Zambia
Mini-Grids Powered by Renewables: Investment Brief

Climate Adaptation Market Opportunities
Infrastructure, Energy and Manufacturing

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GLOBAL CENTER ON ADAPTATION

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GLOBAL CENTER ON ADAPTATION

ABOUT THE GLOBAL CENTER ON ADAPTATION

The Global Center on Adaptation (GCA) is an international organisation, hosted by the Netherlands, which works as a solutions broker to accelerate action and support for adaptation solutions from the international to the local, in partnership with the public and private sector, to ensure we learn from each other and work together for a climate resilient future.

ABOUT AFRICA ADAPTATION ACCELERATION PROGRAM

GCA is providing technical assistance under the Africa Adaptation Acceleration Program (AAAP), a joint initiative launched by the GCA and the African Development Bank in 2021.

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CONTEXT

This investment brief is part of a regional analysis undertaken by the Global Center on Adaptation, developed in close coordination with partners including CGAP and GCA's downstream financial institution partners under the Africa Adaptation Acceleration Program, in collaboration with the consulting firm Pegasys. The analysis identifies and operationalizes climate adaptation investment opportunities in infrastructure, energy, and manufacturing across Tanzania, Kenya, Zambia, and the Democratic Republic of Congo. Building on these results, the present brief aims to provide a decision-support resource for commercial banks, microfinance institutions, and other lenders seeking to assess and integrate climate-related risks and opportunities within their infrastructure, energy, and manufacturing portfolios.

Across energy, manufacturing and infrastructure, climate variability is increasingly translating into material credit risk. Erratic rainfall, rising temperatures, flooding, and more frequent extreme events disrupt energy generation and distribution, impair manufacturing operations, and reduce the reliability and service life of physical infrastructure. These impacts weaken borrower revenues and asset values, with direct implications for both clients and lenders, including deteriorating portfolio performance, elevated non-performing loan ratios, and increased volatility in infrastructure and corporate lending

The analytical framework underpinning this investment brief series reframes climate adaptation as a risk-adjusted investment opportunity. It identifies discrete, technology-driven interventions across value chains and assesses their bankability through market sizing, borrower segmentation, and business model analysis. Each brief is structured to align with financial sector requirements, including compatibility with existing lending instruments (e.g. asset finance, value chain finance) and applicability across borrower archetypes such as utilities, project developers, construction firms, and industrial SMEs.

The investment brief series, focused on Climate Adaptation Market Opportunities in Energy, Manufacturing and Infrastructure, aims to support financial institutions in systematically integrating adaptation into core lending operations, with a view to strengthening client and portfolio resilience while capturing emerging market opportunities.

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Executive Summary

Zambia's power system is structurally vulnerable to climate change. More than 80% of national electricity generation comes from hydropower, making the power grid acutely sensitive to rainfall. The 2024 drought — the worst in decades — pushed the country into a power deficit, with load shedding reaching more than 20 hours per day. Projections indicate these shocks will intensify: longer dry spells, reduced river inflows, and erratic rainfall will make recurrent disruption a structural feature of Zambia's power system.

For banks, this is a credit-quality and portfolio-risk issue. When supply fails, firms in agro-processing, cold chain and light manufacturing lose output, burn diesel, and see cashflows threatened. World Bank enterprise surveys show Zambian firms lose close to 10% of annual sales on average due to power outages. The 2024 drought drove a ~20% contraction in agriculture and a 9.6% fall in electricity output in the first half of the year alone. Where that borrower stress concentrates across energy-dependent portfolios — particularly in Zambia's manufacturing, agro-processing, and trade corridors — it creates the conditions for correlated non-performing loans, not simply isolated arrears.

Mini-grids powered by renewables — site-based systems typically combining photovoltaic generation, battery storage, and a shared local distribution network serving multiple users — directly help address Zambia's three binding power constraints: the access gap in rural and peri-urban areas, structural over-reliance on drought-exposed hydropower, and the absence of reliable electricity for productive use.

Mini-grids create value through two adaptation pathways:

- Access pathway: In off-grid and underserved areas, mini-grids build adaptive capacity — enabling water pumping, milling, cold storage, irrigation, and digital services where reliable electricity is otherwise absent. Operating examples in Eastern, Luapula, Northern, and Western Provinces already show that multi-user solar systems support households, small enterprises, clinics, and schools simultaneously, reducing dependence on diesel and biomass and displacing carbon at measurable scale.
- Reliability pathway: In grid-adjacent productive areas, mini-grids reduce sensitivity to climate-driven power disruption — providing locally controlled power that keeps manufacturers, agro-processors, cold chains, and SME clusters operating during load shedding. Every kWh delivered from solar displaces diesel generation: at prevailing Zambian pump prices, that translates to avoided fuel costs of around ZMW 5–7 per kWh before maintenance, as well as measurable CO_2 avoidance.

Mini-grids can clearly be considered as a climate adaptation investment in Zambia but deliver other tangible developmental benefits. Reliable electricity unlocks productive uses — milling, cold storage, irrigation, small-scale processing — that raise household incomes and reduce post-harvest losses in agricultural communities. Studies by CrossBoundary and the Africa Minigrid Developers Association show appliance financing linked to mini-grids increases average consumption by 48%; 60 Decibels finds 89% of mini-grid customers report improved quality of life, driven primarily by gains in business productivity. For women specifically, GOGLA's metrics document measurable shifts in time use and expanding pathways into enterprise ownership and employment, making gender outcomes from mini-grids traceable.

The Market Opportunity for Banks

Zambia's mini-grid market presents a commercially meaningful and growing opportunity for banks — one that sits at the intersection of climate resilience, productive infrastructure, and an underserved financing gap.

The immediate entry point is through existing client relationships. Banks already carry credit exposure to load shedding through the cashflows of agro-processors, cold chain operators, light manufacturers, and SME estates. Where power disruptions are driving arrears, covenant stress, or repeated restructures, a mini-grid is not an abstract climate investment — it is a direct intervention in the credit quality of an existing borrower. The strategic question is therefore not whether to engage with the sector, but which clients represent anchor demand strong enough to underpin a viable project.

Two distinct commercial logics shape the opportunity. In reliability-driven projects — serving edge-of-grid industrial sites, agri-processing hubs, and mining-adjacent facilities — revenues are anchored in existing productive activity and the investment case rests on verifiable avoided cost and business continuity rather than speculative demand growth. Underwriting shifts from demand projection toward counterparty risk, contract enforceability, and anchor credit quality. In access-driven projects — primarily rural community and social infrastructure clusters — revenues build as demand matures, requiring blended capital in early years before portfolio aggregation opens pathways to structured debt.

Market sizing using a transparent, bottom-up, site-based methodology shows the investable opportunity for mini-grids powered by renewables in Zambia clearly. **The Total Addressable Market (TAM) encompasses approximately 1,440 potential sites, around 150 MW of capacity, and an indicative USD 800 million in capital requirements**. This represents the full universe of locations where mini-grids could viably serve off-grid or reliability-constrained demand. **The Serviceable Addressable Market (SAM) narrows this to around 290 sites and USD 200 million of investment, reflecting current conditions on demand readiness, site definition, and investability.** Within that, the **Serviceable Obtainable Market (SOM)** — the share credibly deliverable within the current planning horizon — reaches approximately 180 sites, 29 MW, and USD 130–150 million by 2030, rising from around 65 sites and USD 40–50 million today.

Market Tier	Sites · Capacity · Capital
Total Addressable Market (TAM)	~1,440 sites · ~150 MW · ~USD 800m — the full universe of viable locations.
Serviceable Addressable Market (SAM)	~290 sites · ~40 MW · ~USD 200m — structurally investable under current conditions.
Serviceable Obtainable Market (SOM)	~180 sites · ~29 MW · USD 130–150m — delivery-constrained, not demand-constrained.

Within this market its clear where the current commercial opportunity is. While rural community mini-grids dominate by site count, more than half of aggregate capital is concentrated in industrial and mining-adjacent reliability clusters and rural agri-processing clusters — segments with higher anchor loads, stronger willingness to pay, and clearer revenue visibility. These are the segments most naturally suited to early commercial debt participation, either through portfolio-level senior debt alongside catalytic capital, refinancing of operating assets once track record is established, or selective anchor-led financing where offtake terms are contractually sound.

The Case for Banks to Act

- Defensive: Mini-grids stabilise cashflows for energy-dependent borrowers by eliminating diesel cost volatility and outage-driven revenue loss — directly reducing the probability of default in existing loan portfolios.
- Offensive: USD 130–150m in realizable capital deployment by 2030, concentrated in anchor-led and reliability-driven segments, with portfolio structures enabling efficient bank participation as the market matures.

Why should banks act now?

The logic for commercial bank engagement in Zambia is compelling. The country faces an acute power crisis that is already affecting borrower performance — the question is not whether banks have exposure to energy risk, but whether they act on it proactively or absorb the consequences passively. At the same time, the global and regional financing ecosystem for mini-grids is shifting: costs have fallen, developer platforms are maturing, and blended finance instruments designed specifically to bring commercial banks into the sector are available and active in Zambia.

The window in which banks can enter on favourable terms — with first-mover access to the strongest sites, the best developer relationships, and the most supportive concessional co-investment — will not stay open indefinitely as the market deepens and competition for bankable deals increases.

The policy and institutional environment is also shifting. The National Energy Compact for Zambia explicitly acknowledges the structural inadequacy of the hydro-dependent grid and frames diversification toward distributed renewables as a national priority. The Rural Electrification Authority has moved from individual project coordination toward structured pipeline management, improving site visibility and reducing origination uncertainty for developers. Regulatory reform has raised the licensing exemption threshold to 5 MW, lowering entry barriers and simplifying development processes for the majority of commercial mini-grid sites. National planning documents identify 149 mapped grid and off-grid projects for 2026 alone, signalling that decentralised energy has been formally integrated into Zambia's electrification strategy rather than treated as a peripheral complement to grid extension.

Zambia's mini-grid market is also moving beyond the pilot phase with sites showing that multi-user systems can be delivered, operated, and revenue-collected at scale in Zambia's specific context. Program-backed pipelines are deepening that base: ZEDSI, launched under the Universal Energy Facility platform, has supported 43 mini-grid sites across three developers, and the Facility for Energy Inclusion has committed USD 7.5 million to MySol Grid Zambia for 60 mini-grids serving 40,000+ people. The World Bank projects at least 200 operational solar mini-grids in Zambia by 2030.

Three factors make early engagement strategically important for commercial banks:

- First-mover advantage: banks that develop credit frameworks, developer relationships, and standard documentation now will secure the strongest sites, earliest performance data, and lowest-cost deal structures.
- Regulatory momentum: ERB licensing frameworks, REA-supported pipelines, and international technical assistance are progressively reducing transaction costs and improving bankability across segments.
- Refinancing access: banks that establish operating track records can access DFI refinancing windows at longer tenors and lower cost, rotating capital into new origination and improving overall return profiles.

What is needed is not the development of an entirely new market. It is the integration of climate adaptation logic, structured offtake arrangements, and portfolio financing tools into client relationships that Zambian banks already hold.

Full analysis of Zambia's mini-grid market — covering segment economics, deployment archetypes, business model structures, borrower economics, practical barriers to bank participation, and a three-stage implementation pathway from client identification to portfolio scale — is set out in the sections that follow.

1. The Adaptation Challenge

Climate change is undermining Zambia's energy security

Climate change is increasingly undermining the **reliability and resilience of Zambia's electricity system**, with growing consequences for economic activity and financial stability. Zambia's power sector remains heavily exposed to hydrological risk: **more than 80% of total power generation is hydro-based**, and recent World Bank diagnostics describe the current drought-driven power deficit as being caused by **low reservoir levels in critical hydropower reservoirs** (National Energy Compact for Zambia, 2022).

This exposure is structural rather than incidental. Zambia's electricity system depends heavily on **rainfall, reservoir storage, and river inflows** in the **Zambezi and Kafue basins**, so drought translates directly into power-system stress. Recent World Bank and IEA materials both note that shorter rainy seasons, more frequent droughts, and hydrological variability are already affecting Zambia's power reliability (IEA, 2025).

The **2024 drought** was widely described as the worst in decades, and multiple World Bank documents note that it pushed the country into a power deficit of **more than 1,000 MW**, with **load shedding exceeding 20 hours per day** in 2024. That follows earlier drought-related power stress in **2015–2016**, when Zambia and Zimbabwe were forced to resort to expensive short-term replacement power after hydropower output fell (World Bank, 2025).

The economic significance of this is amplified by where productive activity is located. Zambia's firms, jobs, and value-adding activity are concentrated in the **central corridor running from the Copperbelt through Lusaka toward Livingstone**, with a second important sub-region around **Chipata/Eastern Province**. World Bank jobs and value-chain work also highlights **agribusiness and agro-processing** as important employment and growth pathways in these geographies. When drought reduces hydropower output, the resulting electricity shortages do not stay within the power sector. They spill quickly into the parts of the economy where manufacturing, agro-processing, logistics, and trade are most concentrated (World Bank, 2025).

Climate projections suggest these pressures are likely to intensify. IPCC and related climate assessments for Africa point to **continued warming by mid-century**, alongside greater evapotranspiration, longer dry spells, and more erratic rainfall in many parts of the region. For Zambia, that implies a power system facing **recurrent climate-driven reliability shocks**, rather than isolated crisis events, unless diversification away from hydrologically exposed generation accelerates (IPCC, 2019).

In that sense, climate change is no longer only an environmental issue for Zambia's power sector. It is becoming a **systemic economic and financial risk**. Climate-driven variability in hydropower generation feeds directly into electricity disruptions, and those disruptions are transmitted into firm performance, operating costs, and the stability of financial portfolios exposed to energy-dependent sectors.

Power unreliability is becoming a business and banking risk

Electricity reliability is a critical input for Zambia's productive economy. When supply becomes intermittent, the first effects are operational: stopped production lines, reduced throughput, spoiled inventory in cold chains, equipment stress from voltage fluctuations, and rising reliance on diesel generation. Over time, these operational disruptions become financial ones. Output falls, orders are delayed, operating costs rise, and cash flows become less predictable. This is particularly damaging for **agro-processors, cold-chain operators, light manufacturers, and other electricity-dependent SMEs**, which often lack the balance sheet strength to invest in robust backup systems or absorb prolonged outages.

The scale of this exposure is well documented. World Bank enterprise-survey evidence shows that firms in Zambia lose **close to 10% of annual sales on average due to power outages**, underscoring how deeply unreliable electricity affects operating performance (World Bank, 2024). During the 2024 drought, the macroeconomic effects became even more visible: IMF reporting notes that in the first half of 2024,

agriculture contracted by 20.6% year-on-year and electricity output by 9.6%, reflecting the economy-wide consequences of drought and power shortages (IMF, 2024).

For firms, these impacts are not just episodic disruptions. They affect working capital cycles, inventory management, delivery reliability, and the ability to meet customer commitments. For sectors dependent on refrigeration, mechanized processing, pumping, or continuous production, even short interruptions can cascade into margin compression and lost revenue. Where outages are prolonged and unpredictable, firms are also pushed toward diesel backup, which raises operating costs and adds further volatility.

For lenders, this matters because physical climate risk is transmitted into the financial system through the borrowers they finance. When power disruptions persist, revenues weaken, receivables lengthen, and debt-servicing capacity deteriorates. The risk is not only at the level of individual firms. In Zambia, drought-driven electricity shortages can hit multiple borrowers in the same value chains and regions at the same time, especially where exposure is concentrated in **manufacturing, agro-processing, trade corridors, and urban industrial clusters**. That creates the potential for **correlated portfolio stress**, rather than isolated borrower underperformance. IMF analysis similarly notes that drought-related shocks in Zambia affect critical sectors such as **agriculture, electricity, and mining**, with broader implications for economic and external stability (IMF, 2024).

Therefore, climate-driven power unreliability is no longer just an operating challenge for firms. It is increasingly a **credit-quality and portfolio-risk issue for banks**. Recurrent electricity shortages can weaken asset quality, increase repayment stress across energy-dependent borrowers, and reduce the risk-return attractiveness of lending into productive sectors that are otherwise central to Zambia's growth and jobs outlook.

What climate adaptation requires in the power context

From an adaptation perspective, the challenge is not only to expand electricity access, but to **maintain continuity of operations when climate stress disrupts supply**. In Zambia's case, that means power solutions that can keep critical loads running during prolonged outages, reduce exposure to hydrologically driven supply shocks, and be deployed within realistic timeframes where grid reinforcement and generation diversification remain slow or uncertain. Zambia's current drought-related power deficit and extended load shedding underline why resilience in the power system cannot depend on grid-side solutions alone.

This is where **renewable-powered mini-grids** become relevant as an adaptation response. Mini-grids are not simply redundant infrastructure. They provide a **locally controlled, modular, and more climate-resilient layer of electricity supply** that can be deployed at the point of demand and continue operating when the wider system is under stress. In practice, mini-grids can use different renewable configurations depending on location and load profile, including solar, small hydro, or biomass. In Zambia, however, the most relevant and scalable configuration for this brief is **solar PV paired with battery storage**, given the country's solar resource, the speed of deployment, and the need to reduce dependence on drought-exposed hydropower.

The adaptation value of mini-grids in this brief is best understood through **two complementary pathways**. In off-grid and structurally underserved areas, mini-grids help build **adaptive capacity** by enabling livelihoods, services, and local businesses to function in places where reliable electricity is otherwise absent. In grid-connected or grid-adjacent productive areas, they play a different role: they reduce **sensitivity to climate-driven power disruptions** by providing a reliable local source of electricity that can sustain operations during prolonged outages. Together, these two pathways show how distributed renewable mini-grids can support both **foundational resilience** and **operational continuity** in climate-exposed economic systems.

Two adaptation pathways through which renewable mini-grids create resilience

The adaptation value of renewable mini-grids in Zambia is best understood through two complementary pathways. In some contexts, mini-grids help households, farms, and local enterprises build adaptive capacity by making it possible to adopt more climate-resilient livelihoods and services in places where reliable electricity is otherwise absent. In others, they help firms and institutions reduce sensitivity to climate-driven power disruptions by providing a local source of supply that can keep operations running when the grid is under stress. These are different functions, but both are relevant to Zambia's climate-exposed economy. Mini-grids are increasingly recognized as part of wider rural resilience and productive-use strategies across African markets, particularly where reliable electricity supports irrigation, agro-processing, cooling, and small-enterprise development.

Pathway 1: Building adaptive capacity in off-grid and underserved areas

In off-grid and structurally underserved areas, mini-grids strengthen adaptation by enabling activities that are otherwise constrained by the absence of reliable power. In practical terms, that can mean water pumping, irrigation, milling, cold storage, digital services, and other income-generating activities that help households and local businesses cope better with rainfall variability, heat stress, and market disruption. This is especially relevant in rural Zambia, where many communities remain outside reliable grid coverage and where agriculture remains highly climate-exposed. In these contexts, mini-grids do not protect firms from hydropower-related outages directly; instead, they improve the underlying capacity of communities and local enterprises to respond to climate stress more productively. Evidence from the wider African productive-use market shows that these applications are already commercially meaningful, with irrigation, processing, and cooling among the largest rural energy-use opportunities linked to mini-grid and solar systems.

A useful Zambia anchor is the presence of operating rural mini-grids in agricultural settings, such as Chitandika and other community-scale sites discussed later in the brief. These do not yet amount to a large, mature pipeline of adaptation-labelled projects, but they do show that multi-user electricity systems can support a mix of households, enterprises, and productive users in rural areas where climate resilience depends in part on stronger local energy infrastructure. In this pathway, the adaptation case rests on what reliable electricity enables on the ground: more resilient livelihoods, better local service delivery, and lower dependence on climate-sensitive, low-productivity activities.

Pathway 2: Reducing sensitivity to climate-driven grid disruption in productive areas

In grid-connected or grid-adjacent productive areas, mini-grids serve a different adaptation function. Here, the issue is not first-time access, but unreliable electricity caused by climate-driven system stress. Renewable mini-grids paired with battery storage can reduce that exposure by providing a locally controlled source of power that can continue supplying critical loads during load shedding or poor grid-quality events. This matters most where firms depend on continuous electricity for processing, refrigeration, pumping, or time-sensitive production, and where outages quickly translate into lost output, higher diesel use, and weaker cash flows.

This second pathway is particularly relevant to Zambia's current context of drought-related power shortages. As hydropower variability increasingly drives system-wide disruptions, distributed solar-plus-storage systems can act as a protective layer of resilience at high-impact demand nodes. They are not a substitute for national generation diversification or grid reinforcement, but they can be deployed more quickly and targeted to places where continuity of operations matters most. Regional experience supports this logic. In Nigeria, mini-grid programmes have explicitly linked electrification with agri-processing investments, while mini-grid-linked cooling and productive-use models are already being used to support fishers, traders, and agricultural enterprises in climate-sensitive value chains. In Kenya, distributed solar-powered cooling models are also being used to reduce post-harvest losses and stabilise value chains serving farmers and traders. Together, these examples show that renewable mini-grids are not only an access solution; they are increasingly being used as **productive resilience infrastructure** in sectors exposed to climate and power-system risk.

From an adaptation perspective, the distinction between the two pathways is simple. **Pathway 1** helps off-grid communities and enterprises become more capable of adapting by expanding what reliable electricity makes possible. **Pathway 2** helps already-connected productive users become less vulnerable to climate-driven power disruption by buffering them against unreliable grid supply. Together, they explain why renewable mini-grids matter not only for energy access, but also for **economic resilience, business continuity, and climate adaptation** in Zambia.

2. Market Context, Solution Readiness and Track Record

What are mini-grids (working definition and technical characteristics)

For the purposes of this Investment Brief, mini-grids are defined as site-based electricity systems that supply power to a clearly defined cluster of users through a local distribution network, operating either independently of the national grid or in a coordinated, grid-parallel configuration. The defining feature is a shared local distribution network serving multiple end-users within a discrete geographic footprint. They are designed to deliver reliable electricity in contexts where grid extension, reinforcement, or service quality improvements are slow, uncertain, or uneconomic within relevant planning horizons.

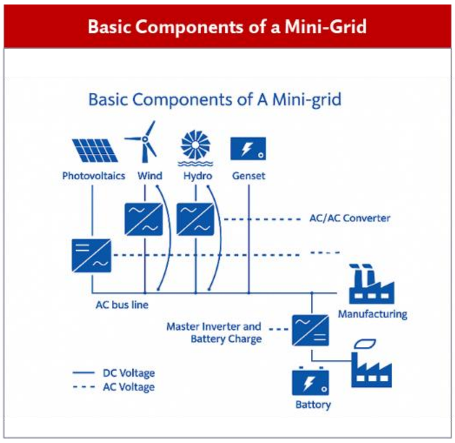
Mini-grids typically combine distributed generation, energy storage, and intelligent control systems to balance supply and demand at the local level. Power can be generated by a range of renewable sources, including wind and biomass. However, in the Zambian context, the dominant configuration is solar photovoltaic (PV) generation paired with Battery Energy Storage Systems (BESS), often complemented by limited diesel hybridization for backup or peak support. This configuration is particularly well suited to Zambia's climate risk profile, as solar generation is less sensitive to drought-related hydrological variability, while battery storage enables dispatchable power during evening hours and grid outages. In practice, this makes PV+BESS mini-grids one of the most scalable options for improving electricity resilience in drought-exposed systems.

From a technical perspective, a standard solar-based mini-grid comprises of four core components:

- Generation assets, typically solar PV, with occasional integration of small-scale hydro or biomass in specific contexts;
- Battery storage, sized to provide several hours of autonomy and to smooth intra-day variability;
- Power electronics and control systems, enabling voltage and frequency stability, load management, and seamless islanding from the national grid when required;
- Hybrid backup, most commonly diesel generators, used sparingly to manage prolonged outages or demand spikes.

These systems are designed to operate across multiple modes. In fully off-grid contexts, mini-grids function as standalone systems supplying all local demand. In grid-adjacent or unreliable-grid contexts, they may operate in parallel with the national grid, importing or exporting power when grid conditions allow, and islanding automatically during load shedding or power quality events. This operational flexibility is central to their role as climate-resilient infrastructure.

These systems sit on a spectrum of scale and complexity. At the smallest end, "nanogrids" are typically sub-5 kW systems serving a single building or facility (often a single PV or PV-plus-battery setup). "Microgrids" generally run from ~10 kW up to around 1 MW and are designed to serve a defined cluster, such as a campus, commercial facility, or community hub, often using hybrid generation with local control. "Mini-grids" are larger multi-user systems (typically ~50 kW to several MW in emerging markets) that combine local generation with a low-voltage distribution network to serve villages, small towns, or productive clusters; they can operate fully off-grid or alongside the main grid where service is unreliable. Beyond that scale, systems transition into local distribution grids (>10 MW), which look more like utility infrastructure integrating multiple distributed energy resources across a wider area. (Figure 1)



Typical System Types and Parameters

System type	Installed capacity (kW /MW)	Typical configuration	Representative use cases
Nanogrid	< 5 kW (up to ~10 kW in some definitions)	Single source or hybrid (e.g. PV + battery)	Individual households, single buildings, telecom towers, clinics
Microgrid	~10 kW – 1 MW	Multi-source hybrid systems with local control	Campuses, commercial facilities, community clusters, light industry
Minigrid	~50 kW – 10 MW (common in emerging markets)	Networked generation with low-voltage distribution	Villages, towns, rural electrification, island systems
Local / Distribution grid	> 10 MW	Utility-scale distribution	Urban districts, industrial zones, utility-operated networks

Figure 1: Mini-Grid Basics, Components and Types

Importantly, mini-grids are distinguished in this brief from behind-the-meter or captive power systems. Captive systems are designed to serve a single facility, such as a factory, mine, or commercial complex, with generation and storage assets located within the premises of that user and without a shared distribution network. Mini-grids, by contrast, are multi-user systems that distribute electricity across a defined local network to multiple customers (households, enterprises and/or public facilities). Revenue is therefore generated across a customer base rather than a single off-taker, and the infrastructure can be replicated across multiple sites using a similar project structure. This multi-user network characteristic is the basis on which mini-grid sites are defined and counted in the market sizing model used in this brief.

While captive solar-plus-storage systems play a critical role in improving energy resilience for individual firms in Zambia, they represent a different investment category from mini-grids and are treated as out of scope for the market sizing in this brief. The focus here is therefore on multi-user, site-based systems that combine generation, storage, and local distribution infrastructure serving multiple end-users within a defined geographic footprint.

Mini-grids also differ from large, centralized generation projects in their modularity and speed of deployment. Systems can be developed incrementally, expanded as demand grows, and tailored to local load profiles. This makes them particularly well suited to environments characterized by demand uncertainty, evolving settlement patterns, and increasing climate volatility. As a result, mini-grids have moved beyond pilot applications in many emerging markets, and are increasingly recognized as a mainstream component of resilient power system planning across many emerging markets and increasingly within Zambia's own electrification and reliability landscape.

Mini-grids as a solution class in Zambia (deployment archetypes and segmentation)

In Zambia, mini-grids do not constitute a single, homogeneous market. Instead, they are deployed across a set of distinct deployment archetypes, each characterized by different load profiles, customer mixes, revenue structures, and financing requirements. Recognizing these differences is essential for understanding where mini-grids are already viable, where they are emerging, and how they can realistically scale.

Throughout this Investment Brief, it is helpful to distinguish between three related but different concepts: (i) Segments (where and for whom mini-grids are deployed, defined by the dominant anchor demand and deployment context), (ii) Use Cases (what electricity enables, such as milling, cold storage or irrigation), and (iii) Business Models (how projects are owned, operated and paid for, such as developer-led SPVs, REA-supported programs or anchor-contracted arrangements). The segmentation used here refers to the first of these, deployment segments, because it is the most practical way to size and finance mini-grid opportunities at site level.

These deployment segments remain the organizing structure used throughout the brief. Later references to **agro-processing, cold storage, timber processing, or industrial processing** describe **use cases within those segments**, not additional market segments in their own right.

In this brief, mini-grids are grouped according to their **primary deployment context and anchor demand**, rather than geography alone. Each segment therefore represents a distinct **investment archetype** with its own technical design, customer mix, revenue profile, and financing logic. This reflects how mini-grid opportunities are typically assessed in practice: developers and lenders focus primarily on the **anchor load and commercial structure of a site**, not simply where it is located.

In reality, many sites combine different forms of demand. A settlement may include households, a clinic, small enterprises, and an agro-processing facility within the same footprint. But in commercial terms, mini-grids are usually developed around one dominant **deployment logic** that shapes system design, utilisation, and bankability. Therefore, the segmentation used here follows that market reality.

These segments are grounded in how mini-grids are already being deployed, or are most plausibly deployable, in Zambia, based on observed developer activity, REA programme typologies, and the geography of productive demand. On that basis, **five core multi-user mini-grid segments** are identified in Zambia.

Table 1: Core Mini-Grid Deployment Segments in Zambia

Deployment Segment	Typical Users	Typical Grid Context	Typical System Size (PV + BESS)	Revenue Characteristics	Dominant Finance Orientation
Rural community mini-grids	Households, micro- and mini-enterprises	Off-grid (typically remote / low likelihood of near-term grid arrival)	20–200 kW PV / 50–500 kWh BESS	Low, tariff-based (often with affordability and collection risk)	Concessional / RBF / blended (often subsidy-supported)
Rural agri-processing clusters	Grain mills, oil presses, cold storage, irrigation	Mostly off-grid or weak-grid (often outside reliable corridors)	50–500 kW PV / 100–1,000 kWh BESS	Medium, productive-use anchored	Blended / semi-commercial
Social infrastructure clusters	Schools, clinics, health posts, water systems	Primarily off-grid/weak-grid (rural clinics/schools/water); can also occur in peri-urban weak-grid pockets	10–100 kW PV / 50–300 kWh BESS	Low, service-driven (often subsidized)	Public / donor-supported
Industrial & mining-adjacent reliability clusters	Multi-user industrial / mining-adjacent clusters (incl. contractor camps, service SMEs, staff housing and nearby commercial users)	Edge-of-grid / unreliable-grid (grid present but service constrained or costly to reinforce)	500 kW to multi-MW PV / multi-MWh BESS	High, reliability and diesel-offset driven (anchor concentration risk)	Commercial / blended (site-dependent)
Peri-urban reliability clusters	Markets, estates, SME zones, small towns	On-grid but unreliable (load shedding / voltage instability / capacity constraints)	100–1,000 kW PV / 200–2,000 kWh BESS	Medium, reliability-driven	Blended / commercial

Each segment reflects a distinct role that mini-grids play in Zambia's evolving power system. They also broadly map to different grid contexts: **rural community** and most **social infrastructure** clusters are primarily off-grid; **peri-urban reliability** clusters are grid-connected but unreliable; and **industrial/mining-adjacent reliability** clusters sit at the edge of grid or in zones where supply is structurally constrained.

- **Rural community mini-grids** primarily address first-time access needs in areas far from the national grid. Demand is dominated by residential and small commercial loads, with predictable evening peaks. While individual revenues are modest, these systems form the backbone of rural electrification and local economic resilience.
- **Rural agri-processing clusters** represent one of the most commercially promising mini-grid archetypes. Productive anchor loads such as milling, cold storage, or irrigation drive higher utilization rates and stronger willingness to pay, improving financial performance and reducing reliance on concessional support.
- **Social infrastructure clusters** (predominantly rural off-grid or weak-grid contexts) prioritize reliability over scale. Mini-grids serving clinics, schools, and water systems are often bundled with nearby households or enterprises to improve utilization and financial sustainability. These systems deliver high social value even where direct revenues are limited, and are most commonly deployed through public- or donor-supported electrification and resilience programs.
- **Industrial & mining-adjacent reliability clusters** deploy larger, often hybridized systems to offset high diesel costs and manage outage risk. These sites are typically characterized by strong anchor loads and clear cost-reduction incentives, supporting commercial or blended financing in many cases.
- **Peri-urban reliability clusters** serve areas located near the grid but affected by frequent load shedding or poor power quality. These systems focus on reliability, peak shaving, and continuity of service rather than first-time access, and are increasingly relevant as system-wide reliability challenges intensify.

Note: The **industrial & mining-adjacent reliability** segment refers to **multi-user** clusters in mining-adjacent or industrial zones, for example where a primary industrial load is complemented by contractor operations, service enterprises, staff housing, or nearby commercial users. **Purely captive single-facility systems are excluded** from the mini-grid definition used in this brief.

While project-level reporting remains fragmented, Zambia already has a documented base of **operating multi-user mini-grids** and several **financed multi-site rollouts** in progress. The examples below illustrate both the operating market and the scale-up pipelines now being financed.

Note: These are selected examples of operating sites and portfolio pipelines with public documentation. They are intended to illustrate market readiness and pipeline depth, not to imply a single consolidated national total.

Table 2: Zambia's Mini-Grid Track Record and Scale-Up Pipeline

Mini-grid programs (Zambia)	Deployment segment mapping	Project details	What it signals about Zambia's Mini-grid readiness
Chitandika Solar Mini-Grid (Eastern Province) – ENGIE / PowerCorner (MySol Grid)	**Rural community mini-grids** (with mixed household + MSME loads)	Commissioned in **2019**, supplying electricity to **households and local businesses** through a shared distribution network (solar-based mini-grid; one of Zambia's best-known private mini-grid deployments)	Demonstrates **private-sector execution** and an operating reference point for solar mini-grids; useful anchor for "what a real mini-grid looks like" in-country
Zengamina Hydro Mini-Grid ("Island Grid", North-Western Zambia)	**Rural community mini-grids** (off-grid access-led, larger-than-typical system size)	Long-running **~700 kW** run-of-river hydro mini-grid serving **~550 customers** in a remote area far from the main grid; multi-user distribution and billing	Shows multi-user mini-grids can operate over the long term in remote settings; highlights the importance of **O&M capability, revenue collection, and governance**

Katamanda / Magodi / Muhanya / Chibwika (Eastern) + Chitandika (Eastern) – operating solar mini-grids	**Rural community mini-grids**; in some cases **social infrastructure–anchored** where clinics/schools are part of the load mix	A documented set of **five operating solar mini-grids** (approx. **24–52 kW** range) with practical lessons on tariffs, affordability, and sustainability	Confirms mini-grids are not hypothetical: Zambia has **multiple operating sites** and lessons-learned evidence, including where **cost-recovery tariffs collide with affordability**
MySol Grid Zambia – portfolio rollout financed by FEI/Cygnum	Primarily **rural community mini-grids** (portfolio), potentially with **social infrastructure–anchored** sites depending on rollout design	**USD 7.5m senior debt** facility to construct **60 mini-grids**, targeting **40,000+ people** (portfolio approach rather than one-off projects)	Strong signal that Zambia is entering a **portfolio finance phase**: standardization + aggregation + debt capital are starting to appear in the market
OnePower Zambia – multi-site developer portfolio	Mixed portfolio, typically **rural community mini-grids** plus **productive-use / agri-processing clusters** where anchor demand is present	Developer portfolio described as **24 sites**, **~2.5 MW PV** and **~7.5 MWh storage** (portfolio-scale deployment model)	Shows presence of an operator able to originate and manage **repeatable pipelines**, important for lenders who prefer aggregation and diversification
ZEDSI-supported mini-grid pipeline (multiple developers)	Predominantly **rural community** and **social infrastructure–anchored** mini-grids; may also include **productive-use clusters** depending on site selection	Results-based/incentive-linked support to develop and operate **43 mini-grids** across developers (including **ENGIE Energy Access, OnePower Zambia, Renwasol/Solar23**, among others).	Indicates **program-backed pipeline building** is underway; improves visibility for developers and supports the shift from pilots to **repeatable deployment structures**.

While these segments are analytically distinct, together they illustrate the breadth of mini-grid applications in Zambia, spanning **access, productive use, social service delivery, and reliability enhancement**. They provide the foundation for assessing **solution readiness, current deployment patterns, and the scale of the opportunity** in the sections that follow.

Segment-level deployment characteristics

While the five mini-grid segments identified above are analytically distinct, they differ most meaningfully in how systems are **designed, operated, and used in practice**. These differences shape system sizing, storage requirements, operating profiles, and the nature of revenue risk, all of which affect **solution readiness and scalability**.

For investors and lenders, this matters because the same mini-grid technology can have very different commercial characteristics depending on deployment context. Load shape, storage needs, revenue density per connection, and risk profile all influence whether a site can support debt, and on what terms.

In Zambia, these deployment archetypes are shaped by the country's settlement patterns, heavy reliance on hydropower, dispersed agricultural production systems, and rising exposure to system-wide load shedding. The characteristics outlined below therefore reflect not just generic mini-grid design principles, but how these systems are **already being deployed, or are most plausibly deployable, in Zambia's power and economic context**.

Understanding these differences is critical for assessing where mini-grids are already deployable at scale, where operational models are proven, and where further innovation or support may be required.

Rural community mini-grids

Rural community mini-grids are typically deployed in settlements located far from the national grid, where household density is sufficient to support a shared distribution network. Demand profiles are dominated by **evening residential loads**, including lighting, phone charging, refrigeration, and small retail activities. Daytime demand is generally limited, resulting in relatively low system utilization without complementary productive uses.

System sizes are modest, and battery storage plays a central role in enabling evening supply and maintaining reliability. These mini-grids are usually designed for high uptime rather than high load factors. Operational simplicity and robustness are therefore prioritized over complex optimization. While revenues per customer are low and evening demand patterns are relatively predictable, cashflows remain sensitive to **affordability, connection uptake, and collection dynamics**. These systems are therefore often structured as a platform for **gradual load growth over time**. In practice, the binding constraint is often not technical performance but affordability: cashflows depend on connection uptake, payment discipline, and where tariffs cannot fully recover costs, continued access to results-based financing or subsidy support.

In Zambia, this deployment archetype is most prevalent in sparsely populated rural districts, particularly in Eastern, Luapula, Northern, and Western Provinces, where grid extension costs remain high and settlement patterns favor shared local infrastructure over individual standalone systems.

Zambia already has operating examples of this archetype, including ENGIE/PowerCorner's Chitandika mini-grid in Eastern Province and the long-running Zengamina mini-hydro "island grid" in North-Western Zambia (see Track Record table above).

Rural agri-processing clusters

Mini-grids serving agri-processing clusters are characterized by **daytime-intensive productive loads**, often anchored by one or more processing facilities such as grain mills, oil presses, cold storage units, or irrigation systems. These anchors significantly improve system utilization, particularly during solar generation hours, reducing curtailment and improving overall system economics. For lenders, this anchor-led structure tends to improve revenue visibility relative to purely residential sites, because a larger share of demand is linked to income-generating activity and daytime utilization is stronger.

Deployment in these contexts often involves a deliberate design choice to **co-locate productive and residential demand**, allowing surplus generation from processing activities to serve nearby households and enterprises. Storage requirements are driven less by residential evening peaks and more by process continuity and reliability needs. As a result, these systems tend to be more efficiently utilized than purely residential mini-grids and exhibit clearer demand-growth pathways.

In Zambia, this archetype is closely linked to maize milling, oilseed processing, irrigation, and emerging cold-chain infrastructure in high agricultural production zones, where processing demand can anchor mini-grid design and improve commercial viability.

A practical signal of anchor demand at scale is the Government-supported **Solar Milling Plant** program. These systems are still mostly deployed as **captive assets**, but they remain relevant here as evidence of **clustered daytime processing load** that could anchor multi-user mini-grid footprints where distribution is built out (see Track Record table).

Social infrastructure clusters

Mini-grids serving social infrastructure clusters prioritize **service continuity and reliability** over scale. Typical anchor loads include clinics, schools, water pumping stations, and administrative facilities, many of which require power during both daytime and evening hours. Load profiles are therefore flatter but smaller in absolute terms.

Battery storage is often sized conservatively to ensure several hours of autonomy during outages, particularly for health and water services. In practice, these systems are frequently bundled with nearby households or small enterprises to improve utilization and cost recovery. While individual social facilities may not generate sufficient revenue on their own, clustering enables shared infrastructure that supports both essential services and surrounding communities. These sites are often justified by service continuity rather than pure commercial returns, which is why they typically rely on public procurement cycles, donor support, or blended structures to close viability gaps.

In Zambia, clinics, schools, and water systems are frequently prioritized within rural electrification and service-delivery programs, making them natural anchor loads for clustered mini-grid deployments. In practice, the track record is better evidenced through **program pipelines** than through a large set of named standalone sites (see Track Record table and ZEDSI-supported pipeline).

Industrial/mining-adjacent reliability clusters

Industrial/mining-adjacent reliability clusters deploy mini-grids primarily to **offset high diesel costs and manage outage risk**. These systems are typically larger in scale, often exceeding several hundred kilowatts and extending into the multi-megawatt range, with substantial battery capacity to support continuous operations. The key commercial risk is often **concentration**. Where one or two large loads dominate demand, the **credit quality of those anchors and the durability of the demand relationship** become central to bankability.

Load profiles are driven by industrial processes and are often relatively stable and predictable. Systems are frequently hybridized, integrating solar, storage, and existing diesel generators to optimize fuel use and reliability. Distribution networks in these contexts are typically more compact than in rural community sites, often serving a concentrated cluster of productive users within an industrial or mining-adjacent zone (for example, anchor operations alongside contractors, service enterprises, and staff housing). Operational complexity is higher, but so too is technical maturity, reflecting the criticality of power supply to industrial operations.

This deployment archetype is particularly relevant in mining-adjacent districts and industrial corridors, where grid reliability is uneven and diesel generation remains a major operating cost for extractive and processing activities. In Zambia, the clearest near-term evidence here comes less from a long list of already-operating named multi-user industrial mini-grids and more from **financed rollout platforms** that can support this type of configuration. In particular, **MySol Grid's debt-backed expansion platform** and **One Power's multi-site portfolio model** show that developers and financiers are already moving beyond isolated pilots toward repeatable site origination and portfolio deployment. These platforms are not evidence that every site is already an industrial multi-user mini-grid, but they do demonstrate that the commercial and financing architecture for **reliability-led clustered deployments** is beginning to take shape in Zambia (see Track Record table).

Peri-urban reliability clusters

Peri-urban reliability mini-grids are deployed in areas located near the national grid but subject to **frequent load shedding, voltage instability, or capacity constraints**. These systems are designed to operate in grid-parallel mode, supplying power during outages, shaving peaks, or supplementing grid supply during periods of stress. Here, customers are effectively paying for reliability and continuity – reduced downtime, protected inventory, and continuity of service, rather than first-time access.

Demand profiles are mixed, typically combining residential, commercial, and small industrial loads. System design therefore emphasizes flexibility, fast response, and the ability to operate seamlessly during grid disruptions. Storage plays a central role in ensuring continuity of service, particularly during evening peaks when grid stress is highest. As reliability challenges intensify, these deployment contexts are becoming increasingly relevant in Zambia's power landscape.

In Zambia, this segment is emerging most clearly in fast-growing peri-urban settlements and secondary towns experiencing persistent load shedding, where **reliability, rather than first-time access, is the main driver of demand** for mini-grid solutions. Named Zambia examples remain limited, so this category is best described as **emerging rather than mature**. Current evidence comes primarily from **developer platforms and financed pipelines** that can be replicated in reliability-constrained towns, estates, and mixed-load settlements, rather than from a large stock of already-documented peri-urban mini-grids. This is consistent with experience in comparable African markets, where standardized solar-hybrid mini-grid rollouts have served mixed customer bases of households, enterprises, and public institutions across multiple sites (see Track Record table).

A useful regional analogue is Husk Power's multi-site solar-hybrid mini-grid rollout in Nasarawa State, Nigeria, which demonstrates how standardized developer-led portfolios can serve mixed household, business, and public-institution demand across multiple sites using a repeatable commercial model.

Across all segments, mini-grids share one common feature: they are site-based systems tailored to local demand conditions, rather than standardised one-size-fits-all assets. That adaptability underpins their value as a scalable solution class, while also creating the distinct operational and commercial profiles explored in the sections that follow.

These differences help explain why uptake and bankability vary sharply across segments. Access-led mini-grids often require concessional support and aggregation, while anchor-led and reliability-driven systems can move earlier toward commercial financing.

Manufacturing-related use cases: evidence of solution readiness

Manufacturing and processing activities provide one of the clearest lenses for testing whether mini-grids are truly investment-ready in Zambia. Unlike purely residential electrification, manufacturing-linked loads place higher and more continuous demands on power systems, require greater reliability, and generate revenue streams that are directly sensitive to outages and power quality. Where mini-grids can support these use cases effectively, they demonstrate not only technical feasibility, but also operational resilience and commercial relevance.

To avoid confusion, this section distinguishes between (i) operating multi-user mini-grids that meet the definition used in this brief, (ii) captive or single-enterprise systems that demonstrate productive demand and distributed-energy viability but remain outside the mini-grid market scope, and (iii) transition pathways, where captive anchors or clustered productive sites could realistically evolve into multi-user mini-grid footprints through deliberate aggregation and distribution build-out.

This distinction matters because lenders are not underwriting the technology in isolation; they are underwriting the cashflow profile around it. Revenue density, diversification beyond the anchor, and the balance of affordability, collection, and concentration risk all shape bankability. In Zambia, this is why some productive-use cases can move earlier toward commercial finance, often through portfolio structures, while others still depend on aggregation support and concessional layering.

The categories below are use cases, not a second segmentation system. They describe the productive application within a site, while the market analysis in this brief continues to use the earlier deployment segments as the main organising structure. Most of these use cases sit primarily within rural agri-processing clusters and peri-urban reliability clusters, and in some cases within industrial or mining-adjacent reliability clusters where multiple users are served through a local network.

The evidence base is also uneven. Zambia shows stronger evidence where there are already operating multi-user mini-grids in agricultural settings or financed rollout platforms with repeatable site logic, and weaker evidence where activity is still largely captive, early-stage, or only indirectly evidenced. The use cases below therefore focus on areas where Zambia already shows operating experience, deal-flow signals, or credible pathways to scalable deployment.

The figure below shows use cases, not additional deployment segments. The first three sit primarily within the rural agri-processing cluster segment, though some cold-chain applications can also appear in peri-urban reliability clusters. The final category should be read as industrial processing in multi-user reliability clusters, aligned with the industrial/mining-adjacent reliability segment used elsewhere in this brief. Purely captive industrial systems remain outside scope unless generation and distribution serve multiple users through a shared local network.

Figure 2: Four Main Mini-Grid Manufacturing Use Cases

Where Zambia already has **named operating deployments** or **financed multi-site rollouts**, these are referenced directly in the subsections below and in the **Zambia mini-grid track record table**. Where direct Zambia evidence is still limited, the text states this explicitly and uses only **carefully bounded regional analogues** to illustrate how similar mini-grid configurations are operating in comparable African markets.

In Zambia, mini-grids have clearly moved beyond conceptual pilots in some **productive and reliability-linked contexts**, but the evidence base is **not equally strong across all manufacturing-related categories**. It is strongest where there are already **operating multi-user mini-grids in agricultural settings** or **financed rollout platforms with repeatable site logic**, and weaker where activity is still largely **captive, early-stage, or only indirectly evidenced**.

From an investment perspective, productive-use-linked mini-grids are most compelling where demand is anchored in income-generating activity (improving utilization and willingness to pay) and where the anchor can be combined with surrounding residential and SME loads to diversify revenue risk. The subsections below therefore focus on use cases where Zambia already shows operating experience, deal-flow signals, or pathways to scalable deployment.

Agro-processing at source: the most mature and bankable mini-grid use case

Agro-processing at or near the point of production represents the **clearest and best-evidenced manufacturing-related mini-grid use case in Zambia**. It most often sits within the **rural agri-processing cluster** segment. The segment is the market-sizing bucket, while the use case refers to the productive activity inside the site, such as **milling, irrigation, or cold storage**, that shapes the load profile and revenue logic. In these settings, demand is often **daytime-intensive, income-generating, and relatively predictable**, which supports higher utilisation and strengthens the economics of solar-based mini-grids.

In practice, this is one of the few rural mini-grid archetypes where **revenue density can be strong enough to attract commercial finance earlier**, especially when the productive anchor has stable throughput and clear ability to pay, and when revenues are diversified across surrounding users rather than concentrated in a single off-taker. Even so, **anchor concentration risk still matters**. Where one facility drives most demand, bankability depends heavily on the anchor's credit quality and the durability of throughput. The stronger projects are therefore those that combine a productive anchor with surrounding users and are increasingly financed through **multi-site portfolios rather than single-asset structures**.

Maize milling is the clearest example of this anchor logic in Zambia. The government-supported **Solar Milling Plant (SMP)** initiative, implemented through the **Zambia Cooperative Federation**, highlights both the scale of rural milling demand and the institutional ecosystem, including cooperatives, aggregation structures, and public support mechanisms, that underpins productive energy use in rural districts. Many SMP installations are still deployed as **captive systems**, but their clustering and daytime operating patterns create a credible pathway toward **shared, multi-user mini-grid configurations**, where surplus generation can also serve nearby households and enterprises. In this brief, SMPs are therefore treated as evidence of productive anchor demand and institutional aggregation, rather than as counted mini-grid deployments unless and until they are integrated into multi-user distribution footprints.

Zambia also already has operating multi-user mini-grids in predominantly agricultural regions, which helps demonstrate the feasibility of productive-use electricity in farming-community settings. The clearest in-country example is ENGIE Energy Access's Chitandika mini-grid in Eastern Province, which serves households and local businesses in a rural agricultural area. Published case-study evidence from Chitandika points to the presence of productive-use customers, including a hammermill operator, alongside farming households, shops, and public-service users. This does not make Chitandika a pure agro-processing-first mini-grid in the narrow sense, but it does provide credible Zambia-specific evidence that a multi-user mini-grid can support agro-processing-related loads within a broader rural demand base (Smart Energy Access and Women Empowerment: A Case Study of Chitandika Village in Zambia, 2021).

The broader investment case is reinforced by both local and regional evidence. In Zambia, the SMP initiative already shows the scale and geographic concentration of rural milling demand, even where many systems remain captive. Beyond Zambia, African mini-grid programmes are increasingly linking site development to agri-processing demand in order to improve utilisation and bankability. The World Bank, for example, has highlighted a Nigeria pilot designed to coordinate mini-grid rollout with agri-processing investments to strengthen the financial viability of both. Taken together, this supports the case for treating agro-processing as a high-priority multi-user mini-grid pathway in Zambia, even if the number of publicly documented Zambia projects explicitly labelled as agro-processing mini-grids remains limited (World Bank, 2023).

Beyond maize milling, similar anchor dynamics are emerging in oilseed processing, irrigation-linked agro-processing, and rural cold-chain applications, particularly in high-production agricultural zones. These activities are geographically dispersed, but they share the features that matter most for project economics: income-linked demand, relatively stable daytime usage, and stronger willingness to pay for reliable supply. That is what distinguishes agro-processing-linked mini-grids from purely access-driven deployments.

Where agro-processing loads are integrated into shared local distribution systems, they meet the defining characteristics of structured mini-grids: multiple users, shared distribution infrastructure, and a clear separation between generation assets and end-users. This is what distinguishes the mini-grid opportunity from purely captive power installations and underpins its relevance for market sizing and commercial financing. Overall, these features make agro-processing at source the strongest near-term pathway for commercially oriented multi-user mini-grid deployment in Zambia, even though the publicly documented base of explicitly agro-processing-led mini-grid projects remains limited.

Cold chains and rural food storage: high-potential anchors with emerging deployment models

Rural cold chains and food storage facilities represent a high-potential but still emerging mini-grid use case in Zambia. Activities such as milk cooling, fisheries cold rooms, ice production, meat storage, and horticulture packhouses are highly sensitive to power reliability, making them technically well suited to solar-plus-storage systems.

Zambia already shows credible signs of productive cooling demand in rural and peri-urban value chains, but the current evidence should be read carefully. The strongest documented examples are still largely at the level of enterprise systems, cooperative service models, and demonstration deployments, rather than clearly documented multi-user mini-grids built explicitly around cold storage. A useful Zambia example is EEP Africa's SelfChill Zambia and Tanzania project, which aimed to deploy intelligent solar-powered cooling solutions for milk tanks, agricultural cold rooms, and ice makers serving agricultural cooperatives through a PAYG model. This demonstrates that cold-chain demand is real, commercially relevant, and already being structured around shared service provision, even if the public Zambia evidence base remains stronger on anchor demand than on already-mature multi-user mini-grid footprints (EEEP Africa, 2021).

The broader investment case is strengthened by regional precedent. In Nigeria, mini-grid market studies under the electrification program have explicitly identified cold storage as a productive-use application linked to mini-grid deployment, including both developer-owned and shared community-owned operating models. Related case evidence from a fishing community in Nigeria also shows a solar mini-grid powering a cold storage facility used by fishers and traders, illustrating how refrigeration loads can anchor wider productive-use electricity systems. In Kenya, off-grid cold-chain businesses have already demonstrated that distributed solar-powered cooling can serve large numbers of farmers and traders through scalable service models. Together, these examples show that rural cooling is not a theoretical use case, but an increasingly bankable productive-energy application in African markets with similar agricultural and infrastructure constraints (Rural Electrification Agency, 2021).

However, this distinction matters for financing. Captive cold-chain systems can often be financed as equipment or behind-the-meter assets, whereas multi-user mini-grids require additional distribution infrastructure, licensing and tariff treatment, and a stronger customer aggregation model to become bankable at site or portfolio level.

From a system design perspective, cold chains are attractive anchors because they combine high willingness to pay, clear economic penalties for outages, and demand profiles that can materially strengthen system utilisation when paired with surrounding households, SMEs, or public-service loads. Where co-located with wider community demand, they can improve both load diversity and revenue density. In Zambia today, the missing ingredient is less the absence of need than the limited extent of aggregation and structuring needed to convert enterprise-level cooling assets into clearly defined, investable multi-user mini-grid footprints.

Cold chains are therefore best understood as a strong anchor-demand pathway and a medium-term growth opportunity, rather than as a fully mature Zambia mini-grid category already evidenced at scale. The economics are compelling, but the transition from stand-alone or captive cooling systems to bankable multi-user mini-grids will depend on deliberate clustering, local distribution build-out, and multi-site portfolio development.

Timber processing and carpentry clusters: structurally aligned, but institutionally underdeveloped

Timber processing and carpentry clusters represent a structurally compatible but still underdeveloped mini-grid use case in Zambia. The case is strongest in forestry-linked provinces, particularly the Copperbelt, which holds around 85% of Zambia's estimated 59,000 hectares of commercial timber plantations. Timber from these plantations is used largely for construction, furniture, mining timber, and poles, which gives the segment a credible economic base and a clear productive-load rationale. Sawmills and woodworking operations are also typically daytime-intensive, which aligns well with solar-based generation (World Bank, 2019).

However, the current Zambia evidence points more strongly to captive or co-located energy use than to formal multi-user mini-grid deployment. Larger sawmills often have some scope for self-generation, including through wood residues, while smaller operators tend to rely on diesel or unreliable grid supply. The real constraint is therefore not the absence of load, but the lack of an aggregation mechanism that can bundle mills, workshops, nearby enterprises, and settlements into a bankable multi-user customer base. This reflects a broader sector reality: while Zambia has meaningful forest resources and plantation activity, the forest industry remains unevenly developed, which weakens the formation of clearly defined mini-grid footprints around timber-processing clusters.

Regional experience nevertheless suggests that the use case is commercially plausible in the right contexts. A useful example is UNIDO's Nigeria project, "Mini-Grid Based Renewable Energy (Biomass) Sources to Augment Rural Electrification in Nigeria," which was designed to promote small biomass-

based mini-grids as a viable private-sector investment model. More broadly, African bioenergy work has highlighted the role that wood residues and sawdust can play in supplying decentralized industrial power where feedstock, clustering, and demand are strong. These examples do not show that Zambia already has a mature timber-cluster mini-grid market, but they do support the view that the underlying commercial logic is credible in comparable African settings (UNIDO, 2011).

Timber processing is therefore best understood as a **longer-horizon and selective opportunity**, rather than a primary driver of near-term mini-grid scale-up in Zambia. It may become investable where **forestry estates, worker settlements, and SME carpentry clusters** are deliberately bundled into a shared-energy model, potentially with **biomass and solar playing complementary roles**. For now, though, it remains a plausible clustered use case rather than a fully evidenced, scalable multi-user mini-grid archetype in Zambia today.

Large private industrial systems: technically mature, but outside the core mini-grid model

Large manufacturing and processing facilities in Zambia, particularly in **sugar, cement, fertilizer, and mining-linked industries**, already show that distributed generation can be deployed and financed at meaningful scale. These systems often combine bagasse cogeneration, solar PV, diesel backup, or hybrid configurations, with generation located inside the industrial site and power used mainly to serve internal process loads. Zambia's sugar industry is a good example. The country has an estimated **bagasse cogeneration opportunity of around 27 MW**, and **Illovo Sugar Zambia's Nakambala estate** already operates a well-established bagasse-based cogeneration system that supplies its own operations and can export surplus electricity to the grid.

What these installations show is not the maturity of the **multi-user mini-grid market**, but the maturity of **captive distributed energy** in Zambia's industrial economy. Similar logic applies in quarrying, cement-linked operations, and some mining environments, where firms invest in on-site power because grid reliability is uncertain, connection capacity is constrained, or downtime is simply too expensive. These systems are technically proven and commercially rational. But they are usually built around **a single industrial off-taker**, with limited or no power distribution to surrounding SMEs, worker settlements, or nearby communities.

Regional experience reinforces this distinction. Across Africa, large industrial operators have already adopted captive renewable-power models where the economics are strong. In **Kenya**, **Mumias Sugar** has long operated bagasse-based cogeneration and has exported surplus electricity to the grid. In **Uganda**, the **Kakira Sugar** complex has also developed bagasse-based power generation at industrial scale. In **South Africa**, mining and industrial firms have increasingly signed up to large private solar and hybrid plants to stabilize supply and reduce power costs. These are important comparators because they show that **industrial distributed generation is already bankable and scalable in African markets**. But they also underline that this is usually a **captive industrial-power model**, not a shared local mini-grid serving multiple users.

That distinction matters because a large industrial plant with on-site generation may, technically, look like a private mini-grid. In commercial and regulatory terms, though, it is something different. The power system sits within one industrial footprint, revenues depend on one anchor, and there is no real customer aggregation or shared distribution model. Even where surplus electricity is exported to the national grid, that does not turn the asset into a structured, multi-user mini-grid.

So while these systems provide strong evidence that **distributed energy is viable and financeable in Zambia**, they remain **outside the core market scoped in this brief**. For market sizing and lender relevance, the focus stays on manufacturing clusters and productive hubs where generation and local distribution serve multiple users within a defined footprint. That is the part of the market that aligns with the mini-grid definition used here, and with the kind of portfolio-based financing models that can scale beyond isolated captive assets.

Synthesis: what manufacturing use cases indicate about solution readiness in Zambia

The picture is **promising, but uneven**. In Zambia, **agro-processing** stands out as the clearest near-term pathway, with the strongest logic for **multi-user mini-grid deployment** where productive anchor demand is combined with surrounding users. **Cold chains** are commercially attractive and increasingly relevant, but the Zambia evidence still sits more at the level of **enterprise systems and emerging service models** than mature multi-user mini-grids. **Timber-processing clusters** remain a more selective, longer-horizon opportunity, held back less by load profile than by weak aggregation and sector structure. **Large industrial systems** confirm that distributed energy is already viable at scale in Zambia, but they are predominantly **captive** and therefore sit outside the core mini-grid market scoped in this brief. For lenders, the implication is clear: prioritize use cases where **anchor demand, user diversity, and revenue visibility** are already strongest, while using aggregation and risk-sharing tools to bring newer use cases into the pipeline over time.

3. Market Opportunity

Defining the Opportunity and Scope Boundary

This Investment Brief sizes the market for multi-user site-based electricity mini-grids in Zambia that serve multiple end-users through a shared local distribution network, typically combining distributed generation (predominantly solar PV), battery storage, and low-voltage distribution infrastructure. The unit of analysis throughout is a **"site"**, defined as a discrete mini-grid footprint with a shared distribution network serving a defined cluster of customers (households, enterprises and/or public facilities) and **a single project structure that can be financed and implemented as one investable asset.**

The opportunity assessed here covers two primary service contexts: **fully off-grid locations** and **areas with unreliable grid supply**, where electricity provision is unavailable, intermittent, or of insufficient quality to meet local demand. In this Investment Brief, **"unreliable grid supply" refers to service conditions where grid power is available in principle but not dependable in practice**, due to local network constraints and/or system-wide generation shortfalls that manifest as load shedding, voltage instability, or poor power quality.

Consistent with this focus, the analysis excludes **behind-the-meter or captive power systems designed to serve a single customer or facility** (for example, a factory, mine, estate, or commercial complex) **without a shared distribution network**, even where such systems are deployed in response to grid unreliability. While these systems may be commercially viable and relevant to broader distributed energy markets, they are treated as a separate investment category and are out of scope for the mini-grid market sizing in this brief.

All market sizing in the sections that follow is anchored to **investable multi-user mini-grid sites** operating in off-grid or reliability-constrained settings. This keeps the opportunity definition focused on projects that can be developed and financed as **replicable infrastructure assets**, while maintaining a clear distinction between mini-grids and other distributed-energy solutions.

Headline Market Size: Total Addressable Market (TAM), Serviceable Addressable Market (SAM), and Serviceable Obtainable Market (SOM)

Using the scope boundaries set out above, the Zambian mini-grid opportunity is sized through a **transparent, bottom-up, site-based approach** that distinguishes between total need, structural invest ability, and plausible delivery within the current planning horizon. The market is assessed across three lenses, **number of sites, installed capacity, and indicative capital investment** to provide a rounded view of scale and investment relevance.

In this brief, three terms are used consistently. The **Total Addressable Market (TAM)** captures the full needs-based universe of potential mini-grid sites. The **Serviceable Addressable Market (SAM)** narrows that to sites that are structurally investable under current market and policy conditions. The **Realizable Market (SOM)** reflects the share of the SAM that can credibly be delivered within the time horizon, once delivery capacity, financing availability, and program constraints are taken into account.

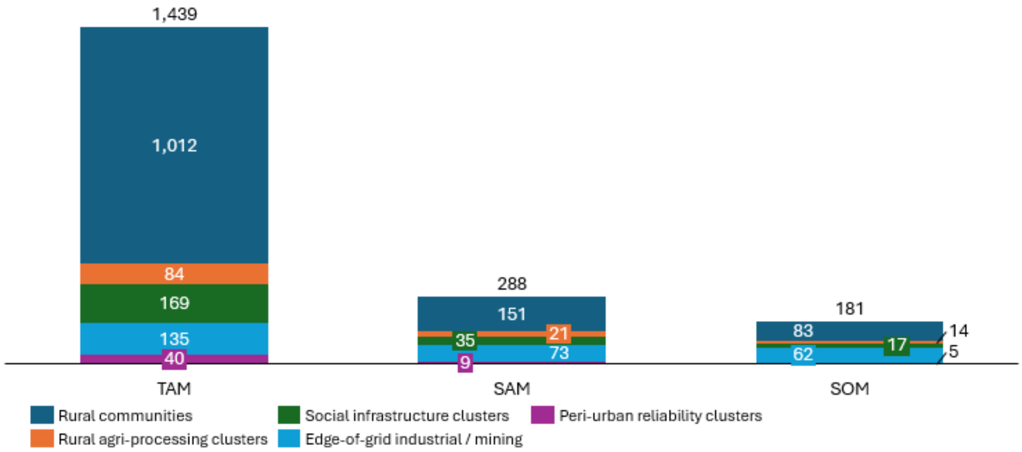


Figure 3: Zambia's Mini-Grid TAM, SAM, and SOM – number of sites by segment

At the broadest level, the **TAM** represents the full technical and needs-based opportunity for site-based mini-grids across off-grid and unreliable-grid contexts in Zambia. Under current assumptions, this equates to approximately **1,440 potential mini-grid sites**, corresponding to roughly **150 MW** of installed capacity and an indicative capital requirement of around **USD 800 million**. This is the full universe of locations where mini-grids could, in principle, provide a viable electricity solution based on service gaps and demand fundamentals.

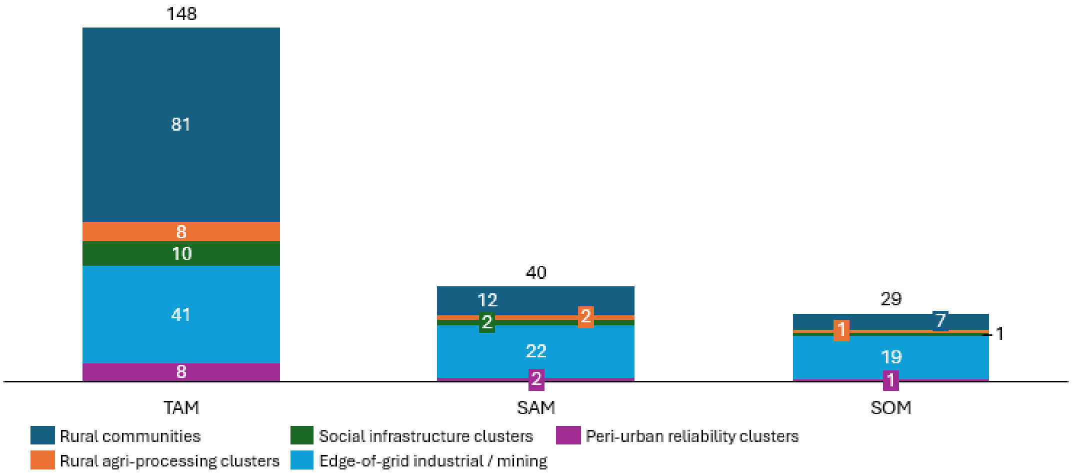


Figure 4: Zambia's Mini-Grid TAM, SAM, and SOM Installed capacity by segment (in MW)

From this universe, the **Serviceable Addressable Market (SAM)** narrows the opportunity to sites that are structurally investment-relevant under current conditions. On this basis, the SAM comprises approximately **290 sites**, representing around **40 MW** of capacity and roughly **USD 200 million** of potential investment. The sharp contraction from TAM to SAM reflects not a lack of need, but the practical realities of **demand readiness, site definition, and investability**.

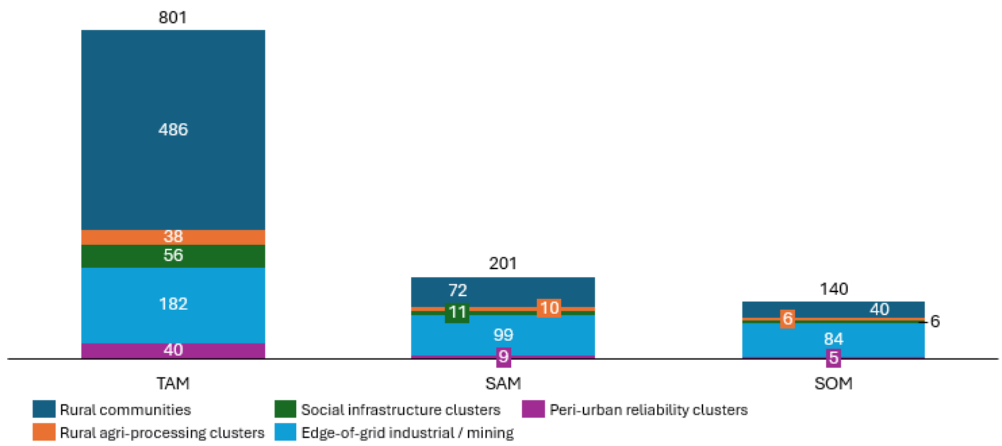


Figure 5: Zambia's Mini-Grid TAM, SAM, and SOM CAPEX by segment (in USD Millions)

The final layer focuses on the Serviceable Obtainable Market (SOM), that is, the share of the SAM that can plausibly be delivered within defined time horizons under current market conditions. Under the conservative base-case deployment scenario, this translates into approximately 65–70 operational mini-grid sites by 2025, representing around 12 MW of installed capacity and USD 40–50 million of investment, rising to around 180 sites by 2030, equivalent to roughly 29 MW and USD 130–150 million of realized capital deployment.

Importantly, this realizable envelope should be read as a delivery-constrained outcome, not a demand constraint. It reflects the pace at which underlying need can realistically convert into investable and executable projects. Taken together, the TAM–SAM–SOM progression shows both the scale of underlying opportunity and the portion that can credibly translate into bankable deal flow within this decade.

Composition of the Opportunity: Where the Scale and the Capital Sit

While Zambia's mini-grid opportunity is sizable in aggregate, its commercial character varies materially by segment. A site-count view alone masks important differences in system size, load profile, and investment intensity. Disaggregating the market by segment therefore gives a much clearer picture of where volume sits, where capital concentrates, and how the realized market evolves over time.

Table 3: Headline realized mini-grid market: 2025 vs 2030

Category	2025	2030
Sites (# units)	~60	~180
Installed Capacity (MW)	11.9	28.7
CAPEX (USD Million)	40-50	130-150

Overall, the realized market is expected to scale by roughly 2.5–3x in both sites and capacity between 2025 and 2030, while CAPEX grows faster as a larger share of deployment shifts toward higher-capacity, anchor-led and reliability-driven systems.

Volume: rural communities dominate by site count

In site terms, rural community mini-grids dominate the opportunity across both the addressable and realised market. This reflects Zambia's dispersed settlement patterns, limited grid reach in remote districts, and the continued need for basic household and small-enterprise electrification. In the base-case deployment scenario, rural community systems account for just over half of realised mini-grid sites by 2030.

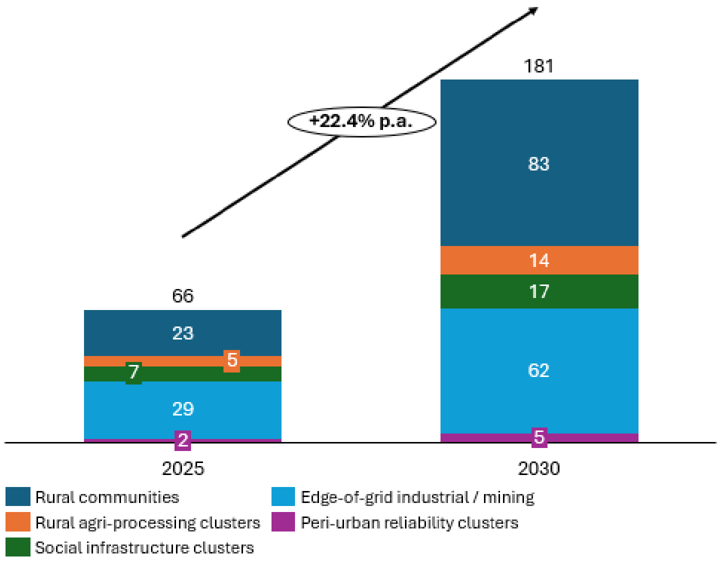


Figure 6: Expected number of mini-grid sites by segment (2025 vs 2030)

However, site volume alone is a misleading proxy for investment relevance. Many rural community systems are relatively small, with modest initial loads and more gradual demand growth. While they remain central to electrification outcomes and long-term market depth, they are not where the bulk of capital or near-term bankable deal flow is concentrated.

Capacity: commercial weight shifts toward productive and reliability-led segments

The commercial profile of the market becomes clearer once the opportunity is viewed through the lens of installed capacity. Total realised capacity is expected to increase from approximately 11.9 MW by 2025 to around 28.7 MW by 2030, reflecting both the scaling of deployment and a shift in the mix of sites delivered over time.

A disproportionate share of this capacity is concentrated in industrial and mining-adjacent reliability clusters and rural agri-processing clusters, even though these segments account for a smaller share of total site counts. These segments are characterised by higher anchor loads, clearer revenue visibility, and stronger willingness and ability to pay, which support larger system sizes and stronger utilisation. In Zambia, this reflects the concentration of mining, industrial, and agro-processing activity in areas where grid reliability remains constrained or reinforcement timelines are uncertain.

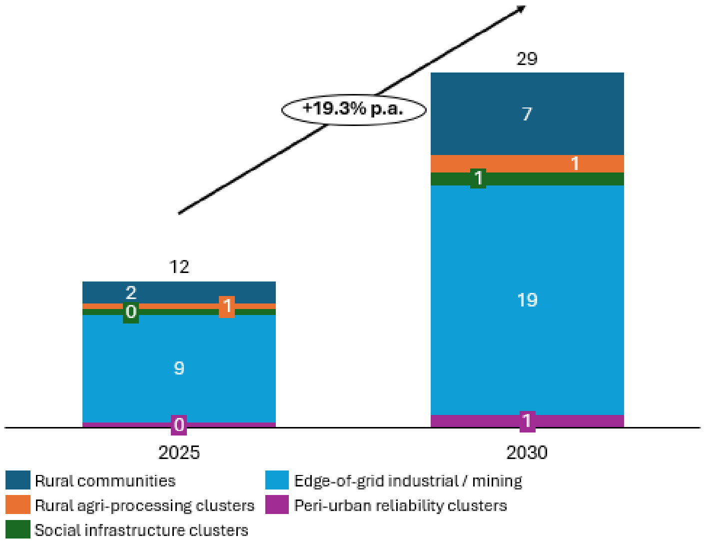


Figure 7: Expected installed capacity by segment (2025 vs 2030)

By 2030, industrial and mining-adjacent clusters alone are expected to contribute roughly **one-third of total realized capacity**, while rural community systems, despite dominating site numbers, account for a similar or smaller share of installed MW. This is where the commercial center of gravity begins to shift: from **site breadth** toward **capacity concentration**.

Capital: the market increasingly resembles a programme-scale infrastructure opportunity

The same pattern becomes even more pronounced in capital terms. Aggregate realised investment is expected to rise from around **USD 40–50 million by 2025** to approximately **USD 130–150 million by 2030**, driven both by larger average system sizes and by a greater share of deployment in commercially stronger segments.

More than half of this capital is concentrated in **industrial and mining-adjacent reliability clusters** and **rural agri-processing clusters**, where higher load factors, larger system sizes, and denser cashflows drive materially higher per-site investment. These segments therefore account for a disproportionate share of total capex despite representing a minority of total site counts. They are also the segments most naturally suited to **portfolio-style facilities and refinancing**, because projects can be aggregated more efficiently and underwritten against stronger demand fundamentals.

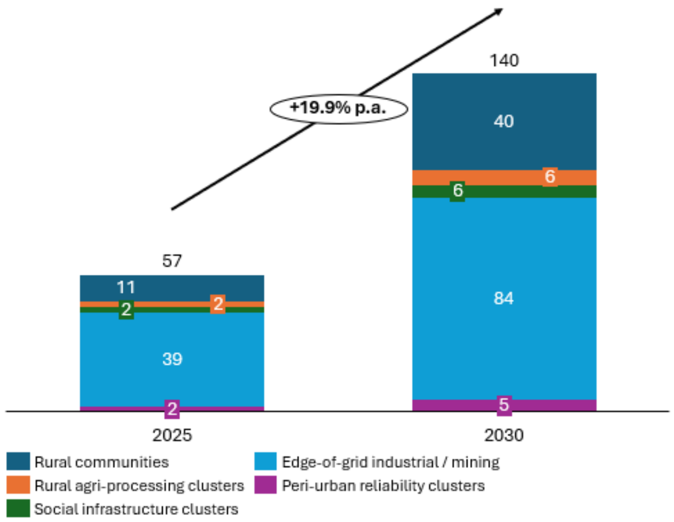


Figure 8: Expected mini-grid CAPEX investments by segment (2025 vs 2030) – USD Mn

By contrast, **rural community mini-grids**, while numerous, account for a smaller share of aggregate investment value because of their lower average system sizes and more gradual load growth. **Social infrastructure** and **peri-urban reliability** sites contribute meaningfully but scale more steadily, shaped by public procurement cycles, affordability constraints, and the need for targeted risk-sharing mechanisms.

What the composition means for investors

Taken together, the segment mix reveals a clear structural dynamic in Zambia's mini-grid market:

- **Rural communities drive scale in site numbers**, underpinning pipeline breadth and long-term electrification impact.
- **Productive and reliability-led segments drive scale in MW and capital**, underpinning commercial relevance and bankability.
- The realised market through 2030 tilts progressively toward **larger, higher-revenue systems**, even as access-focused deployments continue in parallel.

For commercial capital, this composition matters more than the headline site count. Zambia's mini-grid opportunity is best understood not as a single homogeneous market, but as a **layered portfolio of sub-markets**, each with different scale, risk, and financing characteristics. That is what makes the market investable despite its apparent fragmentation, and it is also why financing structures will need to differ by segment.

What This Means Practically for Commercial Capital

Zambia's mini-grid market is meaningful in scale, but it is **not uniform**. The near-term opportunity sits primarily in productive and reliability-driven segments, especially industrial and mining-adjacent reliability clusters, selected agri-processing clusters, and peri-urban reliability applications. These deployments combine stronger load factors with clearer revenue visibility, making debt participation more realistic from the outset, provided concentration risk is managed through diversified customer mixes, robust anchor arrangements, or portfolio structures.

Rural community and **social infrastructure** systems remain essential to access and long-term market depth, but their economics are more sensitive to demand ramp-up, affordability, and the availability of catalytic support. For commercial lenders, these segments are therefore more naturally investable through **portfolio aggregation and blended structures** than as isolated project financings. In most cases, bank participation is likely to depend on risk-sharing mechanisms such as **results-based incentives, guarantees, or first-loss layers**.

The shape of the market also changes over time. In the early years, deployment is a mix of smaller community systems and targeted productive-use sites, often supported by blended capital. By 2030, capacity and capital are increasingly concentrated in fewer, larger, and more commercially anchored systems. Financing structures evolve accordingly, shifting from one-off project funding toward **program-based and portfolio approaches**, where performance is assessed across multiple sites rather than on a single-asset basis.

This favours clustered deployments and platform-level portfolios over stand-alone transactions. The most practical entry points for banks are therefore likely to be: **(i) portfolio-level senior debt** alongside catalytic capital, **(ii) refinancing of operating assets** once performance is established, and **(iii) selective participation in larger anchor-led systems** where demand and repayment capacity are demonstrably strong.

The opportunity is defined less by the number of potential sites than by where **capacity, revenue density, and delivery capability converge**. That is where commercial capital can participate with greater confidence as Zambia's mini-grid market continues to mature.

4. Business Model and Value Proposition for Financial Institutions

The preceding sections showed that mini-grids in Zambia function as **reliability and productivity infrastructure**, not just access solutions. While the overall opportunity is sizeable, the investable portion depends on segment economics, delivery capacity and risk allocation.

This section focuses on how projects are structured, how cashflows are generated and where **commercial capital can participate with confidence**. Mini-grids are not a uniform asset class. Ownership models, revenue structures and segment characteristics differ, and those differences determine bankability.

How mini-grids are delivered in Zambia: the core business models

Mini-grids in Zambia are not delivered through a single standardized template. In practice, a limited number of business model archetypes have emerged, shaped by who originates the project, who ultimately owns and operates the asset, and how revenues are secured. These structural differences matter. They determine where risk sits, how predictable cash flows are, and whether a project can support commercial debt without relying heavily on concessional layers.

In the earlier sections, we used **deployment segments** to describe where mini-grids sit in the economy (rural communities, peri-urban reliability clusters, agri-processing clusters, social infrastructure clusters, and industrial/mining-adjacent reliability clusters). **Business models** describe something different: who originates the project, who owns and operates the asset, and how revenues are contracted and collected.

In practice, segments and business models are not one-to-one, but there are consistent pairings. Access-led rural community and social infrastructure segments are most often delivered through developer-led SPVs with concessional support or through REA-supported programs. Productive and reliability-driven segments tend to be delivered through anchor-led structures (often with a developer/operator), sometimes complemented by cooperative or cluster governance in agro-processing zones. The table below summarizes the dominant business models and shows which segments they most commonly align with.

Table 4: Summary of Major Business Models for Delivering Mini-Grids

Model	Primary Segments	Primary Customers	Revenue Structure	Revenue & Cashflow Risk	Role of Public Sector	Bankability considerations
Developer-led SPV mini-grids (e.g. OnePower / Solar23 / Ignite / ENGIE)	Rural community; peri-urban reliability; some agri-processing clusters (when diversified users present)	Households, SMEs, social services; often with productive anchor loads	Retail tariffs; prepaid metering; connection fees; occasionally anchor PPAs	Moderate–High (context-dependent): affordability and collection risk in rural segments; demand ramp-up risk; improved where productive loads diversify revenues	Regulatory oversight (ERB licensing); selective RBF or capital subsidies	Strongest where sites are aggregated; portfolio-level debt viable; performance track record key
Publicly coordinated / REA-supported mini-grids	Rural community; social infrastructure clusters (often bundled with nearby users)	Rural communities, SMEs, institutions	Regulated tariffs; subsidy-backed revenues; performance-	Lower demand origination risk (site selection and coordination), but continued	Active site identification; RBF, grants or co-financing; streamlined approvals	Well suited to blended finance; debt viability improves with bundling and standardization

			linked incentives	dependence on program continuity and subsidy/risk-sharing windows		
Anchor-led or industrial reliability mini-grids	Industrial/mining-adjacent reliability clusters; larger agri-processing clusters; selected peri-urban reliability sites	Anchor enterprise (e.g., agri-processor / industrial user) plus surrounding community and SMEs within the shared distribution footprint	Anchor PPAs; reliability-driven tariffs; community cross-subsidy	Moderate (often concentrated): anchor concentration risk and contract enforceability are central; volatility depends on offtake structure (take-or-pay / service-level terms)	Limited direct role; may support site identification or approvals	Bankability hinges on anchor credit quality, contract enforceability, and concentration risk; portfolio aggregation can reduce single-anchor exposure
Cooperative or productive-cluster mini-grids	Agri-processing clusters; rural community + productive clusters (where local governance exists)	Rural households and clustered SMEs (e.g. milling, irrigation, cold chain)	Community tariffs; anchor-based contributions; variable payment structures	Moderate–High – governance and collection risk; concentration risk if anchor weak	Often supported by NGO, cooperative schemes or REA facilitation	Viable where governance strong; often requires concessional layering; debt best at portfolio level. Banks typically finance end-user equipment rather than core assets

Across all models, it is helpful to distinguish commercial viability from bankability. A project can be commercially viable in principle (i.e., capable of generating positive cashflows), but still not bankable if cashflows are too uncertain, too concentrated in one anchor, or too dependent on short-term subsidies. The sections below therefore describe not only how each model works, but what it takes for banks to lend into it with confidence.

Therefore, **developer-led and REA-supported models dominate access-led rural community and social infrastructure segments**, while **anchor-led and cooperative/cluster models are most relevant for productive-use and reliability-driven segments**, particularly agri-processing and peri-urban reliability contexts. In Zambia, these models often coexist within the same program pipeline. The sections below describe how each model works in practice and what lenders typically need to see to participate.

(A) Developer-led SPV model

The most common structure is the **developer-led model**, where a private company identifies a site, secures the necessary regulatory approvals (often manageable but still time-consuming, particularly where land access, community agreements, and tariff approvals are required), builds the generation and distribution infrastructure, and operates the system through a dedicated project vehicle. Revenues are collected directly from end-users, typically through prepaid metering systems, and the capital stack often combines sponsor equity with results-based or catalytic funding — particularly in rural community deployments. In access-led rural sites, **tariff affordability is often the binding constraint**. Developers typically rely on a combination of (i) **prepaid metering and customer tiering** to manage collection risk, (ii)

productive-use loads where feasible to improve revenue density, and (iii) **catalytic support** (such as connection subsidies, RBF, or capex grants) to close the affordability gap and keep end-user tariffs within locally acceptable ranges. **Without these mechanisms, purely household-based rural mini-grids are often commercially viable in theory but not bankable in practice.**

In these settings, the strength of the project rests on demand aggregation and payment discipline. Where residential users dominate and productive loads are limited, revenue ramp-up can be gradual particularly where tariffs are kept affordable and connection uptake takes time, even when subsidies reduce upfront capex. Conversely, where milling, irrigation, or SME activity forms part of the load base, utilization improves and revenue stability strengthens. Over time, as developers aggregate multiple sites under a single platform, this model begins to shift from a collection of small rural projects to something closer to a diversified infrastructure portfolio, which materially changes its attractiveness from a lender's perspective.

(B) Anchor-led or industrial reliability model

A second configuration centers on a **productive anchor load**. In this structure, an agri-processing cluster, mining-adjacent facility, or industrial cluster forms the backbone of demand. The generation asset may still be developer-owned, but a significant share of revenues is linked to a commercially active off taker with a clear economic incentive to secure reliable power. In the context of this brief, this model refers to multi-user mini-grids where an anchor load is complemented by additional connected users through a shared distribution network; purely captive systems serving a single facility remain out of scope.

The business case in these deployments is often driven less by electrification expansion and more by reliability economics, avoided diesel consumption, reduced downtime, improved voltage stability, and protection against load shedding. As a result, cash flows tend to be more concentrated and more predictable. That said, **bankability is not automatic**. Where the anchor is using the mini-grid primarily as a partial backup to the grid, revenues can be volatile unless the offtake is structured with **minimum take-or-pay commitments**, clear service-level arrangements, or pricing linked to avoided diesel and downtime. In practice, **anchor credit quality and contract enforceability** are what determine whether this becomes a bankable reliability product or simply a commercially sensible hedge for the anchor. This model aligns most closely with the **edge-of-grid industrial** and larger **agri-processing** segments identified earlier, and it typically presents stronger early-stage debt capacity compared to purely residential systems.

(C) Publicly coordinated or REA-supported deployments

In other cases, site identification and rollout are linked to national electrification priorities, often coordinated through the Rural Electrification Authority or related programs. While private developers may still construct and operate the systems, origination is guided by public planning frameworks, and capital structures frequently incorporate structured incentives or co-financing mechanisms.

These deployments are common in **rural community** and **social infrastructure** contexts. They play an important role in expanding access and building local economic resilience, but their pacing is influenced by procurement cycles and program continuity. In Zambia, this also means **bureaucratic throughput and political prioritization** can shape which sites move and when, creating timing risk for developers and lenders unless programs are governed through clear, rules-based pipelines and standardized documentation. For commercial lenders, participation in this model typically becomes viable where projects are bundled, risks are partially absorbed by catalytic capital, and governance frameworks are standardized.

(D) Cooperative or productive-cluster model

A fourth structure is emerging in areas where productive demand is clustered around cooperatives or local enterprise networks. Here, a milling facility, irrigation scheme, or grouping of SMEs anchors generation, with surrounding households connected within the same distribution footprint. Ownership and governance arrangements can vary, sometimes involving cooperative entities alongside private operators.

This model can be compelling where productive demand is sufficiently concentrated and payment discipline is strong. It tends to work best where the productive anchor generates high utilization and clear willingness to pay, and where governance is structured so that technical operations and revenue collection are handled by a professional operator, reducing the risk that cooperative capacity constraints undermine cashflow performance. At the same time, it introduces governance considerations that require careful structuring, particularly where asset ownership and billing responsibilities are not clearly separated. While still evolving, this approach reflects a locally embedded pathway that may gain relevance in agro-processing zones over time.

Borrower Economics: Two Distinct Mini-Grid Investment Cases in Zambia

Mini-grids in Zambia do not generate returns in a uniform way. In practice, two distinct economic logics are observable, and understanding the difference is critical for lenders assessing risk and structuring debt. The distinction is less about technology and more about what drives cashflow.

For lenders, the practical test is whether the mini-grid's delivered cost of power sits below the borrower's "cost of unreliability" (diesel fuel, downtime, spoilage, and equipment damage) and whether that value can be captured through enforceable tariffs or offtake terms. As a benchmark, diesel-only self-generation is often in the range of ~USD 0.42/kWh, before factoring in downtime and maintenance (Muyiwa, Samuel, & Olanrewaju, 2013) By comparison, mini-grid costs vary widely with load factor and subsidy structure: World Bank benchmarking finds baseline mini-grid LCOEs commonly in the ~USD 0.55–0.85/kWh range (median ~USD 0.66/kWh), but also shows that higher productive use can reduce LCOE materially and that capex grants can bring costs down substantially (e.g., a 60% grant reducing LCOE of the lowest mini-grid to just over USD 0.29/kWh) (World Bank, 2019).

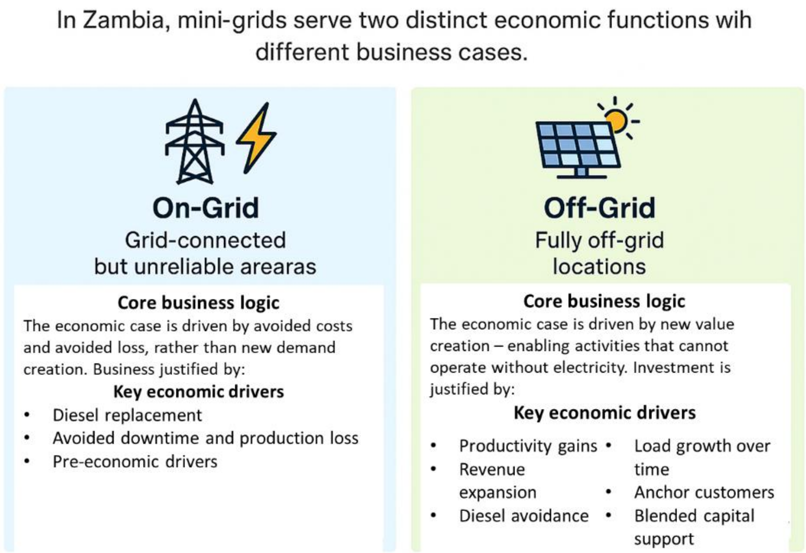


Figure 9: Mini-Grid Business Cases

(A) Reliability-driven mini-grids in grid-connected or edge-of-grid settings

In areas that are nominally grid-connected but exposed to unreliable-grid supply, the investment case is often framed around reliability rather than access expansion. Industrial and mining-adjacent reliability clusters (where an anchor load is complemented by surrounding users within a defined distribution footprint), larger agri-processing clusters, and peri-urban enterprises may already have a grid connection, yet face voltage instability, load shedding, or rising diesel backup costs.

In these settings, the economic rationale rests on cost avoidance and business continuity. In practice, break-even is driven by a small set of variables including diesel price and runtime displaced, the value of avoided downtime for the anchor, the share of demand contracted under minimum offtake or service-level terms, and the capex intensity of storage required to meet reliability needs. On the diesel side alone, Zambia's regulated pump prices have recently been around ZMW ~23–27 per liter, and a typical genset fuel intensity of ~0.25 liters per kWh implies fuel costs on the order of ~ZMW 5–7 per kWh before maintenance and capex recovery (Energy Regulation Board, 2026). On the downtime side, the World Bank's Enterprise Surveys capture outage-related losses as a percentage of annual sales (reported by firms that experienced outages) (Enterprise Surveys, 2026). This provides a practical, comparable way to quantify the "cost of unreliability" that anchors are often willing to pay to avoid.

Where these variables are favourable, and where offtake terms convert reliability value into enforceable cashflows, lenders can underwrite repayments against contracted revenues and verified avoided-cost savings rather than assuming speculative demand growth.

A mini-grid also displaces diesel generation, reduces downtime, stabilizes production schedules, and improves equipment life. For anchor customers, the decision to contract power is typically based on avoided fuel expenditure and reduced revenue loss rather than on incremental demand growth. Cashflows can be more predictable than access-led systems, particularly where long-term offtake arrangements include minimum-take or service-level commitments and where the anchor's economics are linked to avoided diesel and downtime.

From a lender's perspective, this configuration offers clearer visibility on debt service capacity. Revenues are concentrated around productive users with identifiable balance sheets, and the need for reliable supply is often clear. However, willingness to pay still has to be converted into bankable cashflows through contract structure, clear service levels, enforceable payment mechanisms, and pricing linked to avoided diesel and downtime rather than assumed "necessity" alone. The trade-off is concentration risk: where one or two anchors dominate demand, lender confidence rests heavily on anchor credit quality and contract enforceability, and projects may still require risk-sharing instruments. The underwriting focus therefore shifts from demand formation to counterparty risk, contract enforceability, and technical performance.

This model aligns most closely with the edge-of-grid industrial, mining-adjacent, and larger agri-processing segments identified in Section 3, and is likely to represent the most bankable portion of the near-term pipeline.

(B) Access-driven and demand-formation mini-grids in off-grid communities

In fully off-grid settings, the economic logic differs materially. Here, mini-grids expand access and stimulate demand rather than replacing an unreliable existing supply. Revenues are generated from a diversified base of households, micro-enterprises and community services, with load growth often following electrification rather than preceding it.

In these deployments, cashflows are more back-ended. Productive demand may emerge over time as milling, irrigation or small manufacturing activities scale, but initial utilization rates are typically lower than in anchor-led systems. This is a real constraint. Where there is no credible pathway to productive load growth (or where tariffs cannot be kept affordable), the economics will not clear without ongoing subsidy. Pipeline quality therefore depends heavily on site selection, demand-stimulation measures, and anchoring to a productive nucleus where feasible. As a result, early-year revenues can be sensitive to tariff design, connection uptake, and customer payment behaviour.

This does not imply structural weakness. Rather, it reflects a different risk profile. Where projects are designed around a clear productive nucleus, for example, agro-processing at source, the transition from access expansion to revenue stabilization can occur relatively quickly. Where demand remains predominantly residential, concessional capital or results-based incentives often play a stabilizing role during early years.

Zambia-specific evidence reinforces this point: analyses of operating solar mini-grids in Zambia highlight that cost-recovering tariffs are often unaffordable for rural households, contributing to financial unsustainability without appropriately structured "smart" subsidies and strong operations models (Kapole, Mudenla, & Jain, 2013). Affordability constraints also show up in grid uptake: the World Bank finds grid infrastructure present in 58.4% of enumeration areas, yet only 37.7% of households are connected, suggesting that willingness and ability to pay can be a binding constraint even when service is physically available (World Bank, 2019). National planning documents similarly flag low affordability and purchasing power of mini-grid/off-grid customers as a core market constraint (Africa Energy Summit, 2025).

For lenders, this segment requires careful attention to portfolio aggregation and risk layering. Individual sites may be small, but diversified portfolios with consistent performance data can support structured debt participation once track record is established. This model aligns primarily with rural community mini-grids, social infrastructure, anchored deployments (often bundled within community footprints), and selected agri-processing cluster sites where demand formation is still underway.

The distinction between these two cases is straightforward but important. In **reliability-driven projects**, the mini-grid safeguards existing income streams by stabilizing production and reducing exposure to outages. In **access-driven projects**, it enables new economic activity to take root, with revenues building as demand matures. That difference influences cashflow stability, capital structuring, and the timing of commercial debt participation. For financial institutions, recognizing where a project sits along this spectrum helps lenders align product design and risk appetite with the underlying revenue dynamics, while clarifying where blended finance remains necessary to support earlier-stage, access-led deployments.

What mini-grids cost and what drives CAPEX

The CAPEX numbers in Section 3 are driven by what gets built in the realized market, not by simply scaling up large volumes of small rural systems. By 2030, the projected **~28.7 MW** of installed mini-grid capacity is increasingly concentrated in **fewer, larger anchor-led and reliability-driven sites**, particularly **industrial and mining-adjacent reliability clusters** and **rural agri-processing clusters**, even though **rural community systems remain the majority of sites**. Capacity and investment therefore scale unevenly across segments, with productive and reliability-driven deployments accounting for a disproportionate share of total capital deployed.

At project level, total capex reflects a combination of **generation equipment, storage, distribution infrastructure and enabling costs**, as illustrated in **Error! Reference source not found.**. Generation and balance-of-system components, including PV modules, inverters and related equipment, account for a significant share of total investment. **Battery systems** form a distinct cost block, particularly where reliability requirements extend beyond daylight supply.

Beyond core equipment, costs accumulate through **distribution networks and smart metering**, land acquisition, logistics and installation, taxes and duties, as well as development and management overheads. Figure 5 illustrates the typical cost stack for mini-grids, where distribution and smart metering are often the single largest block (~26.6% of total capital cost), followed by batteries (~14.9%), installation (~11.3%), and taxes/duties (~11.5%). Generation hardware is also material—PV modules (~9.7%), inverters/EMS (~8.6%), and other balance-of-system components (~6.1%). Enabling and delivery costs (management/SG&A ~5.9%, logistics ~4.6%, land ~0.6%) round out the stack (ESMAP, 2022).

As noted in Section 3, FX exposure also matters, as many core components are priced in hard currency, so kwacha depreciation can materially shift installed costs and financing needs over time. These components become particularly material in dispersed rural settings where connection distances are longer and transport chains more complex. Contractor overheads and margins (developer, EPC, and integrator), while typically modest in competitive environments, are also reflected within total installed capital cost.

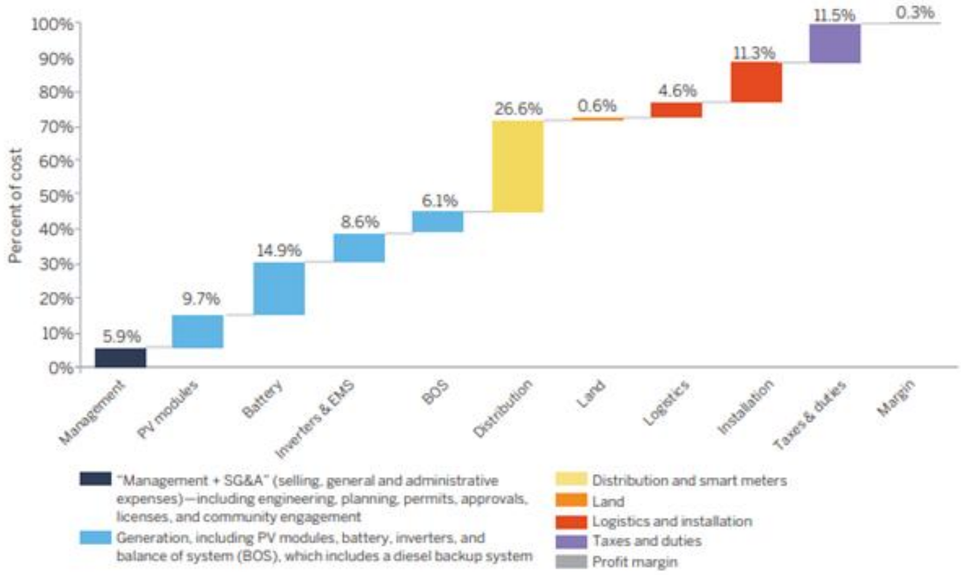


Figure 10: Mini-Grid Cost Waterfall (Source: ESMAP, 2022)

This cost structure helps explain why capital concentration in the realized market follows productive load concentration rather than site count. Anchor-led and industrial reliability projects tend to deploy larger systems with compact distribution footprints, improving capital efficiency per unit of useful energy delivered. Rural community systems involve smaller generation capacity but often higher distribution cost per connection, increasing relative capital intensity even where total system size is modest.

For lenders, the implication is straightforward. Debt capacity tracks revenue density, not the number of sites. This is why portfolio-level approaches (bundling sites with similar cost and performance profiles) matter for bank participation, particularly in access-led segments. Segments with concentrated demand and higher utilization rates are structurally better positioned to support commercial leverage, while access-driven deployments rely more heavily on aggregation and catalytic support during early stages.

Where banks fit and how financing structures evolve

Mini-grid financing in Zambia remains equity and concessional capital-led in its early stages, but the structure of the realized market suggests a gradual shift toward greater participation from commercial lenders. The distinction outlined earlier between reliability-driven and access-driven deployments is central to understanding where that shift begins. Put simply, reliability-driven projects are underwritten on avoided cost and business continuity for existing productive loads (often with an anchor offtaker), while access-driven projects rely on demand formation over time across households and micro-enterprises and therefore depend more on affordability support and aggregation in the early years.

In reliability-driven projects, particularly those serving edge-of-grid industrial sites, agri-processing hubs and mining-adjacent facilities, revenues are anchored in existing productive activity. In these cases, debt participation can be structured around identifiable offtakers, clearer utilization profiles and stronger early-year cashflows. Internationally, similar configurations have supported senior debt at portfolio level once operating history is established. Zambia is beginning to see early movement in this direction through program-backed pipelines and developer platforms that aggregate multiple sites under a single structure.

For example, the Zambia Energy Demand Stimulation Initiative (ZEDSI) has awarded over **USD 1.1 million** across **OnePower Zambia, Renwasol/Solar23, and ENGIE Energy Access Zambia (PowerCorner/MySol Grid)** to support the development and operation of **43 mini-grids** (Rockefeller Foundation, 2025). The World Bank also expects Zambia to reach at least **200 operational solar mini-grids by 2030** (World Bank, 2025).

In parallel, debt capital is starting to back platform rollouts: the Facility for Energy Inclusion (FEI), managed by Cygnum Capital, has provided USD 7.5 million of debt to MySol Grid Zambia to construct 60 mini-grids connecting over 40,000 people. (Cygnum Capital, 2023)

Access-driven deployments in rural communities follow a different trajectory. Here, concessional layers such as results-based incentives or catalytic capital absorb early-stage risk and support demand ramp-up. Commercial banks are more likely to participate once projects are bundled, performance data is available and revenue volatility is moderated through aggregation. In practice, this means debt is better deployed at **portfolio or platform level** rather than at isolated site level.

The financing structure therefore evolves alongside the market. Early transactions rely on blended capital stacks and sponsor equity. As operating track record improves and segment economics differentiate, refinancing and structured portfolio facilities become more feasible. This progression mirrors developments observed in other African markets, where program-backed mini-grid rollouts have gradually transitioned from grant-heavy pilots to debt-supported portfolios once scale and performance data are established. For example, CrossBoundary Energy Access has raised dedicated capital to finance solar mini-grid portfolios across Africa, explicitly positioned around portfolio deployment and repeatable project structures (CrossBoundary, 2022). More broadly, results-based financing programs and lessons-learned workstreams (e.g., BGFA) emphasize the role of standardization, aggregation, and performance verification in enabling later-stage commercial financing (BGFA, 2024).

For financial institutions, the opportunity is not uniform across all segments. It is concentrated where **revenue density, anchor strength and aggregation** reduce cashflow volatility. Recognizing this allows banks to engage selectively, supporting the portion of the mini-grid market that aligns with their risk appetite while catalytic capital continues to unlock more access-oriented deployments.

Practical barriers and enablers for local commercial bank participation

While the structural opportunity is increasingly visible, local commercial bank participation remains uneven. The constraints are not conceptual; they are practical. Most relate to revenue predictability, tenor availability and macro exposure rather than to the underlying technology itself. As operating track record improves and projects are aggregated at portfolio level, several of these barriers begin to ease.

Table 5: Key considerations shaping local bank participation

Debt-Relevant Barrier	Why It Matters	Implications for Lending
Limited operating track record	Short performance history reduces confidence in asset reliability and downside resilience	Higher risk margins, lower leverage, conservative underwriting
Revenue ramp-up uncertainty (access-led sites)	Early-stage demand growth can be slower than projected	Shorter tenors, tighter DSCR (Debt-Service Coverage Ratio) covenants, phased drawdowns linked to connections, or preference for portfolios with anchor diversification
Customer affordability and collection risk	Payment discipline directly affects cashflow stability	Greater emphasis on prepaid systems or anchor PPAs
Anchor concentration risk	When one or two users dominate demand, cashflows hinge on	Take-or-pay / minimum offtake, stronger security package,

(productive/reliability sites)	anchor credit quality and contract enforceability	guarantees, portfolio diversification to reduce single-anchor exposure
Tenor mismatch in local banking system	Local banks fund primarily with short-term deposits	Limited availability of long-term project debt; refinancing risk
FX and macro volatility	Equipment priced in hard currency; revenues in kwacha	Higher pricing, reduced leverage, or demand for hedging mechanisms
Regulatory and grid-arrival risk	Tariff changes, licensing/treatment shifts, or early grid arrival can reduce revenues or strand assets without clear transition rules	Concession/permit clarity; grid-arrival clauses; buy-out/compensation or interconnection provisions; step-in rights

Enablers that reduce these barriers over time could include, (i) portfolio aggregation and standardized documentation, which lowers transaction costs and diversifies risk; (ii) performance data from operating sites, enabling refinancing and higher leverage; (iii) targeted risk-sharing instruments (RBF, partial guarantees, first-loss layers) to bridge affordability and FX risk; and (iv) clearer regulatory pathways, including licensing thresholds and grid-arrival provisions that protect revenue continuity.

These constraints do not eliminate the opportunity. They shape sequencing. Reliability-driven and anchor-led segments (particularly industrial/mining-adjacent reliability clusters and larger agri-processing clusters) tend to overcome these hurdles first, followed by access-led portfolios once performance data and aggregation reduce perceived risk. As the market matures, the balance shifts from perceived technology risk toward conventional credit assessment—counterparty risk, contract structure, and portfolio performance.

5. Development and Climate Adaptation and Mitigation Benefits

Beyond the immediate business case for firms and banks, mini-grids in Zambia deliver a concentrated set of development, adaptation, and mitigation benefits that translate into measurable investment outcomes. They improve **access to reliable electricity, support productive use and local enterprise growth, strengthen continuity of service during grid stress, and reduce dependence on diesel and traditional biomass**. Zambia's own mini-grid experience already points to these benefits in rural communities such as Chitandika, while regional evidence from other African markets shows similar gains through cold storage, irrigation, milling, water services, and other productive-use applications (Energy Democracy in Africa, 2023).

These benefits are also relevant from a **gender and inclusion** perspective. In off-grid settings, reliable electricity can reduce time burdens, improve safety, and expand income-generating opportunities for women through lighting, processing, refrigeration, and small-enterprise activity. In grid-adjacent productive settings, the benefit is different: mini-grids help protect women-led businesses, service providers, and workers from the effects of prolonged outages on incomes and operating continuity. At the same time, mini-grids deliver a clear **mitigation co-benefit** by displacing diesel use and increasing the share of electricity supplied from renewables (Wampata & Mwanza, 2021).

Table 6: Development, Climate Adaptation and Mitigation Benefits of Mini-Grids in Zambia

Core benefit	Primary SDG alignment	Secondary SDG alignment	Quantifiable ESG metrics (examples)
Expanded access to reliable electricity	SDG 7 – Affordable & Clean Energy	SDG 10 – Reduced Inequalities	• New connections (HH, SME, public) • Average hours of supply per day • SAIDI / SAIFI or % uptime • Average tariff vs. diesel/kerosene cost
Local economic growth via productive uses	SDG 8 – Decent Work & Economic Growth	SDG 9 – Industry & Infrastructure	• Number of productive-use customers • Share of load from PUE (%) • Jobs created/sustained • SME revenue growth or electricity spend
Diesel and biomass displacement (mitigation co-benefit)	SDG 13 – Climate Action	SDG 12 – Responsible Consumption	• Litres of diesel displaced per year • tCO_2e avoided (annual) • kWh generated from renewables (%)
Climate resilience and drought adaptation	SDG 13 – Climate Action	SDG 11 – Sustainable Communities	• Share of electricity supplied independently of the hydropower-dependent grid • Continuity of service during grid outages • Number of critical productive or service loads maintained during load shedding
Improved health, education & water services	SDG 3 – Good Health & Well-being	SDG 4 – Quality Education	• Clinics/schools/water systems electrified • Cold-chain uptime (%) • Service hours enabled per facility
Gender and inclusive economic participation	SDG 5 – Gender Equality	SDG 8 – Decent Work	• Women-led enterprises connected • Women employed in O&M / customer engagement / sales

			• Time saved or income gains for women-led businesses where data is available
Market building and governance strengthening	SDG 9 – Industry & Infrastructure	SDG 17 – Partnerships	• Operating track record (months/years) • Collection rate (%) • Debt service coverage ratio (DSCR) • Availability of audited performance data

6. Implementation and Scaling Pathway

Mini-grid deployment in Zambia is growing, but the participation of commercial banks at meaningful scale requires a structured approach to identifying, assessing, and managing risks that are unfamiliar to most credit teams. This chapter sets out the steps banks can take independently — and the broader enabling conditions they can support collectively — to put the sector on a durable pathway to scale.

Starting with the Client: Identifying Bankable Demand

A natural entry point for a commercial bank is through its existing client base. Banks already carry credit exposure to load shedding through the cashflows of affected borrowers — in agro-processing, cold chain logistics, manufacturing, and SME estates. Identifying these clients is not a new activity; it draws on relationship intelligence that credit officers already possess.

The strategic question is which clients represent anchor demand that could underpin a viable mini-grid project — and where improved electricity reliability would directly reduce the bank's own probability of default. Four screening questions help prioritize this analysis:

Client Screening: Four Diagnostic Questions

1. Is load shedding creating measurable cashflow stress — through lost production, spoilage, or diesel costs that are material relative to debt service?
2. Can the client commit to a credible offtake arrangement — a minimum-volume energy purchase agreement over a bankable tenor?
3. Is there a cluster of demand nearby — MSMEs, households, or public facilities — that can increase utilisation and support a standalone mini-grid rather than a captive system?
4. Are the permitting and grid-interface requirements for the client's sites feasible within a reasonable development timeline?

Where these conditions align, the bank has both a commercial rationale for engagement and a natural entry point for introducing a mini-grid developer.

A Sequenced Pathway from Engagement to Scale

Building greater understanding of the sector requires a sequenced approach. Banks that attempt to jump directly to long-tenor project finance before establishing the data, relationships, and operational understanding needed typically stall at credit committee. The high-level pathway is one banks could follow. It is structured in three stages, each building the foundations for the next.

Table 7: 3 stages of the implementation pathway

Stage 1 - Identify	Stage 2 - Structure	Stage 3 - Scale
Sub-step 1a: Map portfolio exposure of clients to load-shedding	*Sub-step 2a:* Engage experienced mini-grid developers and EPC's. Develop standard documents	*Sub-step 3a:* Build portfolio facilities for financing to lower transaction costs
Sub-step 1b: Select 5–10 anchor clients who may be suitable mini-grid anchors	*Sub-step 2b:* Size debt against stress-tested cashflows	*Sub-step 3b:* Access refinancing windows
Sub-step 1c: Screen for offtake readiness, ensuring there is sufficient load demand	*Sub-step 2c:* Engage first-loss facilities (for example G4A / ElectriFi)	*Sub-step 3c:* Track benchmarked performance
		Sub-step 3d: Publish performance track record

Stage 1 - Identify: Building the Client Pipeline

- Map portfolio exposure: identify sectors and borrowers where outages are driving arrears, covenant breaches, or repeated restructures. Agro-processing, cold chain, and SME estates are the highest-priority starting segments in the Zambian context.
- Select 5–10 anchor prospects: prioritise clients with concentrated and predictable demand, demonstrated diesel spend, and the organisational capacity to negotiate and honour an offtake arrangement.
- Offer targeted bridge products: once a client has been identified as an anchor candidate, short-tenor working capital for energy-service payments and equipment finance for productive loads (efficient motors, cold rooms) can deepen the relationship, improve mini-grid utilisation, and generate cashflow data relevant to credit underwriting.

Stage 2 - Structure: Building the Transaction Toolkit

- Partner with 1–2 experienced developers or EPCs to pre-screen sites, define technical options, and agree a pipeline of candidate projects before committing to formal appraisal processes.
- Develop or adopt standard documentation: concession agreements, offtake contracts, EPC terms, and O&M service arrangements based on recognised international templates reduce per-transaction legal costs and accelerate credit approvals.
- Address currency risk explicitly: mini-grid revenues are denominated in kwacha while equipment costs and most DFI facilities carry dollar exposure. The bank's credit structure must either hedge this mismatch, allocate it to a counterparty with natural dollar revenues, or size debt conservatively enough to absorb depreciation scenarios. This is a first-order underwriting question in Zambia's current macroeconomic environment, and cannot be treated as a footnote.
- Access first-loss and guarantee facilities: the Green for Access First Loss Facility (G4A) provides first-loss protection for up to 20% of losses in a portfolio of energy-access loans for local financial institutions. ElectriFi offers comparable first-loss and guarantee instruments. Both allow banks to extend tenors and improve leverage ratios while managing capital at risk within board appetite.

Stage 3 - Scale: Portfolio Facilities and Refinancing

- Once a track record of ~18–24 months of operating performance has been established across a minimum cluster of projects, move from project-by-project credit assessment to portfolio facility structures with standardised eligibility criteria and streamlined approval.
- Use audited performance data — collection rates, system uptime, battery degradation — to access refinancing from DFIs and development banks at longer tenors and lower cost, rotating bank capital into new origination.
- Publish anonymised performance benchmarks, perhaps through AMDA's Zambia chapter or the ERB data platform to build market confidence and support peers entering the sector.

Accessing External Technical Support

As banks build sector knowledge, they can access dedicated technical assistance programmes designed specifically for local financial institutions entering the energy-access market. These reduce the internal investment required to develop credit frameworks, operational due-diligence tools, and portfolio monitoring systems. Examples are shown in the table below.

Table 8: Programmes/Institutions and their relevance for Zambian Banks

Programme / Institution	Relevance for Zambian Banks
Mission 300 TA Facility	World Bank-managed programme supporting financial institutions in Sub-Saharan Africa to develop mini-grid lending products; includes transaction support, legal template development, and staff training
GEAPP Local FI Window	Global Energy Alliance for People and Planet; provides grant-funded technical assistance alongside co-investment in qualifying portfolios; well-suited for Zambian banks building first transactions

AFD Group	Agence Française de Développement offers concessional credit lines and technical assistance specifically for financial sector engagement in distributed renewable energy
AMDA / ZREA	The Zambia chapter of the Africa Minigrid Developers Association and the Zambia Renewable Energy Association provide access to developer networks, performance data, and emerging regulatory guidance

Broader Enabling Conditions: What the Industry Must Build

Individual bank action is necessary but not sufficient. The constraints set out below require coordinated responses from regulators, developers, development partners, and banks acting collectively. For each, we identify both the structural issue and the specific step banks are positioned to take or advocate for.

Regulatory Certainty

For a commercial bank, regulatory certainty is a precondition of bankability — not merely a desirable feature. Lenders consistently prioritise the enforceability and durability of revenue arrangements over the level of tariffs themselves. In the Zambian context, the most material unresolved questions are: the treatment of grid arrival and asset compensation, the clarity of tariff approval processes under ERB jurisdiction, and the conditions under which licences can be terminated or transferred.

From a credit perspective, these questions define whether cashflows are legally defensible over the full loan tenor and whether terminal asset value is exposed to political or regulatory intervention. Until they are resolved, lenders will compensate through shorter tenors, lower leverage, and higher pricing — all of which erode project viability.

> **What banks can do**
>
> Prioritise projects where tariff arrangements and regulatory status are already clearly documented in concession or licensing agreements.
>
> Engage collectively — through the Bankers Association of Zambia alongside AMDA — to seek explicit treatment of grid-arrival risk in standard licensing terms. Individual bank engagement with ERB carries limited weight; coordinated advocacy from the financial sector does.
>
> Work with developers to standardise regulatory submissions, reducing approval delays that create execution risk for both parties.

Technical and Commercial Performance Data

Banks lend against observed performance, not modelled projections. The absence of credible, independently verified performance data for Zambian mini-grids can be a constraint on credit assessment. Two categories of data are likely to matter for underwriting, and both must be addressed:

- Technical performance data: system uptime, technical losses, battery degradation rates, and warranty claim frequency. These allow lenders to assess technology risk and model realistic generation profiles rather than relying on manufacturer specifications.
- Customer revenue data: payment collection rates disaggregated by customer class, churn rates, and consumption growth trajectories. In mini-grid cashflow models, revenue risk typically dominates over technology risk. Lenders need evidence on customer behaviour — not just system performance — to size debt confidently.

Strong precedents for how performance data can unlock lending exist in Nigeria's Electrification Project (NEP) and Tanzania's REA geospatial platform. Both demonstrate that a credible, accessible data infrastructure materially reduces perceived risk and enables more competitive financing structures.

What banks can do

- Advocate — through AMDA's Zambia chapter and ZREA — for the establishment of a national mini-grid performance database, building on data already collected by the ERB, with standardised reporting requirements for systems benefiting from public or DFI support.
- Require transparent, audited performance reporting as a condition of financing, and share anonymised data into the central platform to build the market-level evidence base.
- Develop internal benchmark tools for calibrating DSCR assumptions, production estimates, and cashflow stress tests — and share methodology with peer institutions to accelerate sector-wide capability.

Contract Standardisation and Risk Allocation

Contractual clarity and standardisation reduce transaction costs, accelerate credit approvals, and make portfolio financing feasible. Commercial lenders strongly prefer mini-grid projects that rely on established templates for concession agreements, anchor-load offtake contracts, EPC arrangements, and O&M services.

Key structural issues that must be addressed in each transaction include:

- Currency exposure: as noted above, the kwacha/dollar mismatch must be explicitly allocated and structured, not left as residual risk within the project cashflows.
- Change-in-law and tariff adjustment provisions: contracts must include credible mechanisms for passing through regulatory changes to revenue without triggering lender default events.
- Termination and force majeure: clauses must align with precedents that lenders' legal teams understand and that have been tested in comparable jurisdictions.
- Battery replacement reserves: as mini-grid battery systems approach end-of-life, the absence of a funded replacement reserve is increasingly a credit risk. Lenders should require evidence of a reserve account or a manufacturer-backed replacement pathway — and note that battery recycling obligations are an emerging regulatory and ESG issue that will need to be addressed as the sector scales.

What banks can do

- Access first-loss and guarantee instruments from G4A and ElectriFi to improve bankability at the transaction level while managing capital at risk within board appetite.
- Develop or adopt standard term sheets and due-diligence checklists for mini-grid transactions, reducing per-transaction legal and appraisal costs to a level compatible with smaller deal sizes.
- Engage AMDA and development partners to develop Zambia-specific contract templates based on international precedents from comparable markets.

Long-Term Market Signals and Pipeline Visibility

Deeper engagement by local banks requires visible and credible pipeline — not just individual transactions, but a sense of the volume and sequencing of future opportunities that justifies the internal investment in sector expertise. Recent signals from the Zambian government are encouraging: the Presidential commitment to electrify 1,000 communities and the expansion of mini-grid deployment through ZEDSI provide an important anchor for lender confidence.

What banks still lack is explicit segmentation between off-grid markets, grid-weak markets, and areas scheduled for grid extension — a distinction that directly affects the regulatory risk profile and viable tenor of any individual transaction.

What banks can do

- Engage with the Ministry of Energy and ZESCO to advocate for published geospatial zoning that distinguishes off-grid, grid-weak, and grid-extension priority areas — reducing stranded-asset risk and enabling more precise pipeline planning.
- Participate in AMDA pipeline forums and ERB licensing data releases to build internal knowledge of the development pipeline before it reaches formal appraisal.

Local Operations, Maintenance, and Service Capacity

A mini-grid's creditworthiness depends not only on its design, but on its ability to continue operating reliably in remote or resource-constrained environments. Lenders who underweight O&M risk in their initial credit assessment frequently encounter revenue interruptions — and, in severe cases, collateral impairment — when systems experience extended outages due to component failures, battery degradation, or metering faults.

From a credit perspective, adequate O&M capacity means more than a service agreement on paper. Lenders should verify:

- Minimum response-time commitments for critical system failures, with contractual escalation provisions.
- Local spare-parts inventory or guaranteed supply chain access for components with high failure probability.
- A funded battery replacement reserve, with a clear technical plan for end-of-life cycling consistent with the loan tenor.
- Clarity on battery disposal and recycling obligations — an issue of growing commercial and regulatory significance as the sector scales, and one that ERB is likely to address formally in the medium term.

What banks can do

- Include O&M standards and response-time commitments as explicit conditions of drawdown in loan documentation, not as optional covenants.
- Engage with the regulator to encourage minimum O&M standards as a condition of licensing — creating a level playing field and reducing the risk of sub-standard operators undermining market confidence.
- Treat battery replacement reserve accounts as a required structural feature of mini-grid project finance, equivalent to standard debt-service reserve accounts.

The pathway described in this chapter is incremental by design. Banks that attempt to deploy large-scale project finance before establishing client relationships, operational understanding, and access to the enabling conditions above will find the sector harder than it needs to be. Banks that begin with the client — and build systematically from there — will find that the risks are manageable, the market signals are positive, and the opportunity to grow a differentiated financing franchise in a structurally undersupplied market is real.

RESOURCES

This brief directly builds on the following technical reports:

- GCA (2026), Rapid Climate Risk Assessment and Adaptation Investment Opportunities Mapping in Infrastructure, Energy and Manufacturing, Tanzania Country Report. Developed in cooperation with partners including CGAP, and consulting firm: Pegasys.

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APPENDIX

ANNEX 1. MARKET OPPORTUNITY

Growth Drivers: Why the Market Expands Through 2030

The expansion of Zambia's mini-grid market is being driven by **concrete, observable shifts in the power system and the real economy**, rather than abstract energy-transition narratives. These drivers are already shaping investment decisions today and are expected to intensify over the remainder of the decade.

Persistent service gaps driven by system adequacy and reliability stress

A defining feature of Zambia's electricity landscape is that grid connection does not always guarantee reliable supply. The country remains heavily dependent on hydropower, accounting for over **85%** of electricity generation in recent reporting (IEA, 2024). This structural reliance increases exposure to rainfall variability and reservoir levels.

The **2023/24 El Niño** drought made that exposure tangible. Reduced water availability translated into generation shortfalls, prompting explicit acknowledgement from government and system operators of emerging supply deficits. **A June 2024 statement from the Ministry of Energy** outlined the drought's impact on the power sector, while ZESCO issued successive power rationing schedules, including a revised schedule effective August 2024, reflecting sustained system-level constraints rather than isolated technical outages. (Ministry of Energy, 2024)

Public reporting and utility communications during this period documented extended load shedding in several areas, with electricity rationed to only a few hours per day in some cases (News24, 2024). For households and businesses, the distinction between being grid-connected and having dependable power became increasingly blurred. In this environment, **reliability has shifted from a peripheral concern to a core economic variable**, particularly for enterprises exposed to production losses, equipment damage, or rising diesel backup costs.

Productive demand anchored in Zambia's real economy, not pilot projects

Zambia's mini-grid opportunity is increasingly shaped by **productive-use loads that already sit at the core of the economy**. **Mining** remains central, contributing roughly **15% of GDP** and accounting for around **70% of export earnings** (IFC, Dec 2024). It is also one of the country's largest electricity-consuming sectors. In mining-adjacent and edge-of-grid zones, reliability is not a marginal issue; it directly affects production schedules, equipment performance, and operating costs. Zambia's copper expansion ambitions and recent production momentum suggest that mining-related activity and supporting services will continue to grow through this decade (World Bank, 2025). Where grid reinforcement does not keep pace, the need for dependable power is unlikely to diminish. In the context of this brief, the relevant opportunity is not captive power for a single mine, but multi-user reliability clusters in mining-adjacent zones where a primary industrial load can be complemented by contractor operations, service SMEs, and nearby settlements within a defined distribution footprint.

Agriculture presents a parallel story. The sector employs approximately **70%** of the population (Zambia Development Authority, Dec 2024) and **value chains are gradually shifting toward value-added activities** such as milling, storage, cold-chain logistics, and primary processing. These functions are power-dependent and frequently located beyond consistently reliable grid corridors. As these value-added segments expand, electricity demand becomes more concentrated and more commercially sensitive, particularly in agro-processing clusters.

The result is that mini-grid demand in Zambia is increasingly anchored in **existing productive activity**, rather than stand-alone pilots. Where electricity reliability directly affects output and income, willingness to pay is structurally stronger, and the case for decentralized supply becomes commercially grounded rather than programmatic.

Grid expansion plans create timing gaps that decentralized solutions can fill

Zambia's grid expansion agenda is active and ambitious, but delivery is constrained by sequencing and throughput, particularly in distribution reinforcement and last-mile extension beyond major urban corridors. The World Bank documentation for the Electricity Service Access Project notes that progress on grid extension and reinforcements has been slower than anticipated due to contracting and safeguards delays, compounded by shipping disruptions (World Bank, 2017). At the same time, national planning documents point to a substantial pipeline of rural energy interventions, including 149 mapped grid and off-grid projects for 2026 (ESI, 2026). The ambition is clear, but implementation unfolds over multiple years.

For communities and productive clusters outside consistently reliable corridors, this creates a window of uncertainty. A connection may be planned, yet dependable service remains some distance away. In that interval, mini-grids are not competing with the grid but complementing it. They can be deployed more quickly in low-density or hard-to-reach areas and can stabilize supply in secondary towns and edge-of-grid zones where reliability, rather than connection status, is the binding constraint. As regulatory processes have become more structured through ERB licensing and tariff guidance, the pathway for such deployments has become clearer, improving the case for interim and potentially long-term decentralized solutions.

Policy reform and program pipelines are moving from pilots to scale

Zambia's institutional approach to mini-grids has shifted from isolated pilot projects toward more structured, program-based deployment. The Rural Electrification Authority has increasingly focused on site prioritization and coordination between grid and off-grid planning, improving visibility for developers and reducing origination uncertainty. Recent program mechanisms such as the Zambia Energy Demand Stimulation Initiative (ZEDSI) have explicitly shifted support toward multi-site developer portfolios, including funding agreements covering dozens of mini-grid sites.

This direction is reinforced by donor-backed initiatives designed to crowd in private capital at scale. Under electrification and mini-grid acceleration programs supported by the Rockefeller Foundation, developers including ENGIE Energy Access, OnePower Zambia and Renwasol have entered into results-based and incentive-linked agreements to develop multi-site portfolios rather than stand-alone projects. The emphasis on standardized technical designs, aggregation and repeatable commercial structures lowers transaction costs and supports portfolio-level financing. Together, these reforms point to a market that is gradually consolidating around structured pipelines rather than one-off demonstrations.

Delivery-side maturation and declining execution risk

Zambia's mini-grid ecosystem has moved beyond isolated demonstration projects toward more repeatable deployment. Several developers now operate with standardized PV–battery configurations, modular distribution layouts and established O&M practices, reducing variability in construction timelines and system performance.

ENGIE Energy Access has expanded from early flagship installations in Eastern Province into a broader multi-site rollout strategy supported by structured financing, signaling confidence in portfolio economics and operating stability. At the same time, developers such as OnePower Zambia and Renwasol are advancing pipelines under results-based incentive frameworks, indicating that delivery capacity is no longer concentrated in a single actor. Local EPC capability, improved site origination processes and greater commercial standardization have shortened development cycles and reduced execution uncertainty.

Challenges remain, especially in remote locations, but the overall trajectory points toward a market that is increasingly **standardized, replicable, and portfolio-ready**. The practical implication is lower perceived execution risk for financiers, supported by clearer O&M models, more repeatable system designs, and greater confidence in multi-site deployment.

Binding Constraints: What Limits Realization (and why uptake is uneven by segment)

The market opportunity is substantial, but rollout through 2030 is shaped by a handful of practical constraints that are already visible on the ground in Zambia. These factors explain why deployment scales progressively rather than immediately converging on the full addressable market, and why certain segments advance faster than others.

Delivery capacity and implementation throughput

Even where demand is evident, deployment depends on execution bandwidth. Site origination, logistics, EPC mobilization and coordination with district authorities all take time. Zambia's broader electrification efforts have experienced procurement and safeguards-related delays in major access programs (World Bank, 2025), underscoring that infrastructure roll-out is rarely frictionless.

For mini-grids, these constraints are most pronounced in **remote rural communities**, where transport distances are longer, site sizes are smaller and local processes take time to complete. By contrast, **productive and edge-of-grid sites** tend to move faster. Loads are concentrated, distribution networks are more compact, and projects can often be bundled under a single developer platform, improving throughput. This is one reason realized deployment tends to tilt toward anchor-led and reliability-driven sites over time as they are typically **faster to originate, easier to bundle, and less operationally fragmented** than smaller remote community deployments.

Subsidy and affordability gaps (especially for access-led segments)

A second constraint lies in the **affordability gap** that characterizes access-focused deployments. In many rural communities, tariffs that fully recover capital and operating costs are difficult to sustain without catalytic support such as **results-based financing (RBF)**, capital grants, or other forms of concessional support. Zambia has taken visible steps to address this through mechanisms such as **ZEDSI**, launched in November 2024 under the Universal Energy Facility platform to stimulate demand for mini-grids and productive use of electricity (Sustainable Energy For All, 2024).

However, the near-term funding envelope remains modest relative to the scale of the opportunity. For example, a June 2025 ZEDSI funding round awarded **~USD 1.1 million** across multiple developers to support the development and operations of **43 mini-grids** (Rockefeller Foundation, 2025). This is an important signal of momentum, but it also highlights that sustained and predictable catalytic capital will be required for large-scale acceleration. The constraint is not only the absolute amount of subsidy, but also its predictability, since developers and lenders need multi-year visibility on RBF and grant windows to originate and finance portfolios at scale.

The constraint is therefore most binding in **rural community and social infrastructure segments**, and less so in industrial or agri-processing contexts where ability to pay is stronger.

Cost of capital, FX exposure, and macro-volatility

Mini-grid economics in Zambia are also sensitive to macro conditions. Core equipment and battery systems are typically priced in hard currency, while revenues are denominated in kwacha. This creates a structural **FX mismatch**, particularly during periods of depreciation. Zambia has experienced elevated inflation and currency pressures in recent years, with IMF reporting inflation averaging around **15%** in 2024 and noting ongoing depreciation dynamics. Tighter monetary conditions have kept interest rates elevated, increasing local-currency financing costs (IMF, 2025). This pushes the market toward blended structures such as local-currency lending where possible, concessional layers to absorb FX shocks, and portfolio facilities that can diversify risk across sites rather than leaving each project to carry macro volatility on its own.

These factors narrow the set of projects that can proceed without risk-sharing mechanisms and again favour segments with higher revenue density and stronger anchor loads. Smaller, dispersed systems are more exposed to these pressures unless structured within blended finance arrangements.

A policy enabler that helps but does not remove the constraints

Recent regulatory reform in Zambia has reduced one friction point. The threshold for licensing exemption has been increased to projects up to 5 MW under recent regulatory changes (Africa AMDA, 2024), lowering entry barriers and simplifying development processes for many sites. This improves pipeline conversion once financing and execution capacity are in place.

However, licensing reforms alone do not eliminate the structural constraints described above. It reduces administrative burden, but delivery bandwidth, subsidy dependence and macro exposure remain the primary determinants of rollout pace.

A parallel constraint in anchor-led segments is concentration risk, where one or two large users dominate demand, bankability depends on the anchor's credit quality and durable demand/offtake arrangements, often requiring guarantees or portfolio diversification to make projects financeable.

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