to the Keymaker model. Husk sources rice husks and maize cobs (by-products of crop processing) from local millers to fuel the generators within their solar-biomass-hybrid power plants.[304] While solar photovoltaic (PV) powers daytime loads, biomass-fueled generators run during the microgrids' evening hours of peak demand. As a result, battery expenditures can be reduced because there is less need to store solar power to supply evening loads. With this technology, Husk Power found an efficient way to reduce their capital and operating expenses while also enabling farmers and millers to collect more value from their crops.[305] This also demonstrates the virtuous circle that clean energy microgrids and agriculture can create: while Husk Power purchases feedstock from millers, the millers purchase electricity from Husk Power.

Rwanda

Ignite Power is a clean energy product distributor (SHS, clean cooking, home appliances, solar water pumps). The distributed solar surface water pumps are supplied by Ennos AG. Because farmers make their money mainly during the harvesting season and not throughout the entire year, Ignite Power devised a specific payment model called pay-as-you-grow, allowing them to pay only during harvesting. This made the systems affordable for many.[306]

CropTech Ltd is an agri-tech company that provides modern on-farm harvest handling services to maize, beans, and soybeans growers in Rwanda and aids them in accessing the higher market through the provision of transport and logistic services. The company has developed a comprehensive on-farm harvest handling service through which they take biowaste or solar-powered dryers at the farmers' location and dry the crop harvest in a period of three hours instead of three weeks, and support the farmer to sell that to the high-end market.[307]

Ox Delivers is a Rwandan-based company that operates electric trucks and rather than selling the vehicles themselves, OX Delivers sells space on its trucks to market traders and anyone else looking to transport goods from one place to another.[308] In Rwanda, 8 in 10 people own a mobile phone. To take advantage of the widely available but varied use of mobiles, OX and Endava have devised a world-leading transport system app that is compatible with both 2G phones and smartphones meaning a customer will be able to request an OX service such as transport or distribution of goods to and from a location.

[302] RMI, Powering Small-Format Electric Vehicles with Minigrids, 2022 (link)
[303] Global Distributors Collective, Selling productive use of energy products to last mile-consumers, Lessons Learned, 2022 (link)
[304] USAID, Powering Agriculture, Technology Case Study, Micro-Grids and Productive Agricultural Uses, 2023 (link)
[305] USAID, Powering Agriculture, Technology Case Study, Micro-Grids and Productive Agricultural Uses, 2023 (link)
[306] Ignite, Redefining Infrastructure Through Life-Enabling Technologies, 2023 (link)
[307] Croptech, About us, 2023 (link)
[308] Endava, Ox Re-imagines Africa's Transport Ecosystem Using Innovative PAYG Solution with Endava, 2023 (link)

Zambia

Vitalite is one of Zambia's largest solar products distributors, and although their main portfolio products are SHS, Vitalite also distributes surface solar water pumps such as Futurepump.[309] Vitalite piloted the implementation of a PAYG model for their water pumps but internal operational challenges limited its scalability. The company is currently updating the platform and remote monitoring systems to incorporate back the PAYG modality, since it is their customers preferred payment option.[310]

Zimbabwe

Natfort Energy has been using a 'pay as you grow' model to lower their portfolio at risk ratio, since the seasonality of farmer incomes was affecting the default rates.[311] Their agents were reporting that while some customers didn't have cash, they had produce or livestock they were willing to barter. The company accepts these products, as they can easily find markets for them. A fair price is agreed upon with the customer and a contract is signed, so it's formalised.[312]

Powerlive wanted to incorporate seasonal payments to mitigate unsteady customer incomes but couldn't make this model work. Instead, they just lengthened payment periods and reduced the size of instalments. Some PUE products cost as little as US$10 a month, and most cost $50-60 a month, sold over ten to 12 months. They have also implemented instalments via cooperatives, where people can vouch for each other.[313]

Other examples outside of target countries

Bboxx is one of the leading solar product distributors in Africa and in partnership with SunCulture, they offer a standard solar water pump under their PAYG modality.[314] So far Bboxx has piloted the distribution of solar water pumps in Togo, but the portfolio may grow to other countries with the recent acquisition of PEG Africa (leading West Africa solar water pump distributor).[315]

Sunny Irrigation is a Kenyan start-up that offers solar water irrigation solutions to farmers. The pumps are available to farmers on a pay-as-you-go basis, renting the product before acquiring it after eighteen months of regular payments.[316] Once the payments are made, the pump is owned by the farmer. In addition to the equipment, Sunny Irrigation's offer includes an application, developed in association with agro-industrial partners, giving farmers advice on how to optimise irrigation based on crop and weather data to help them improve their crop yields.

Simusolar is a distributor offering solar lights for fishers and solar water pumps for farmers in Uganda and Tanzania. Their Pay-As-You-Go and lease-to-own system enables and assures that customers make their equipment payments by phone during the loan period. Reasonable payback terms are offered based on the increase in consumer incomes.[317]

Aptech is a Ugandan solar water pump distributor (among other products and services) that offers a Pay-n-Pump option. This model uses smart technology to offer pay-as-you-go water services to small-scale farmers.[318] Solar water pumps are delivered and installed at no cost to the farmer, and farmers use mobile money to make easy payments to activate their pumping system whenever needed. Farmers typically pay fixed monthly fees to have water available for irrigation but never own the system.

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[309] Vitalite, Quality made affordable, 2023 (link)
[310] Source: Authors' interview
[311] Natfort Energy, Modern, Affordable & Sustainable Solutions, 2023 (link)
[312] Global Distributors Collective, Selling productive use of energy products to last mile-consumers, Lessons Learned, 2022 (link)
[313] Powerlive, who are we, 2023 (link)
[314] Bboxx, Standard Water Pumps, 2023 (link)
[315] African Energy, Togo Solar Pump Partnership, 2021 (link)
[316] Sunny Irrigation, solar power irrigation for east africa, 2023 (link)
[317] Simusolar, Building the foundation of the rural economy, 2023 (link)
[318] Aptech, Pay-n-Pump, 2023 (link)

Annex 3: Solar water pump and agro-processing equipment prices

Agro-processing equipment

Country	Company	Model	Upfront costs (USD)	Throughput (kg/hour)	Max power rating
Nigeria	**Niji Lukas**[319]	Lukas Cassava Stainless Grater	$4,820	3-4 tons/hour	3 phase 5hp (electrical)
		Hydraulic Press (cassava)	$12,500	500 kg/batch in 30 mins	***Data is unavailable**
		Lukas Pulverizer (cassava)	$4,820	3-4 tons/hour	3 phase 5hp (electrical)
		Screw Feeder (cassava)	$4,820	***Data is unavailable**	***Data is unavailable**
		Stainless Hammer Mill (cassava)	$15,665	5 tons dried material per day	15hp 3-phase
Rwanda	**Agsol**[320]	Agsol Solar Rice Mill System	$4,850	20 kg/hr 50 kg 2.5hr/day	***Data is unavailable**
		Rice husker (PV, battery & cabling included)	$2,960	45 kg/r	***Data is unavailable**
		Rice polisher (PV, battery & cabling included)	$2,760	35 kg/hr	***Data is unavailable**
		MicroMill	KSh145,000 ($1,092.04)[321]	45-75 kg/hr	1000W
General SSA	**Solar Milling**	Zebra mill[322]	***Data is unavailable**	50 - 200 kg/hour	2 200 W
Zambia	***Data is unavailable**				

[319] Stakeholder outreach
[320] FAO, Costs and Benefits of Clean Energy Technologies in the Milk, Vegetable and Rice Value Chains, 2018 (link)
[321] Facebook, Agsol, 2022 (link)
[322] Solar milling, New Zebra Mill, 2023 (link)

Zimbabwe	***Data is unavailable**

Solar Water Pumps

REGION	COMPANY	Model	UPFRONT COSTS (local Currency)	UPFRONT COSTS (USD)	Max flow rate (l/hour)	Max power rating of machine, unless otherwise stated	Suitable land size
Sub-Saharan Africa	**World Bank Data**[323]	General industry cost parameters	N/A	$107-$1559		0-999W	
			N/A	$120-$2427		1000-1999W	
			N/A	$403-$2713		2000W	
Nigeria	**Exulted Eagles**[324,325]	Exulted SP-1300 2HP-3HP Solar water pump (Submersible) Full system	₦730,000	$1,585.21	5,000l/hour	400W - 800W	
		Exulted SP-600 1HP-1.5HP(Submersible) Full system	₦590,000	$1,281.25	3,000l/hour	400W - 800W	
		Exulted SP-2HP – 3HP (Surface) Full system	₦700,000	$1,520.13	2,700 l/hour	1200W	
		Exulted SP-600 1HP-1.5HP(Surface) Full system	₦620,000	$1,346.38	3,000 l/hour	600W	
		Exulted SP-1300 2HP-3HP Solar water pump (Submersible) Full system	₦730,000	$1,585.21	5,000 l/hour	400W - 800W	
	Solar Depot[326,327]	Feili Solar water pump 3FLD(Full system)	₦335,400	$728,32	2,700 l/hour	1300W	

323 The World Bank, Off-grid Solar Market Trends Report, 2022 (link)
324 Exulted Eagles, Solar Water Pumps, 2023 (link)
325 Exulted Eagles, Solar Water Pumps: Exulted SP-2HP – 3HP Surface Solar water pump, 2023 (link)
326 Solar Depot, Feili Pump Co Ltd, 2023 (link)
327 Solar Depot, Feili Pump Co Ltd, 2023 (link)

		Feili Solar water pump (4FLD5-120M-96V-1300W) Full system	₦451,500	$980,46	5,000 l/hour	1300W	
		Feili Solar water pump (4FLD5-72M-72V-1100W) Full system	₦399,900	$868,39	5,000 l/hour	1100W	
		Feili Solar water pump (4FLD3.4-80M-48V-750W) Full system	₦380,550	$826,38	3,400 l/hour	750W	
		Feili Solar water pump (4FLD7-95M-96V-1300W) Full System	₦425,700	$924,37	7,000 l/hour	1300W	
Rwanda	**Futurepump**	SE1[328]	RWF 554,931	$504	1,800 l/hour	60W	One acre
		SF2[329]	RWF 701,922	$637,50	3,600 l/hour	120W	Two acres
	Davis & Shirtliff[330]	Sunflo-A 270H (solar pump system)	KSh 100,800	$765,31	125 l/hour at 50m	270W	
		Sunflo-A 600H (solar pump system)	KSh 142,200	$1,039.52	166,6 l/hour at	600W	70m
		Sunflo-B 500C (solar pump system)	KSh 181,800	$1,380.68	250 l/hour at 40m	500W	
		Sunflo-B 1000C (solar pump system)	KSh 273,600	$2,077.74	500 l/hour at 70m	1000W	
Zambia	**Vitalite (Futurepump distributor)**[331]	SE1	ZMW 10,900	$540	1,800 l/hour	60W	One acre
		SF2	ZMW 14,900	$738	3,600 l/hour	120W	Two acres

328 Futurepump, SE1 solar pump for one acre, 2023 (link)
329 Futurepump, SF2 solar pump for two acres, 2023 (link)
330 Stakeholder outreach
331 Stakeholder outreach

	SunCulture	Rainmaker 2 w/battery	KES 109,999	$850 (Kenyan price)	2,500 l/hour	150 W	Two acres
		Rainmaker 2C Kubwa	KES 92,999	$720 (Kenyan price)	2,500 l/hour	150 W	Two acres
		Climatesmart Direct	KES 94,999	$500 (Kenyan price)	1,000 l/hour	310W	One acre
	Solarmacs Energy[332]	Solar submersible	ZMW 24,840	$1230	3,100 l/hour	500W	
		Solar submersible	ZMW 31,040	$1540	6,500 l/hour	1500W	
		Solar submersible	ZMW 32,040	$1590	5,800 l/hour	1100W	
		Solar submersible	ZMW 27,040	$1340	3,800 l/hour	750W	
		Smaller unit	ZMW 21,680	$1074	1,800 l/hour	370W	
Zimbabwe	**Davis & Shirtliff**[333]	Sunflo - S 300 (Positive Displacement Pump)	$221	$221	3,000 (per day)	300W	
		Sunflo - 600H Helical	$307	$307	4,000 (per day)	600W	
		Sunflo B 500C Centrifugal	$559	$559	6,000 (per day)	500W	
		Sunflo B 1000C Centrifugal	$624	$624	12,000 (per day)	1000W	
		Sunflo X 1200H Helical	$1,179	$1,179	6000 (per day)	1200W	
		Sunflex 750 C3 Centrifugal	$1,331.97	$1,331.97	10,000 (per day)	750W	
		Sunflex 1100C3 Centrifugal	$1,497.81	$1,497.81	9,000 (per day)	1100W	
	Celfre Energy (Futurepump distributor)[334]	SE1	$550	$550	1,800 l/hour	60W	One Acre

[332] Solarmacs Energy, Get finance for office or home power system and solar water pumping system, 2023 (link)
[333] Stakeholder outreach

		SF2	$750	$750	3,600 l/hour	120W	Two Acres
	Shinko Afrika[335]	SunMax 0.3hp solar pumpset	$660	$660	1,300 l/hour	221W power draw 2 x 330W ideal power supply	
		SunMax 0.5hp solar pumpset	$690	$690	4,000 l/hour	368W power draw 2 x 330W ideal power supply	
		SunMax 0.75hp (54m head) solar pumpset	$640	$640	4,000 l/hour	552W power draw 2 x 330W ideal power supply	
		SunMax 0.75hp (120m head) solar pumpset	$810	$810	2,100 l/hour	552W power draw 2 x 330W ideal power supply	
		SunMax 1hp (80m head) solar pumpset	$940	$940	4,000 l/hour	735W power draw 4 x 330W ideal power supply	
		SunMax 1hp (95m head) solar pumpset	$1,020	$1,020	4,000 l/hour	735W power draw 4 x 330W ideal power supply	
		SunMax 1hp (120m head) solar pumpset	$1,230	$1,230	4,500 l/hour	735W power draw 6 x 330W ideal power supply	
		SunMax 1hp (150m head) solar pumpset	$1,020	$1,020	2,000 l/hour	735W power draw 4 x 330W ideal power supply	

[334] Stakeholder outreach
[335] Shinko Africa, Solar and Hybrid Pumpsets, Zimbabwe, 2023 (link)