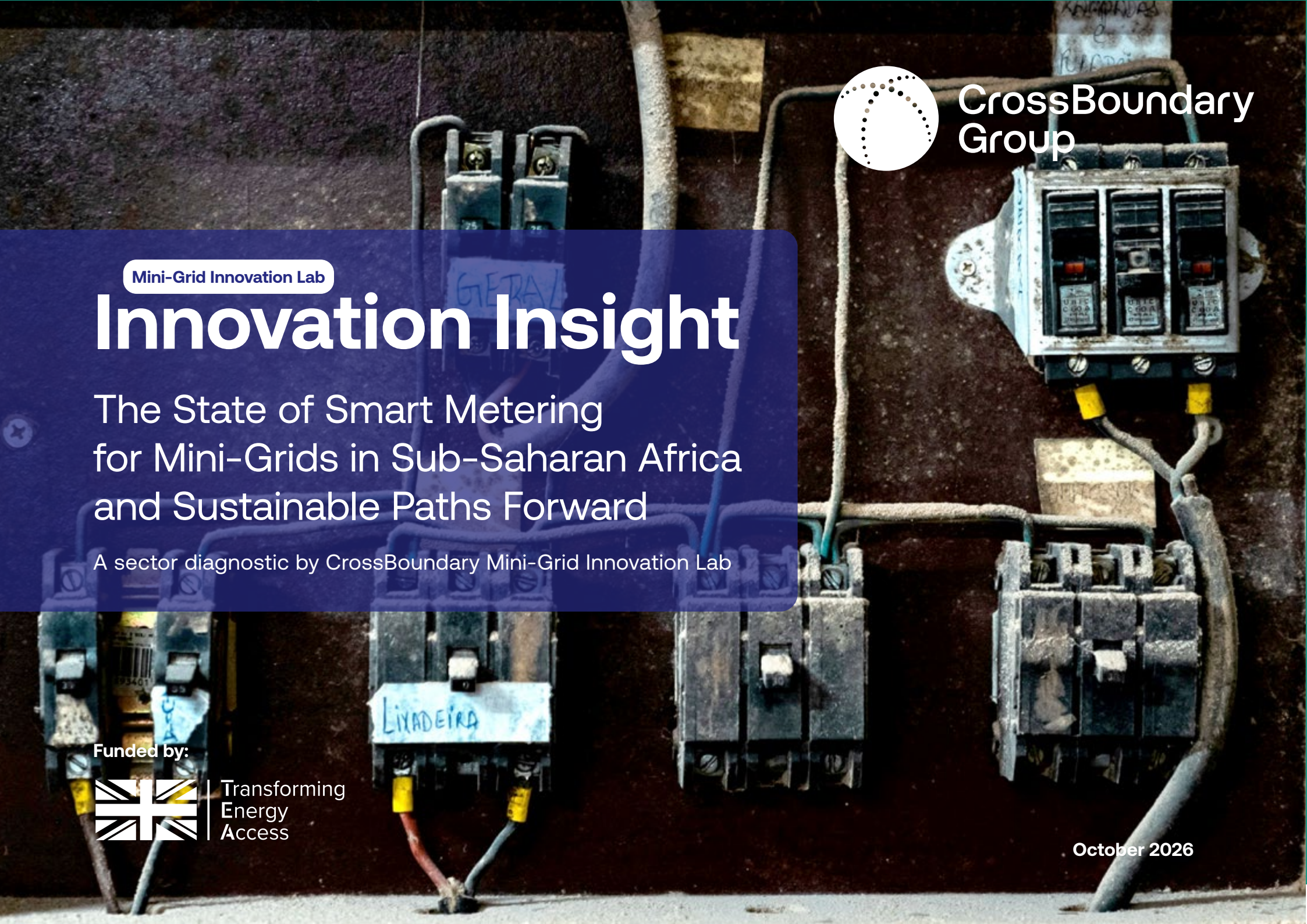

CrossBoundary Group

Mini-Grid Innovation Lab

Innovation Insight

The State of Smart Metering for Mini-Grids in Sub-Saharan Africa and Sustainable Paths Forward

A sector diagnostic by CrossBoundary Mini-Grid Innovation Lab

Funded by:

Transforming Energy Access

October 2026

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Funded by:

CrossBoundary Advisory

Transforming Energy Access

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Context Setting

This diagnostic of the mini-grid metering sector is grounded in market conversations. It synthesizes how the sector got here, what efforts are underway, and our own analysis and recommendations. It is a conversation starter, not an exhaustive study.

Who we are

CrossBoundary's Mini-Grid Innovation Lab produced this document from a developer-driven perspective, in line with our mandate to improve the mini-grid business case. We write as an independent party synthesizing the sector's own views, seeking to bring the sector together on critical issues, without speaking for any single developer, funder, or meter supplier.

What this document is

- A diagnostic of the sector as of October 2026, consolidating what we heard across 35+ stakeholder discussions
- An aggregation of perspectives from across the market, presented as our current assessment rather than a final position
- A conversation starter, intended to align the sector on a shared reading of the problem and to invite challenge
- Early, actionable business intelligence; directional insight the sector can act on now
- A floor to build from — a shared minimum rather than a fixed endpoint

What this document is not

- Not exhaustive. It is an aggregation of our conversations and research, not a complete census of every market, meter, developer, or data point
- Not academic or peer-reviewed research, and not audited. Figures are indicative, drawn from interviews and the data available to us
- Not a single prescription for the whole sector
- Not an endorsement of any specific vendor, product, or funder, and not investment, legal, or procurement advice

How we got here (methodology)

- 35+ semi-structured discussions with mini-grid developers; funders and Development Finance Institutions (DFIs); meter suppliers, including international Original Equipment Manufacturers (OEMs) and local producers; sector bodies; and ecosystem implementers
- Bottom-up cost modeling of meter hardware and software, tested against the per-connection costs suppliers report today and cross-referenced against the Lab's own field tests with developers

About our recommendations

- Developers vary widely in their capacity to run a metering back end, from those who can self-manage to those fully dependent on a managed service. We scoped our recommendation to the least developed end of that range, so it works as a baseline every operator can build on regardless of their in-house capability
- The market is bifurcating, with developers running different strategies suited to different markets, funders, and revenue sources. Our recommended pathway sets a shared minimum that each of those strategies can build on

This diagnosis of the sector is a precursor to future research we will conduct to test our hypotheses, including fieldwork with local developers focused on the MVP and its target economics.

Executive summary

The mini-grid metering sector is at a structural inflection point. Metering lets developers bill and monitor consumption remotely, and gives funders independent verification of site activity, but it is also a major cost driver, reaching up to 15% of capex and up to 64% of opex per connection. **The sector now faces a skewed household-level cost-benefit trade-off and performance issues that are hurting operations and reliability.** These pressures, combined with delayed mini-grid rollout at scale, have driven the collapse of the smart-meter companies that built and sustained the market for over a decade, leaving 250,000 connections at risk of losing power and the sector to determine its next steps.

A consortium by A2EI, EnAccess, the National Rural Electric Cooperative Association (NRECA), with support from the Africa Minigrid Developers Association (AMDA) and OpenAMI is implementing a two-track plan. A Funders Group is being convened to coordinate funding for the plan, with RF Catalytic Capital (RFCC) funding the first track to date*. The first track stabilizes existing infrastructure for six months and releases the legacy vendors' metering code to the market; the second would develop an Open Metering System (OMS) to enable interoperability across metering solutions and encourage innovation.

As these solutions continue in their implementation and development, this research aims to answer two key questions:

1. **What does the minimum viable product (MVP) for mini-grid metering look like?**
2. **What are the paths to sustainability for the sector in deploying this MVP?**

35+ stakeholder interviews suggest demand for a basic meter, priced at $20–$40 per meter with Software as a Service (SaaS) fees <$10 per month per site. Billing, per-household consumption recording (hourly or daily), and remote on/off capability would meet developer and funder needs. **Deploying this MVP at scale may best be achieved by adopting a custom-built mini-grid-specific meter or the Standard Transfer Specification (STS) model historically used by utilities,** though this could still require an open-source software back end to accommodate different locally produced hardware.

While we put forward recommended pathways to deliver this MVP at scale, this is not an exhaustive list; multiple pathways should continue to be explored in parallel to diversify risk. Our preliminary recommended pathways include increased local production of metering solutions and grant-supported open-metering options, alongside enablers such as International Renewable Energy Certificates (I-RECs), cross-subsidies, and import duty relief to reduce costs.

Several open questions remain that would strengthen this analysis and confirm the recommendation. At a minimum, these require further analysis of feature-level costs and benefits, cloud dependency, standardized reporting and achieving local economies of scale. As the Innovation Lab continues to explore solutions to support the sector, we invite collaboration with stakeholders to help achieve long-term sustainability.

*Note: Track 1 covers maintenance, firmware and software update costs, funded by RFCC, with the African Development Bank (AfDB) having covered initial consulting costs; support from Global Energy Alliance (GEA) is under discussion. The Nordic Environment Finance Corporation (NEFCO) has funded the OMS technical description. The Rockefeller Foundation (RF) along with FCDO via the Transforming Energy Access (TEA) platform, CEI Africa and GIZ are also engaged, with several signaling support for Track 2 subject to Track 1 delivering. Discussions are ongoing.

Glossary – Acronyms and abbreviations used in this report

Acronym	Definition
A2EI	Access to Energy Institute
AfDB	African Development Bank
AMDA	Africa Minigrid Developers Association; the sector's convening body for developers, suppliers, and funders
AMI	Advanced Metering Infrastructure; smart meters plus the communications and data systems behind them
BAU	Business as Usual; in this context, continuing today's response of stabilization plus building the OMS
CEI AFRICA	Clean Energy and Energy Inclusion for Africa Foundation
DARES	Distributed Access through Renewable Energy Scale-up; a $750M World Bank mini-grid program in Nigeria
DART	Demand Aggregation for Renewable Technology; a GEA program pooling demand for bulk meter procurement delivered by All On and Odyssey Energy Solutions
DFI	Development Finance Institution; a government-backed lender for development projects
DLMS	Device Language Message Specification; open protocol that allows meters and software from different makers to communicate
FCDO	Foreign, Commonwealth & Development Office (UK)
FX	Foreign exchange; here, the currency risk on recurring payments

Acronym	Definition
GEA	Global Energy Alliance
GIZ	German government development agency (Deutsche Gesellschaft für Internationale Zusammenarbeit)
IP	Intellectual Property
I-REC	International Renewable Energy Certificate; tradable proof of renewable generation, a potential revenue stream
kWh	Kilowatt-hour; unit of energy
MRV	Monitoring, Reporting and Verification; verifying data so it qualifies for carbon credits or I-RECs
MVP	Minimum Viable Product; the basic meter spec (billing, consumption, remote on/off, low cost)
NEFCO	Nordic Environment Finance Corporation
NEMSA	Nigerian Electricity Management Services Agency; sets national utility meter standards
NERC	Nigerian Electricity Regulatory Commission; Nigeria's power-sector regulator
NFC	Near Field Communication
NRECA	National Rural Electric Cooperative Association
OEM	Original Equipment Manufacturer

Acronym	Definition
OMS	Open Metering System; a proposed open platform intended to let meters from different suppliers connect to a shared back-end, reducing vendor lock-in; scope under discussion
PUE	Productive Use of Energy; power for income-generating uses such as mills, welders, or shops
RBF	Results-Based Financing; funding released only after verified results such as new connections
REA	Rural Electrification Agency
RF	Rockefeller Foundation
RFCC	RF Catalytic Capital
SaaS	Software as a Service; recurring subscription fees for the vendor software platform
SKU	Stock Keeping Unit; here, a dedicated mini-grid meter model built to the MVP spec
STS	Standard Transfer Specification; an open, token-based prepaid metering standard used by utilities, works offline
TEA	Transforming Energy Access; the FCDO-backed platform funding this research
USD	United States Dollar
WTP	Willingness to Pay; the $20-$40 per connection developers say they will pay, below market

01

How did we get here?

The metering sector's disruption traces to a decade-long mismatch between vendor business models and the market they served, rather than a failure of the technology itself

1. Mission-driven origins

SparkMeter spun out of EarthSpark, a nonprofit fighting energy poverty in Haiti. SteamaCo emerged from early solar mini-grid work in East Africa.

2016

Both companies sought commercialization

- Though initially capitalized with grant funding, both companies subsequently raised venture capital on the expectation that mini-grid deployment would scale rapidly and built their cost bases accordingly
- Venture capital turned out to be the wrong fit for thin-margin infrastructure serving low-income users. It demanded growth and margins this market could not generate, committing both companies to a trajectory the sector was unlikely to deliver

2. The market shortfall

The addressable market remained a few hundred thousand connections, concentrated among low-income, low-consumption customers

The revenue model couldn't sustain the business

- To meet venture return expectations, both legacy vendors pivoted to a software-first approach in an attempt to vertically integrate, charging SaaS fees of $0.20–$0.60 per customer per month
- Developers, whose own margins were already thin, absorbed them instead, adding up to over $100 per month for a typical site
- The model survived mainly because grant capital flowing into the sector subsidized it, and pressure to survive forced difficult trade-offs as core volumes fell short
- Both legacy vendors pursued diversification, including an expensive push into software for national grid utilities, on the theory that mini-grids alone couldn't generate sufficient recurring revenue, and drifted from purpose-built mini-grid-specific meters toward white-label utility-grade hardware
- This response to low volumes left both companies competing as resellers on margins below 10%.

3. Collapse

The retraction of global aid funding meant grant capital sustaining the model could no longer prop up the sector, leaving SparkMeter and SteamaCo no longer viable

2026

The revenue model couldn't sustain the business

- Proprietary, non-interoperable meters and platforms prevented developers from migrating, leaving 250,000 connections dependent on failing back-end owners
- Prepaid meters gate supply via an internal relay, so losses are staged: developers first lose remote billing, consumption data, and disconnect, then connections are cut off as customers exhaust their credit with no vending platform to top up
- Without alternatives, up to ~1 million people (at 4–6 per connection) were at risk of losing power
- The sector responded with shared commitment to existing customers: mission-aligned buyers acquired both legacy vendors' assets to keep meters supported and lights on
- In September 2025, EarthSpark International rescued the SparkMeter assets (~200,000 meters); its metering subsidiary now runs operations and customer service and is readying an open-source backend, funded for 10 months by private foundations with further funding pending
- Similarly, the merged SteamaCo–Shyft Power Solutions entity has stabilized the cloud software, maintained over-the-air firmware updates, and secured mobile-money and payment integrations to prevent downtime

Why the value equation didn't work for developers, in interviewees' words

The evolution of mini-grid meters:

Metering companies including SparkMeter and SteamaCo primarily sold white-labeled utility-grade meters from Chinese Original Equipment Manufacturers (OEMs), a response to demand volumes too low to justify producing their own mini-grid-optimized meters. These were cheaper to procure but over-specified for mini-grids: rated at 60 amps, certified to national utility standards such as the Nigerian Electricity Management Services Agency (NEMSA), and mostly running proprietary protocols that locked developers into a single vendor. SteamaCo was a partial exception, adopting the Device Language Message Specification (DLMS), an open protocol letting equipment from different manufacturers interoperate, as part of its shift to white-labeled hardware. The result: a market supplied with meters designed for a different customer, priced for a different market, and backed by a support model that doesn't reach the field.

The value of smart metering, in context:

Smart metering offers real strengths: demand management, theft detection, transformer-loading insight, and near-real-time operational data, turning revenue infrastructure into a basis for commercial and operational decisions for a customer base the sector otherwise knows little about. Compatibility with grid codes and future interconnection also widens the demand base and aligns with government direction. But that value scales with consumption, and for the low-consumption households that dominate mini-grid connections, the richer functionality may not justify its cost. This is precisely the trade-off the sector is now confronting.

Adoption was funder-driven instead of value-driven.

Sites are remote, and funders required remotely verifiable consumption data before committing capital. Simpler metering alternatives lacked a software back end suited to funder demands and mini-grid operations.

"Smart metering is the eyes for all developers." - Developer

Developers paid for capability they couldn't monetize.

Smart meters offered granular data that provided greater visibility into communities the sector knew little about, and the opportunity to better incentivize energy usage. However, capturing that value required capital, staff, and risk appetite a low revenue base can't support. Paradoxically, funders asked for far less data than the meters produced.

"The value add of data in the market hasn't yet been well captured." – Funder

Subsidy masked the gap.

Grant flows sustained vendor cost bases that the market alone could not support, so the underlying mismatch surfaced only when aid funding retracted. India shows the counterfactual, where debt-and-equity-funded mini-grids stayed frugal, opting for $10 load limiters over smart meters.

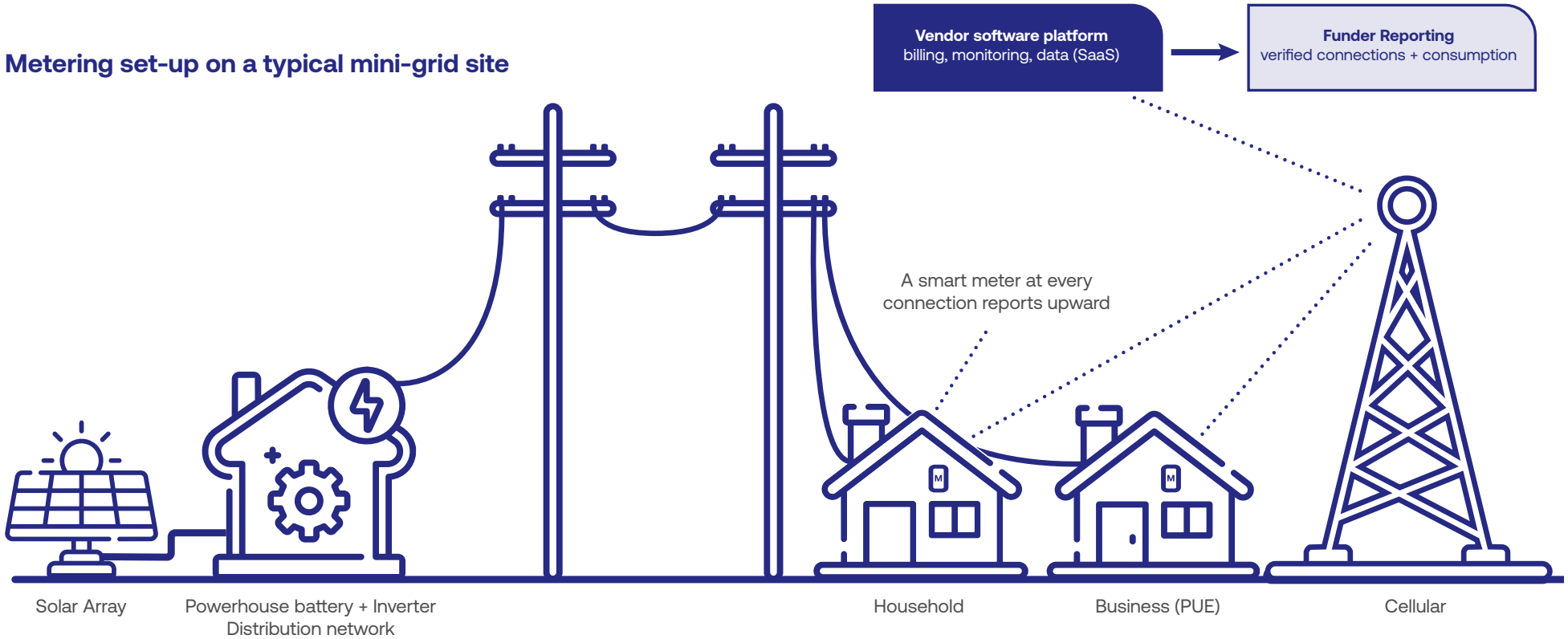
"The sector was heavily subsidized despite being privately structured." – Funder

02

Where does the sector stand today?

What does mini-grid metering look like today?

Metering set-up on a typical mini-grid site



Two communication architectures behind today's mini-grid meters; **radio frequency (RF, e.g., sub-GHz RF mesh or LoRa-based star networks such as LoRaWAN)**, linking meters to the cloud via a data concentrator unit (DCU) or gateway, and cellular (2G/3G) that sends data directly from a sim-card in the meter to the cloud. Neither is universally best: the right choice depends on site density, terrain, gateway placement, network coverage, data frequency, power availability and maintenance capability. See the Appendix for further details.

1. What does the average meter do?

- Prepaid billing and revenue collection (including multicurrency payment integrations)
- Remote on/off switching per connection
- Per-household consumption recording, transmitted over cellular
- Remote monitoring, alerts, and tamper detection
- Utility-grade build: 60A rating, DLMS protocol, grid certification

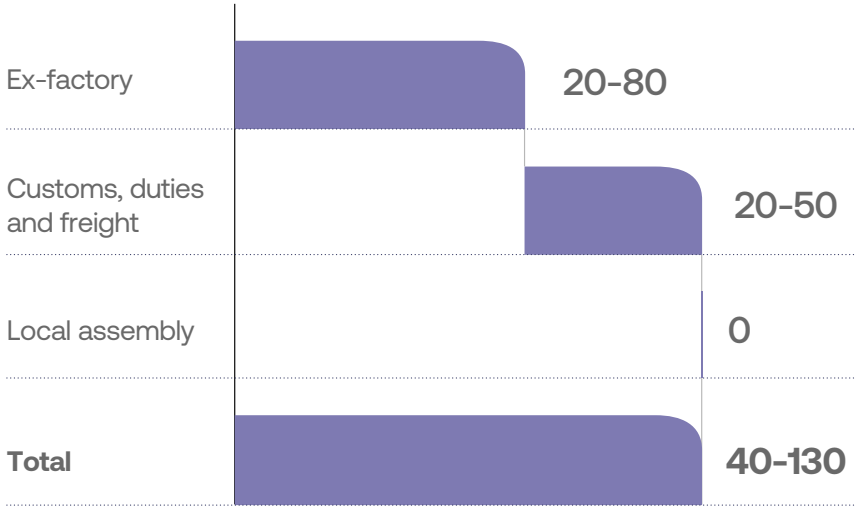
2. Why are meters overly-specified for a low-consumption audience?

- Funders made remotely verifiable data a condition of capital, and because requirements were never standardized, developers bought meters capable of satisfying whatever any funder might ask for
- Remote sites added their own demands: developers needed to disconnect or reconnect customers without traveling to site, which a connected, remotely controllable meter is best positioned to do
- The sector also bought a data story, with granular consumption data promising smarter tariffs and analytics that few developers ever had the capital, time, or risk appetite to take advantage of

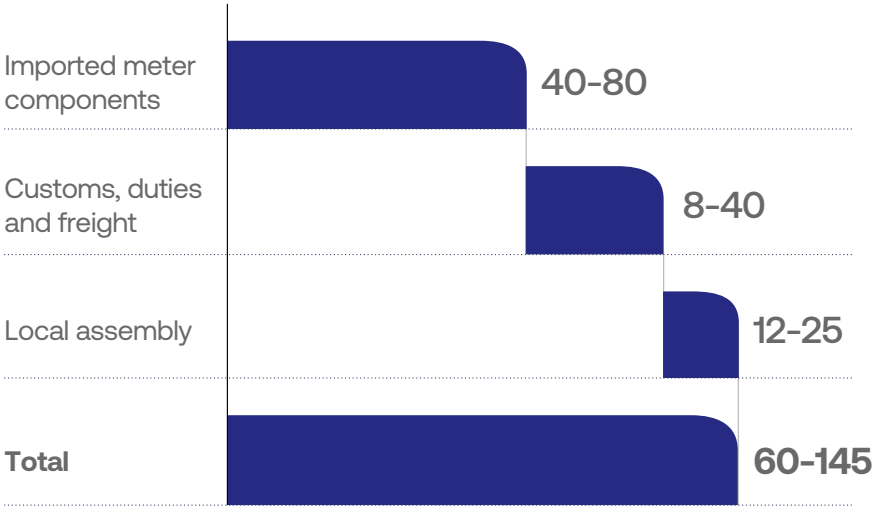
3. What do meters cost today?

Typical cost build-up for basic meter hardware, USD

International OEM



Local production



Assumptions

General - Cost build-up for international and local meter hardware excludes proportional cost of DCUs, antennas and other site-level communications accessories. This cost is sometimes included as part of the SaaS fees depending on supplier.

International OEM meter

Customs and import duties estimated to be up to 40%; landed cost inclusive of air freight which can exceed 60%. Figures most closely reflect Nigeria, Africa's largest mini-grid market.

Local production (SKD/CKD components)

Components include metrology IC, MCU, comms modules, PCBs, enclosures, etc. Cost varies significantly with features, and increases with functionality.

Customs, duties and airfreight are lower than for complete units: estimated at 20–50%, baked into component cost where sourced locally, and varying by geography.

Local assembly cost (labor, testing/calibration, QA, facility overhead) estimated at ~30% of landed hardware cost. Local SKD assemblers interviewed could not provide a costing breakdown for this line.

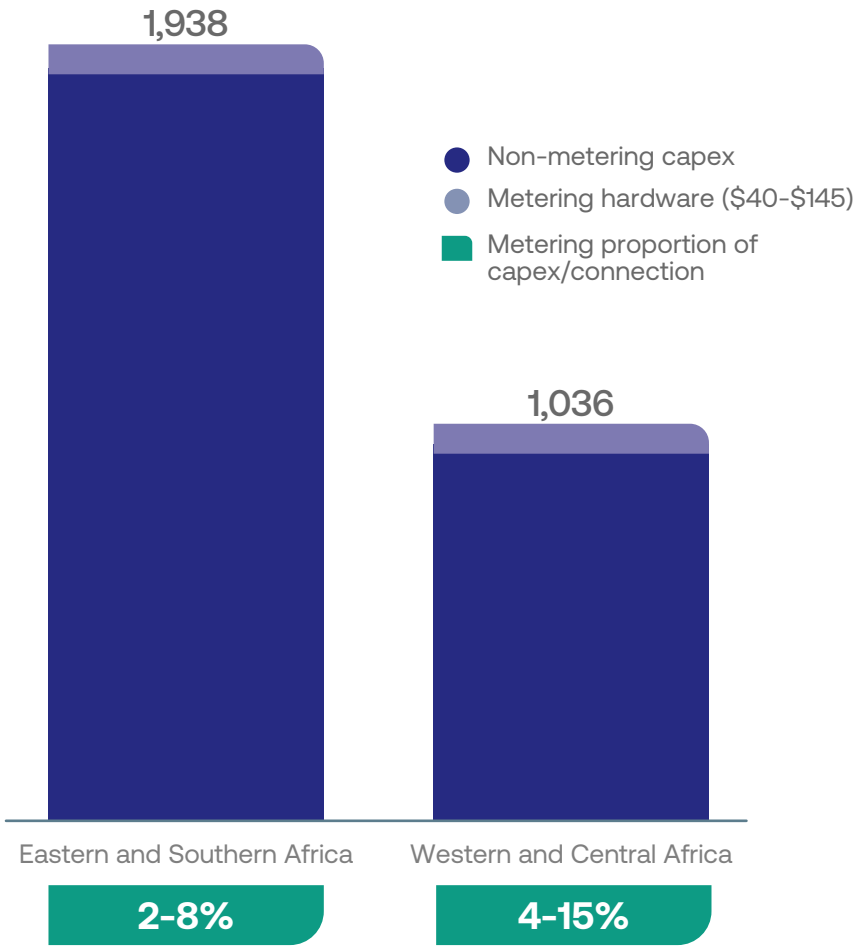
- Locally produced meters tend to be more expensive than OEM-supplied meters at the lower end of the range - local producers rely on imported components and cannot match the economies of scale of international OEMs producing millions of units annually

- In addition to hardware costs, meters attract recurring software fees. These can translate to $0.20–$0.60 per customer per month, regardless of consumption*.

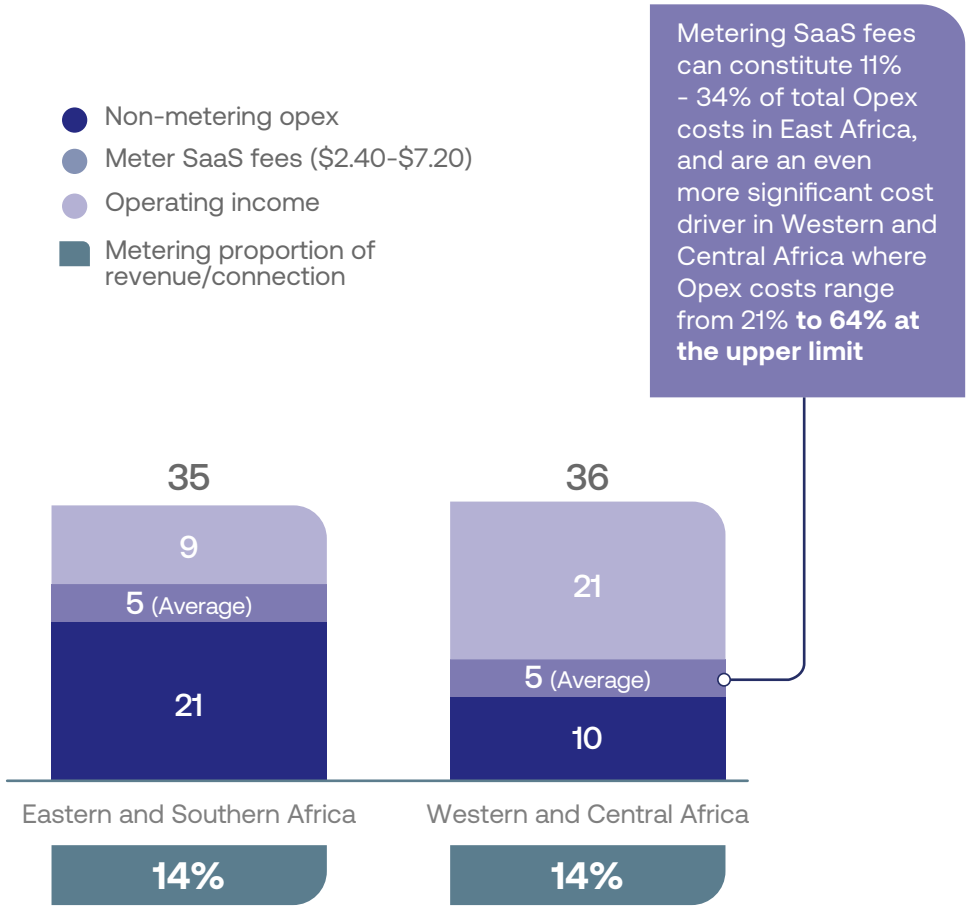
- **Note:** some vendors charge SaaS per site-level server/gateway rather than per meter. **Source:** Meter suppliers, OEM data, Developer interviews, Lab data

Metering hardware can constitute up to 15% of the cost of a connection, and its ongoing SaaS costs can comprise up to 64% of opex per connection

Metering share of per-connection cost by region, USD



Metering opex share of annual revenue per connection, USD

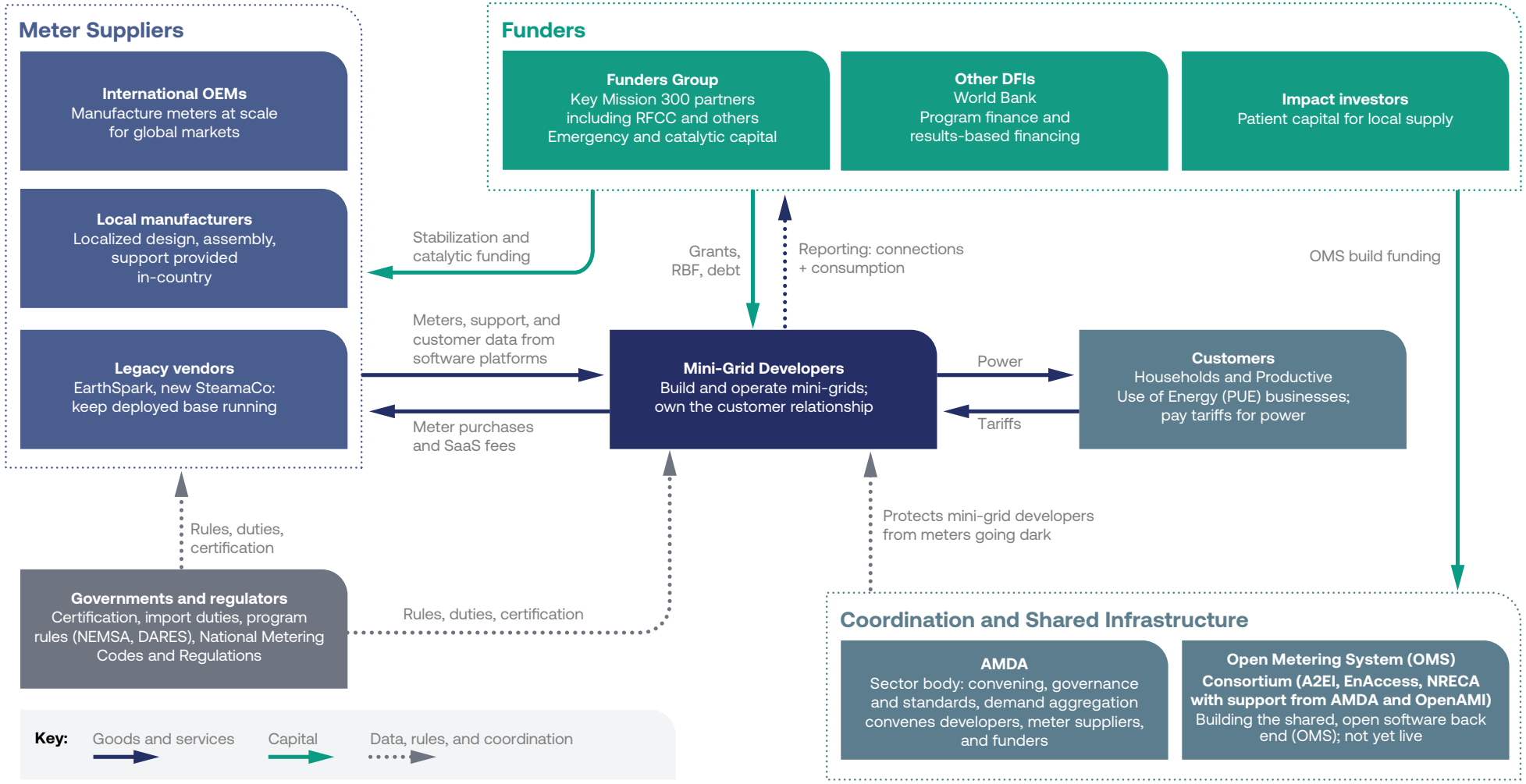


- Meters are a material component in a mini-grid P&L, with **fixed hardware costs (~$40–$145 per connection)** in capex and **recurring SaaS fees (~$2.40–$7.20 per connection)** in opex
- The latest sector-wide benchmarks from AMDA reflect a higher average capex per connection in Eastern and Southern Africa (~$1,938) than in Western and Central Africa (~$1,036), driven by differences in community make-up (rural concentration, population density, remoteness)
- Lab data from four different meter suppliers show that fixed metering hardware costs constitute a smaller share of the higher-capex Eastern and Southern Africa base (up to 8%) and a larger share of the lower-capex Western and Central Africa base (up to 15%)
- Metering's share of opex is larger than its share of capex, as fixed SaaS fees weigh more heavily against a smaller annual revenue base
- This has a meaningful impact on mini-grid economics: average annual revenues per connection are ~$35 for Eastern and Southern Africa, and ~$36 for Western and Central Africa, meaning ~14% of revenues are required to cover SaaS fees at an average cost of ~$5 per connection

Assumptions: Based on average annual revenues per user per month for households and businesses of $2.5 and $5.2 respectively for Eastern and Southern Africa, and $2.0 and $10 respectively for Western and Central Africa. Household to business split of 86% and 14% in Eastern and Southern Africa; 88% and 12% in Western and Central Africa.

Sources: AMDA, Benchmarking Africa's Minigrids 2024. OEM Meter hardware costs from CrossBoundary field testing with Developers

Who shapes the mini-grid metering sector?



What are the challenges with meters today? According to 10 developers...

Operational Challenges

Unreliable connectivity

Meters fail to sync in low-network areas (further detailed in the Appendix, pp. 53–56), leaving developers without consumption data for extended periods and forcing daily manual site restarts. When data finally syncs, it arrives lumped together and cannot be disaggregated by time of use, undermining billing accuracy and funder reporting. However, our field data shows data connectivity varying up to 4.5x between sites using the same OEM, suggesting that site conditions and network coverage influence connectivity as much as the choice of meter.

OEM hardware uncustomized for local environment

Developers report routine damage and failure from rain, lightning and storms. Some attribute this to utility-grade meters designed for grid environments and to component cost-cutting. In practice, failures are multi-factorial: installation quality, enclosure design, surge protection, gateway placement, network coverage, specification, quality control and after-sales support all play a role. Purpose-built, weather-resistant designs remain scarce.

No in-country repair, replacement, or support

Smart meters often cannot be repaired in the field because damage can compromise security and calibration integrity, rendering the device unlawful for tariffed purposes, so faulty units must be replaced from spare stock that few meter suppliers hold in country. One developer shared they are left waiting up to a month for a replacement. Support is remote-first, with developers as the first line of support and local vendor presence emerges only past a soft density threshold (~25,000 meters in a region according to one of the largest meter suppliers).

Note on unreliable connectivity: Where prepaid credit is held and enforced at the meter (e.g., STS), a communication failure should mean a temporary loss of visibility, not of revenue; the cut-offs above arise where top-ups and balance updates depend on the link.

Eroding customer trust

Syncing delays push customers into negative balances and abrupt disconnections, creating disputes over consumption they cannot verify themselves. Developers forgive balances and absorb lost revenue to preserve relationships in tightly connected communities where reputation spreads.

Proprietary vendor lock-in

Each vendor's meters run only on its own platform, so a hardware choice binds the developer to that vendor's software, fees, and survival. When SteamaCo and SparkMeter collapsed, developers had no way to migrate 250,000 deployed meters to an alternative platform.

Financial Challenges

SaaS fees that outrun revenue

Recurring fees of $0.20–$0.60 per customer per month added up to upwards of $100 per month for the average developer and could not be passed on to low-income users. Developers absorb them directly, and in some cases fees exceed what households pay for power itself.

High hardware costs, exacerbated by import costs

Basic meters costing $20 ex-factory reach $40 after customs, import duties and freight costs, while vendor margins sit below 10% across the chain. Once software, repairs and replacements are accounted for, an illustrative 10-year lifecycle cost per operational connection is roughly $80–$240, before installation and integration labor (Appendix pg.57). Actual costs vary with supplier, communication architecture, software model, replacement rate and support arrangements. Developers report willingness to pay of $20 to $40 per connection, below what the market currently delivers.

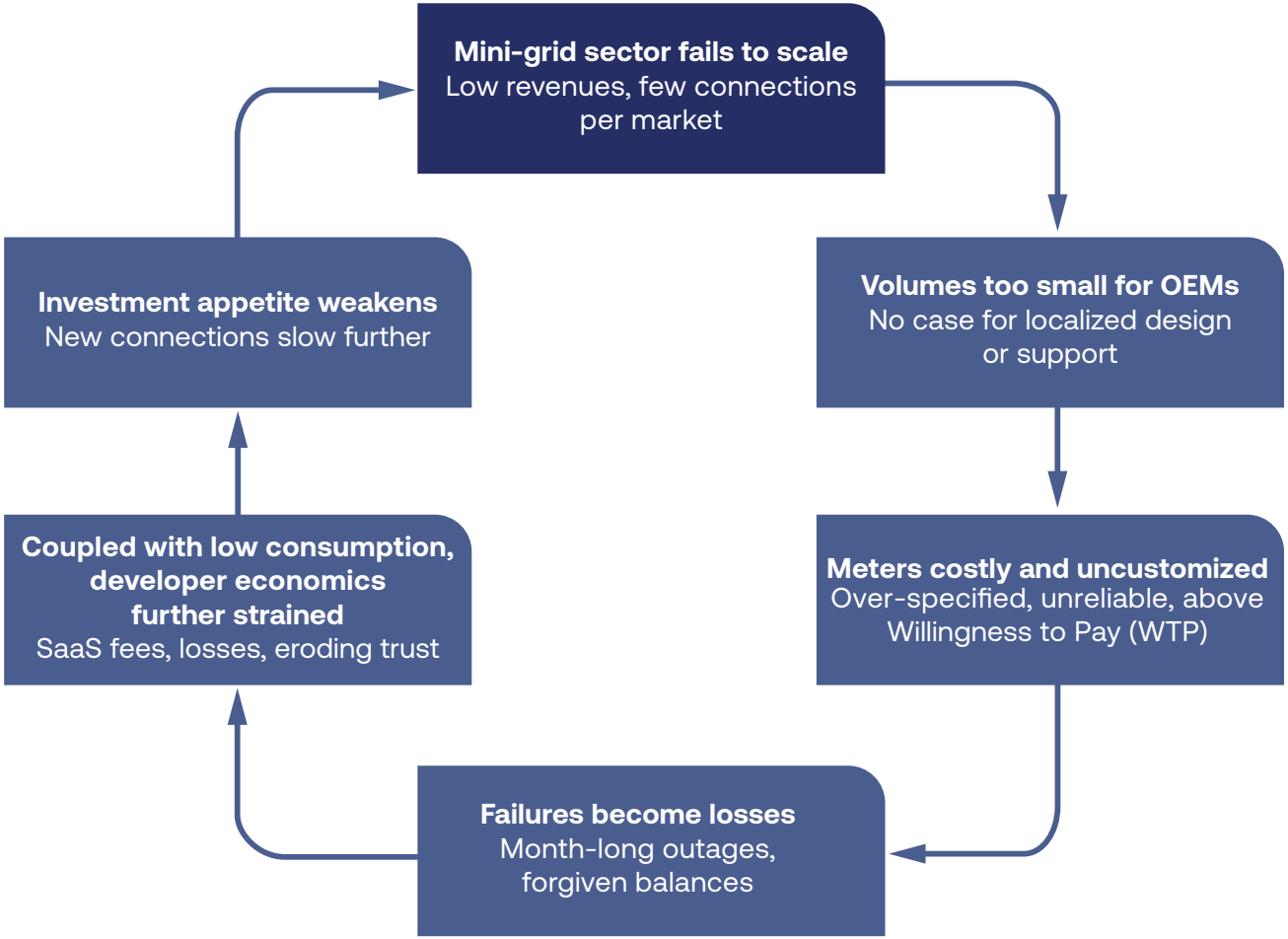
Data paid for but not used

Funders require far less than smart meters provide, typically connection counts and periodic consumption, and most developers lack the bandwidth to analyze the rest or take practical actions suggested by the insights delivered by the software platforms. The sector pays smart meter prices for load-limiter usage patterns.

A self-reinforcing feedback loop

The mini-grid sector's limited scale sits at the root: low consumption across sites (6–8 kWh per residential user per month according to AMDA's 2024 Benchmarking Report) and delays for grant-funded programs, such as the Distributed Access through Renewable Energy Scale-up (DARES) program, a World Bank initiative in Nigeria that saw a delay of more than 12 months to commencement, have kept mini-grids from scaling as expected. For meter suppliers, small volumes cannot justify fit-for-purpose design, local support, or in-country repair, so the market supplies only costly, over-specified meters unfit for rural sites, and thin margins leave no room to invest in better. For developers, those meters fail in the field with no path to repair: failures become forgiven balances and month-long outages, while SaaS fees and absorbed costs strain already-thin margins. Revenue and trust drain away, weakening the investment case for new connections and keeping both the sector and meter volumes small.

Figure 5: The self-reinforcing loop



Each challenge feeds the next: supplier and developer failures compound in a reinforcing cycle rooted in sector scale. Breaking it at any one point is not enough.

Where does the sector stand today?

A funder-backed bridge is holding the sector steady, coordinated by the A2EI-led consortium (A2EI, EnAccess, NRECA with support from AMDA and OpenAMI), and funded by the "Funders Group" (RF Catalytic Capital and other key funders). The Open Metering System is the proposed fix for the sector's cost and lock-in concerns. Discussions are ongoing at the time of publishing.

Track 1: Stabilization (now)

Emergency funding keeps 250,000 vulnerable connections running for six months, covering engineering staff, cloud hosting, and firmware and software updates. Track 1 also releases the SteamaCo and SparkMeter code to the market, so developers can choose their own path rather than default into Track 2.

Track 2: Open Metering System (next)

A proposed open-source platform building on donated SteamaCo and SparkMeter IP. Intended to let DLMS-compliant meters connect, subject to published connection specifications and integration testing, and existing meters migrate where suppliers release keys and documentation. Intended nonprofit, cost-recovery pricing, expected below today's fees.

6-month runway **A durable solution must be live before it ends**

What the Open Metering System (OMS) could fix

- **Vendor lock-in.** Donating SteamaCo and SparkMeter's core IP to the DLMS standard lets any compliant meter connect and existing meters migrate, including local and smaller hardware makers and simpler MVP-level hardware such as STS (Standard Transfer Specification) meters, removing the proprietary barriers that stranded the sector. Specifications and communication standards must stay open too, so software providers can build on the system rather than recreate the lock-in it's meant to escape.

- **The cost base.** A2EI is a nonprofit legally barred from distributing a profit, charging at cost on lean infrastructure; service fees are expected to land well below incumbent levels.
- **Data sovereignty.** Customer data would be encrypted and held by a neutral party rather than a single commercial vendor, with OMS linked to the Prospect Digital Public Good governance framework, meaning no one party controls it.
- **Concentration risk.** Delivery sits with a consortium rather than a single operator, with AMDA convening developer feedback through an advisory group, a deliberate response to the sector's earlier over-dependence on a single stakeholder.
- **Funder data alignment.** Funders' need for wide-ranging data from disparate sources drove the over-specified, high-cost meters that sank the sector. As a neutral verification layer, OMS can capture and validate a shared set of data points, aligning funders on what matters and removing pressure for ever-more-sophisticated hardware. Scoping which variables to capture is part of the work now underway.
- **A platform for further services.** Because it sits as shared, open infrastructure, OMS could support capabilities like cross-developer benchmarking, mobile-money integration, and a commercial layer of analytics, visualization and simulation built on top of the common data foundation.

Open questions from interviews

- **Life after grants.** The Open Metering System (OMS) is being developed with grant funding, but the intended model is for maintenance of the platform to become commercially self-sustaining once live, funded through a small per-developer fee set to break even against maintenance costs, rather than to generate a return. The platform's scope, pricing and basic data layer remain to be defined; select industry actors will convene to agree on scope prior to implementation.
- **Developer burden.** Ownership of platform onboarding, support, and maintenance under OMS remains undefined. Until it is determined, that burden risks defaulting onto operators, falling hardest on smaller ones.
- **Hardware.** A software answer to a partly hardware problem. Developers are asking for cheaper hardware, field-ready design, and local repair, which remain untouched. Additionally, platform economics depend on adoption volumes that do not yet exist.

The bridge stabilizes the current crisis and the software layer is taking shape. What remains unsolved is the meter itself, which is the subject of the next section.

03

How could we move forward?

35+ interviews define a need-to-have MVP that closes the cost-capability gap in today's smart meters

Today's smart meters deliver capability that developers don't use, funders don't require, and end users can't afford. To solve for cost and sustainability, we first define the minimum viable product. Drawing on 35+ interviews with developers, funders, and meter suppliers, we include below the features developers define as their "need to have" (a feature developers use daily, funders require before committing capital, or field conditions demand) and "nice to have" (valued but not vital features).

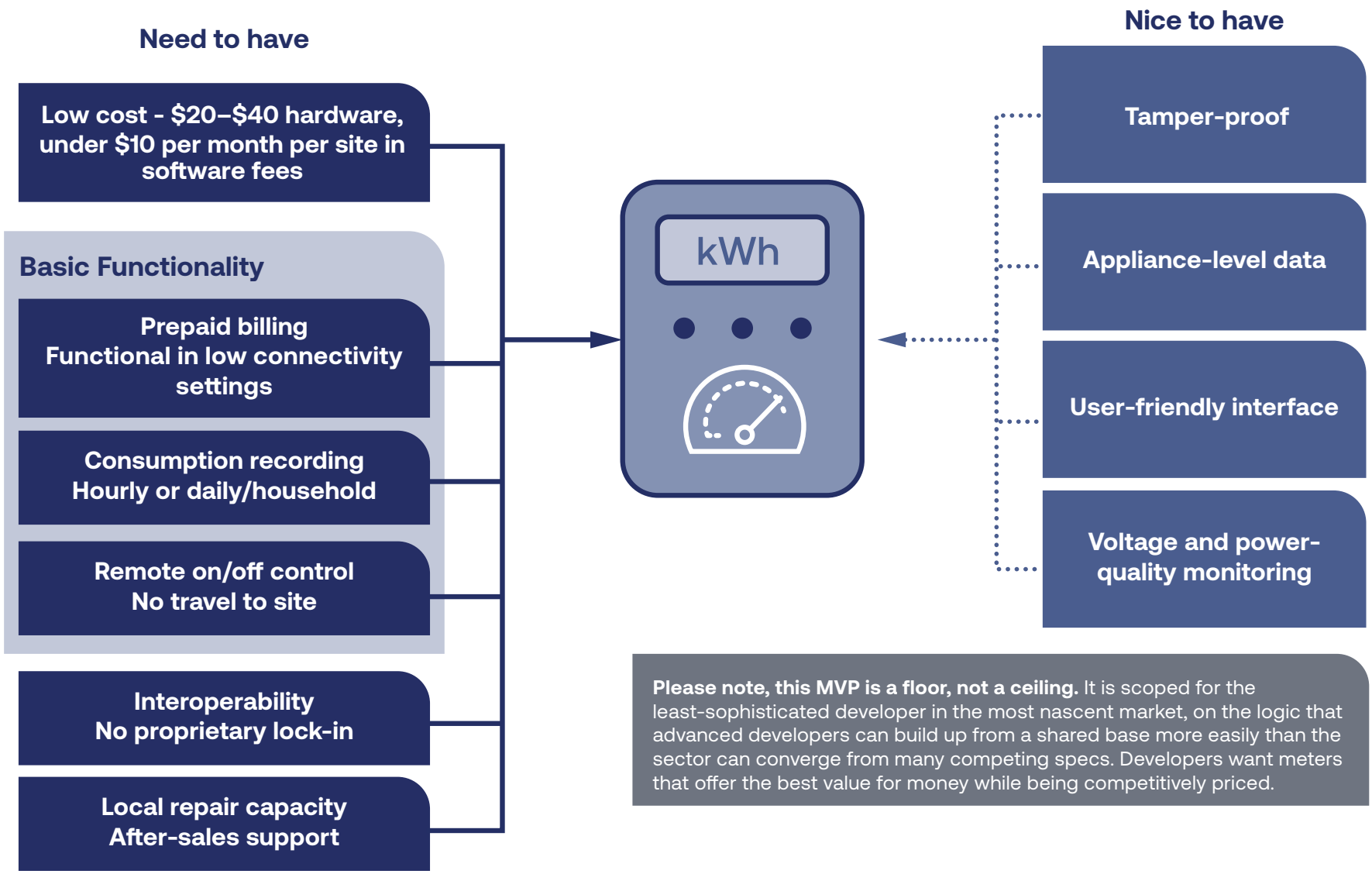
How could the MVP be deployed in practice?

On a single site, most household connections (~6– 8 kWh) could run on a basic MVP meter while productive-use customers (~13–40 kWh), including a mill, a welder, a shop, could run on smart meters if their loads justify, as the added data and control will pay for themselves.

An AMDA-administered poll (May 2026) points the same way: only 30% of members said basic prepaid metering covers their needs and 26% said they need granular data outright, while a plurality (43%) want both, but as separate layers rather than a single meter carrying both.

In this way, metering cost matches the revenue behind each connection, and both tiers feed one back end, so developers manage a single platform, and the sector keeps granular visibility exactly where consumption patterns matter most.

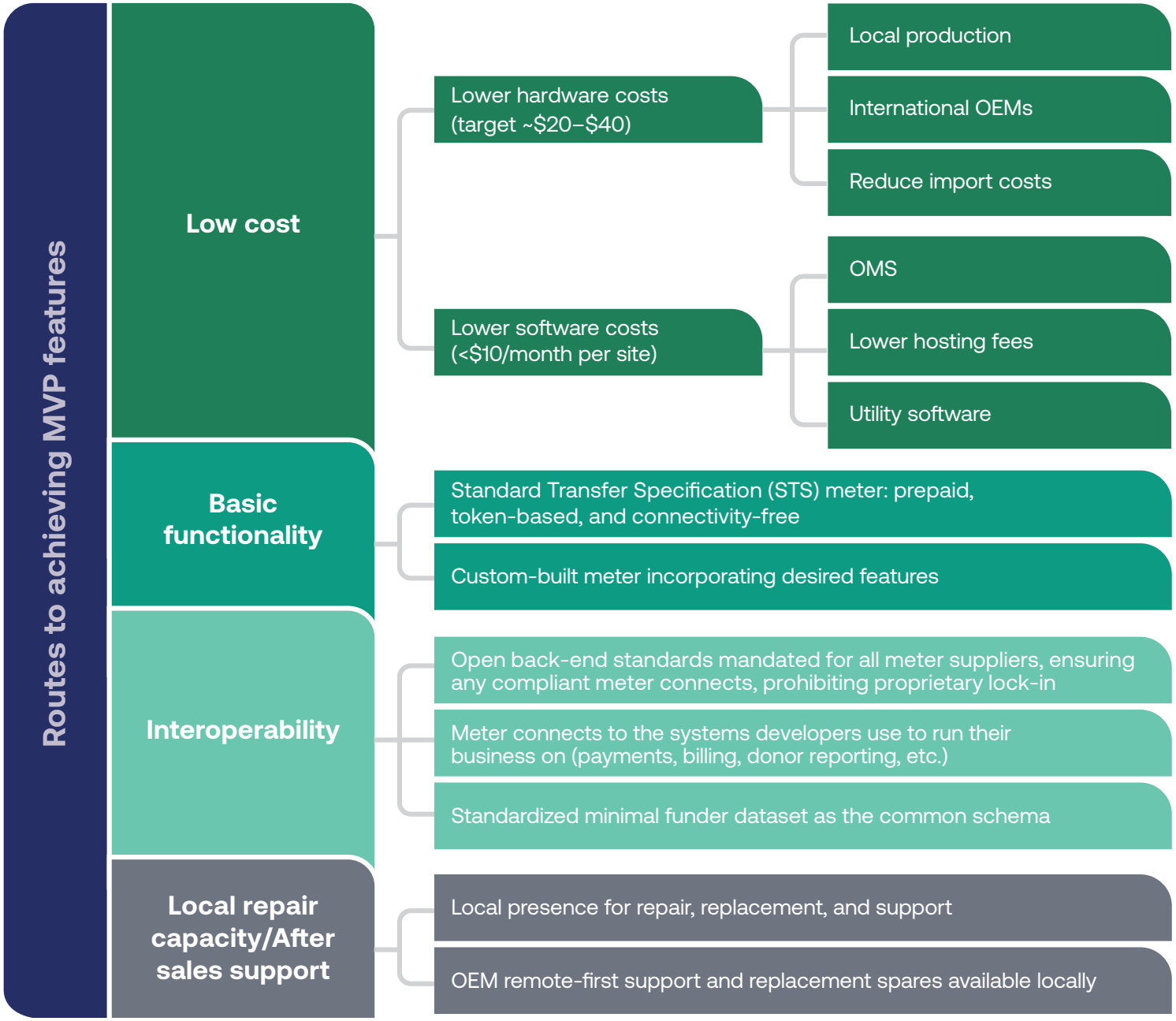
Figure 6: The MVP meter



Please note, this MVP is a floor, not a ceiling. It is scoped for the least-sophisticated developer in the most nascent market, on the logic that advanced developers can build up from a shared base more easily than the sector can converge from many competing specs. Developers want meters that offer the best value for money while being competitively priced.

Source: Stakeholder interviews, AMDA Benchmarking Africa's Minigrids Report (2024)

What are the options for delivering the desired features of the metering MVP?



Achieving MVP features requires trade-offs across cost, functionality, interoperability, and local support, with distinct paths available for each

- Low cost hinges on hardware (~$20–$40 target) and software (<$10/month per site) achievable through scale economies via demand aggregation, reduced import costs, lower hosting fees, and localized design, production, and after-sales support to reduce repair and replacement costs. Additionally, local innovations such as hardware sharing have been successfully explored to reach the MVP target price point.
- Basic functionality and interoperability can be met through STS-compliant meters and open back-end standards, avoiding custom builds and proprietary lock-in
- Local repair capacity requires either in-country technician presence or OEMs providing responsive remote technical support

The following pages set out three potential paths to achieve the MVP at scale.

The 250,000 meters currently at risk are already being served by Pathway 1; Pathways 2a and 2b are recommendations for long-term commercial viability.

Multiple paths will likely be pursued in parallel, as the sector balances functionality, ease of implementation, and commercial sustainability

A sustainable model will combine sector coordination, market-led delivery, and time-bound donor support

What are sustainable pathways to deploying the metering MVP while keeping the sector afloat?

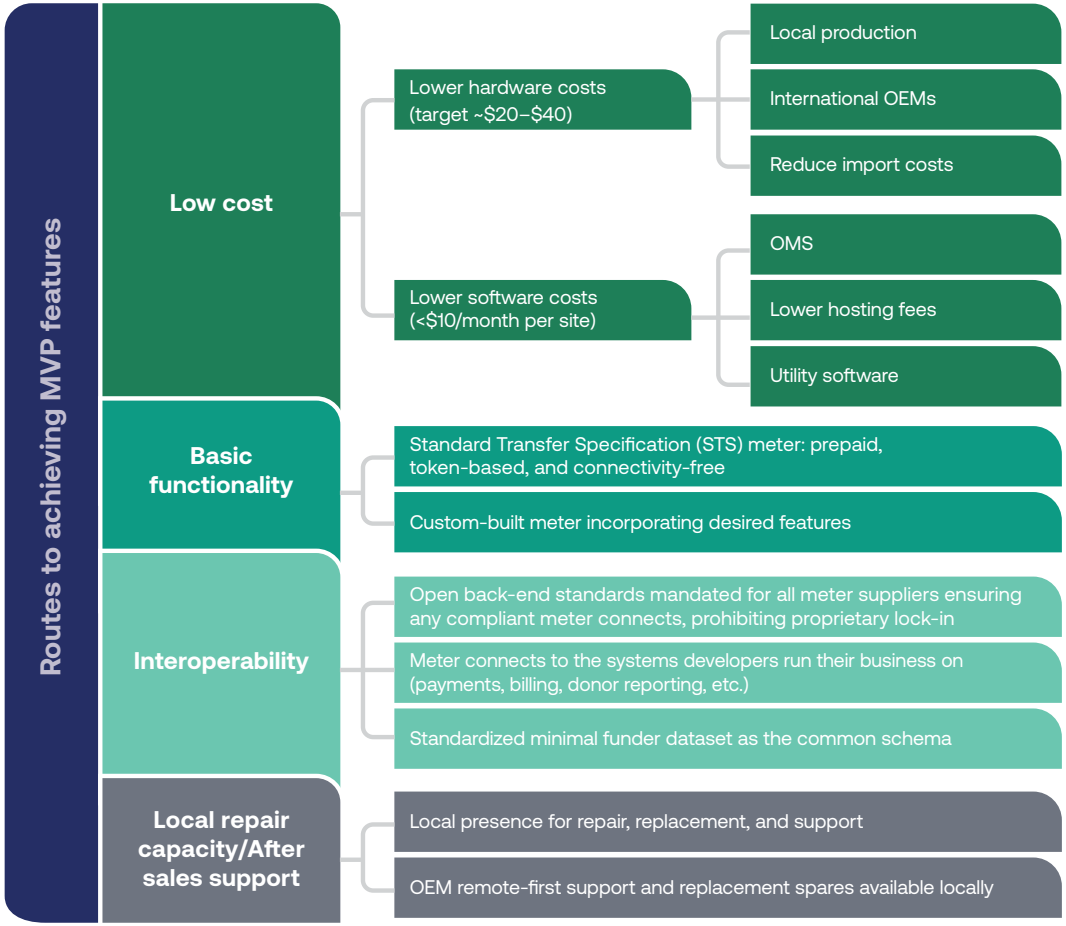
	Description	Pros	Cons	Risks	Commercial Sustainability*
1. BAU: stabilize + build OMS	**1.** The sector continues the two-track response: 1) 6-month stabilization of 250,000 deployed meters (staff, hosting, firmware), 2) development of the OMS as a shared, open software layer. Pathway currently being followed to support 250,000 at-risk meters	• Keeps lights on for 250,000 connections • Broad funder and industry alignment	• Explicitly a bridge: 6-month runway • No hardware, cost, or business model answer	• Grant dependence persists • Delay past 6 months, connections go dark	
2. Standardize the metering MVP and aggregate demand	**2.** The sector converges on MVP features (billing, per-household consumption, remote on/off) and aggregates demand across more operators and sites to be used as bulk procurement leverage. Recommendation for sector to reach long-term commercial viability	• A standard MVP gives funders one simple dataset to align on. DARES in Nigeria shows this already works. • Standardization breaks vendor lock-in; opens entry for new meter suppliers	• Requires funder coordination across programs • May still require OMS or custom-built STS software back-end for mini-grids • Design and manufacturing risk of building new hardware from scratch and uncertain delivery timelines	• OMS governance unresolved • Support burden shifts to developers if no support staff for OMS established	
2a. Localize production	**2a.** Local firms import and customize STS meters OR design, assemble, and support a custom-built standardized MVP meter, with design, IP, and after-sales service owned in-country. Firms use OMS to reduce software costs and deliver interoperability. Appetite for participation driven by supply volumes	• Fast local repairs and support • Design quickly iterates on field feedback and local conditions • Builds local skills and invests in the local economy	• Higher unit costs at low volume • Core components still imported	• Needs patient capital and time to build manufacturing scale	
2b. Commission international OEMs	**2b.** Aggregated demand leveraged to negotiate bulk procurement terms with international OEMs for example, through DART[1]: discounted pricing, order book management, and approved meter supplier lists. Scale also secures light OEM support presence, regional or in-country where volumes concentrate, for quick repairs. OMS optional as OEMs have their own software back end.	• ~$20 ex-factory manufacturing scale exists today • Proven supply chain; fastest route to volume	• High customs, duties, and governmental price hikes • Below scale thresholds, no in-country support leads to significant downtime when issues arise • SaaS fees could be higher than OMS fees	• MVP-specific SKUs[2], bulk pricing, and local presence all depend on firm volume commitments (~25,000 connections, according to one of the largest meter suppliers)	

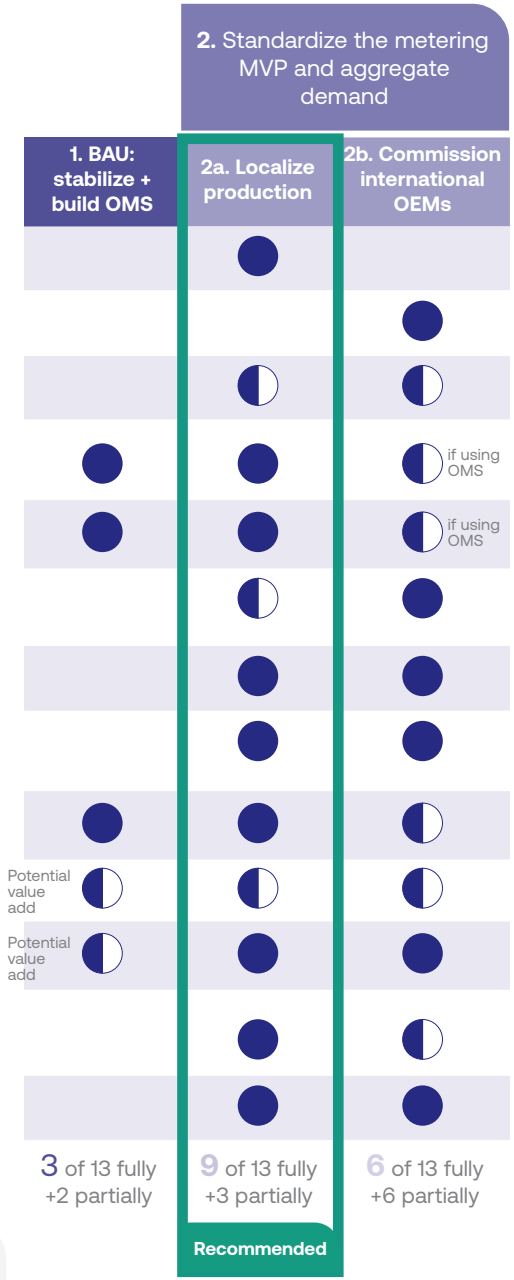
Backbone: Open Metering System (OMS) underpins pathways 1 and 2a as the shared, open software layer

Enablers: Demand aggregation | Local repair and support | Carbon finance & IRECs | Cross-subsidies | Import duty & currency

*where dark blue represents sustainability **Notes:** 1. Demand Aggregation for Renewable Technology is a GEA program that aggregates developers' equipment demand for bulk procurement at lower cost. 2. Stock Keeping Unit; here, a dedicated mini-grid meter model built to the MVP spec

Standardizing the metering MVP and localizing production is our recommended path for the sector, meeting 9 of 13 developer requirements in full





Criteria assessed qualitatively against interview evidence; not weighted equally, presented uniformly for simplicity

Note, Option 1 is a bridge, rather than a destination, and is also the backbone the following recommendations build on

2a and 2b inherit path 2's standardization; they differ on hardware supply and support.

Key
Fully meets need
Partially meets

04

What needs to happen to achieve these paths to sustainability?

1. BAU: stabilize + build OMS

The bridge the sector is on today

How it would work

The sector's two-track response continues as designed. Track 1 stabilizes the deployed base: emergency funding covers engineering staff, cloud hosting, firmware, and software updates for existing SparkMeter and SteamaCo meters over a six-month runway, keeping roughly 250,000 connections in service. Track 2 builds the longer-term software layer: an Open Metering System built on core IP and code donated by both legacy vendors and operated at cost by a nonprofit implementer. DLMS-compliant meters could connect once integration is validated against published specifications, while existing meters could migrate provided that vendor keys and documentation are released and developer or hosted-platform capacity can support the migration. Sector stakeholders shape the basic service layer, expected to cover consumption, billing, and payment data, and the implementer's budget covers building connectors for meters that need them. Funders pay the reduced overheads of transition; thereafter, minimal SaaS fees are intended to cover platform hosting and hardware upkeep.

What the evidence shows

- Demand for an open platform is real as operators stranded on legacy platforms say they would readily adopt an alternative that fixes syncing and transparency failures
- Service runs on lean infrastructure, and fees are expected to fall well below incumbent levels once migration completes
- **However**, adoption assumes capacity many operators lack. Developers prefer plug-and-play systems with local repair, and onboarding and troubleshooting demands skills small operators do not have

"Metering is shared infrastructure. It should be treated as a public good." — Ecosystem implementer

"The governance question has to be answered first: who owns it when it gets hard?" — Meter supplier

What must be true for this pathway to succeed

OMS requires a durable business model and critical mass adoption to be sustainable beyond grant funding

OMS also needs clarity on ownership, accountability, and data security before the runway ends, including a neutral party for key and credential management

Developers need support on migration and after-sales service to protect their workload

Key stakeholders

Stakeholder	Role in this Pathway	What They Need to Play It
AMDA (or procurement intermediary)	Clarify governance, coordinate both tracks and keep the working group aligned through the transition	Mandate from members; funding for the coordination work
Funders Group (RFCC, RF, GEA, AfDB, and others)	Sustain stabilization funding through the runway and steer OMS scope toward a defined handover	A credible exit point so the bridge does not become permanent; auditable data showing the funding is working
Meter suppliers (international OEM or local producers)	n/a	n/a
Legacy vendors (EarthSpark, new SteamaCo)	Keep deployed meters running through the transition and support migration	Stabilization funding through the six-month runway
Mini-grid developers	Migrate meters onto the OMS and take on first-line customer support	Migration assistance; fees low enough to absorb; service continuity during the switch
Governments & regulators	n/a	n/a
Consortium (A2EI, EnAccess, NRECA)	Develop the two-track solution and conduct fundraising; build and operate the OMS platform at cost including supporting migration of existing meters	A funding model that survives grant tapering; critical mass of meters migrating so cost-recovery pricing works

2. Standardize the metering MVP and aggregate demand

Converging on what the sector needs and no more

How it would work

The sector converges on a standard meter and aggregates its demand behind it, creating the leverage to deliver the core MVP (low cost, basic functionality, interoperability, and local repair capacity) through either an STS or a custom-built meter. Pooled procurement replaces fragmented markets with a single credible order book, giving the sector one negotiating voice on two fronts.

On supply, it means better pricing and terms from meter suppliers, whether local producers or international OEMs; the specification is sustained because suppliers build to confirmed demand. Hardware then tiers by customer need, e.g., basic meters for low-consumption households and smart meters for productive-use and business customers, whose loads justify richer data.

On reporting, it aligns funders on one shared dataset. Today each funder wants different data in different formats, which pushes developers toward more complex meters and duplicate reporting, hardest on small developers with several funders. As previously mentioned, the OMS could be one way to align and verify these data requirements.

What the evidence shows

- Developers are already aligned on MVP requirements, consistently naming billing, consumption recording, and remote on/off as core features. Metering above the MVP has only sold because grant capital covered what low-income, low-consumption customers cannot; the MVP is the level sustainable without subsidy
- Innovative metering designs driven by local developers have already demonstrated that the industry's target cost of $20-$40 per connection is commercially achievable for the majority of deployment scenarios. The remaining challenge is scaling production, certification, interoperability, and after-sales support.
- Funder convergence has precedent. DARES in Nigeria standardized minimal reporting requirements at program scale
- **However,** funder convergence remains unproven beyond that example and reporting demands still vary widely across programs. Additionally, bulk procurement benefits also depend on predictable demand timelines, which developers cannot always commit to.

> "Developers are content with the bare minimum. Unless the value of additional data outweighs its cost, it is not worth paying for." — Funder

> "Some funders want hourly system-level consumption, others want appliance-level data. That is exactly the problem: there is no agreed standard." — Developer

What must be true for this pathway to succeed

Funders across programs agree on one minimal reporting standard

A meter MVP design is agreed upon across the sector, tiered by consumption level

Developers commit aggregated volumes credible enough to move meter suppliers to the MVP spec

Key stakeholders

Stakeholder	Role in this Pathway	What They Need to Play It
AMDA (or procurement intermediary)	Steward the pathway by convening standard-setting across mini-grid developers and meter suppliers; coordinate demand aggregation with meter suppliers via DART; advocate for funders to align on minimal reporting; partner with a university lab to independently test meters against the standard	Mandate from members; funding for the convening work
Funders Group (RFCC, RF, GEA, AfDB, and others)	Align on one consistent, minimal data requirement for mini-grids and hold to it in financing conditions; price in the risk that bulk procurement projects go unfunded or face delays or scope changes after initial commitment.	Assurance the minimal schema still supports RBF (results-based financing) and debt verification; without sacrificing data they currently use
Meter suppliers (international OEM or local producers)	Build to the MVP spec and offer the tiered range instead of utility-grade defaults	Demand at volumes that justify a dedicated SKU; confidence the spec will hold long enough to recoup tooling
Legacy vendors (EarthSpark, new SteamaCo)	n/a	n/a
Mini-grid developers	Adopt tiered hardware and pool procurement into one order book	A coordination vehicle to aggregate through; funder acceptance of the standard so the MVP meter satisfies their financing
Governments & regulators	n/a	n/a
Consortium (A2EI, EnAccess, NRECA)	Extend the back end to host the standardized schema, including STS support	Funded scope extension; the schema defined before they build to it

2a. Localize production

Aggregated demand creates orders worth building for: hardware designed, assembled, and supported in-country.

How it would work

Localizing production takes two forms. The lighter route imports STS meters and customizes them locally, adapting firmware, configuration, and service to the market. The deeper route designs, assembles, and supports the standardized MVP meter in-country. Both converge on the OMS as the shared software layer, cutting software costs and delivering interoperability. Several suppliers already design locally while sourcing components internationally, and most innovation is coming from current or former mini-grid developers with field experience, pushing the sector toward operator-led meter design. Proximity improves the product, as local firms iterate the whole stack against field failures like storm damage, syncing errors, and billing faults at a pace offshore meter suppliers cannot match. But the sharpest advantage is after-sales support. Because the firms that design and build the meters are in-country, both the expertise and the spare parts sit near the sites, so a failed meter is back online in days rather than the month an offshore replacement can take, limiting lost revenue, on-site manual billing, and downtime for the customer. Aggregated demand drives today's $60+ unit cost down toward the MVP target.

In-country assembly does not yet escape import costs, since components attract duties comparable to finished meters, but pooled demand strengthens the case for component duty relief, extending the exemptions that already exist for government-linked projects to energy-access programs. Volume determines where production sits: larger markets can sustain their own producer, while smaller ones are better served regionally. The path also carries a development return, as engineering skills, jobs, and enterprise ownership accumulate in the markets the meters serve.

What the evidence shows

- Purpose-built mini-grid meters have precedent; in fact many developers are currently designing for this context and innovating to provide low-cost and reliable meters to the sector
- The price target is reachable. One local meter supplier has already delivered per-connection costs as low as $23 on multi-channel meters today
- Interviewees ranked in-country repair capacity and after-sales service above any meter feature, with one stating after-sales support should be treated as part of the product
- **However**, there is currently a cost gap: a locally produced meter runs $60+ against roughly $40 for an imported OEM unit once duties and transport land it.

With scale, this gap should close, as larger order volumes spread fixed costs across more units, strengthen local firms' purchasing power on imported components, and justify the tooling and process investment that brings assembly costs down, while the landed cost of imports has no equivalent path downward.

"A $20 meter that takes a month to replace is more expensive than a $40 meter fixed in a day." — Developer

"Core components will still be imported. What changes is who designs the meter and who repairs it." — Meter supplier

What must be true for this pathway to succeed

Patient capital and early buyers carry the local premium, $60+ unit costs against $40 imports, until volume closes the gap

Component supply chains and national certification pathways are navigable for local assemblers

Local designs stay certified on the open back end, so hardware innovation never rebuilds proprietary lock-in

Key stakeholders

Stakeholder	Role in this Pathway	What They Need to Play It
AMDA (or procurement intermediary)	Steward the path by convening standard-setting across mini-grid developers and meter suppliers; coordinate demand aggregation with meter suppliers via DART; advocate for funders to align on minimal reporting and serve as single reference point for funders; partner with a university lab to independently test meters against the standard	Mandate from members; funding for the convening work.
Funders Group (RFCC, RF, GEA, AfDB, and others)	Provide patient, local-currency capital through the years unit costs exceed imports	A credible route to unit-cost parity; order books that make the investment bankable
Meter suppliers (international OEM or local producers)	Design, assemble, and support the standardized meter in-country	Patient capital for the scale-up period; firm orders from the aggregated book; reliable access to imported components
Legacy vendors (EarthSpark, new SteamaCo)	n/a	n/a
Mini-grid developers	Commit aggregated volumes to local producers and host field pilots	Repair and supply service levels that beat the import alternative; pricing with a path to the $20 target
Governments & regulators	Grant duty relief on components and provide workable certification pathways	Evidence linking local production to jobs, skills, and energy-access outcomes
Consortium (A2EI, EnAccess, NRECA)	Certify local meters onto the open back end	Published connection standards; testing capacity

2b. Commission international OEMs

Aggregated demand buys manufacturing scale that already exists

How it would work

Commissioning means contracting international OEMs to manufacture the standardized meter as a dedicated SKU, built to the sector's spec rather than adapted from utility product lines. This applies to the custom-built meter, which must be contracted and produced to order; the STS option can be bought off the shelf and does not need this route. DART runs the procurement, negotiating bulk terms directly with meter suppliers on behalf of developers: discounted pricing and approved meter supplier lists that vet the supply base and check component-cutting. It holds the order book and carries the resulting capital and inventory risk, batching orders every few months against committed connection numbers rather than forecasts, adding a margin for repairs and replacements, and holding excess as stock for the next round. AMDA oversees the process and coordinates developer demand into it. The price point is within reach, as OEMs already produce utility-grade meters at roughly $20 before import duties and functional connection on proven supply chains, and the MVP asks for less complexity, making this the fastest route to volume. Either software layer can serve this path: OEMs ship their own back ends and utility-scale platforms already exist, so no OMS is strictly required, though the sector could still adopt the OMS if it prefers an at-cost open platform to higher SaaS fees and vendor dependence. Scale also secures a light OEM support presence, regional for most markets and in-country where volumes concentrate. Meter suppliers establish local support once a region holds a critical mass of deployed meters (at least 25,000) with revenue and a steady growth trajectory, and program rules can accelerate this by making presence a condition of participation. Beneath the OEM layer, trained developers provide first-line support themselves.

What the evidence shows

- $20 ex-factory manufacturing scale exists today, before import costs, for utility-grade meters, and a proven supply chain makes this the fastest route to volume
- OEM meters entering these markets are already largely STS-capable; the hardware capability the MVP needs is on the shelf
- According to an East African national utility, utilities buy from the same OEMs on far better terms because of their scale, and mini-grids could capture that value by aggregating demand. Their scale delivers three things the sector lacks: steep discounts from ordering up to 600,000 meters a year through competitive public tenders; local presence and after-sales service OEMs will not extend to smaller buyers; and independent verification of meters in their own labs before acceptance, which AMDA could replicate through a university lab.
- **However**, import costs push $20 meters to $40 in the hardest-hit markets, and today's volumes fall below the threshold at which OEMs will establish local support. SaaS fees on an OEM's own platform also run well above the at-cost fees of the OMS, and OEM-supplied meter quality can be inconsistent without independent verification.

"At current market volume, no OEM can justify putting hardware or support teams on the ground." — Developer

"Without firm volume commitments, OEMs will default to shipping over-specified utility-grade meters." — Meter supplier

What must be true for this pathway to succeed

Developers deliver firm, pooled volume commitments large enough to justify MVP-specific SKUs and support presence

Import duty and currency relief materialize in the markets where volumes concentrate

OEM support extends to the field: regional repair hubs, spare parts, and local service partners

Key stakeholders

Stakeholder	Role in this Pathway	What They Need to Play It
AMDA (or procurement intermediary)	Steward the path via convening standard-setting across mini-grid developers and meter suppliers; Coordinate demand aggregation with meter suppliers via DART; advocate for funders to align on minimal reporting and serve as single reference point for funders; partner with a university lab to independently test meters against the standard	Mandate from members; funding for the convening work.
Funders Group (RFCC, RF, GEA, AfDB, and others)	n/a	n/a
Meter suppliers (international OEM or local producers)	Manufacture the standardized meter as a dedicated SKU; maintain regional support presence where volumes concentrate	Firm volume commitments large enough to justify tooling and support; a clear published spec
Legacy vendors (EarthSpark, new SteamaCo)	n/a	n/a
Mini-grid developers	Pool procurement into one order book and standardize purchasing on the MVP spec	A coordination vehicle; a trusted intermediary to negotiate on their behalf
Governments & regulators	Grant import duty and currency relief in the markets where volumes concentrate	Evidence linking currency relief to energy-access outcomes
Consortium (A2EI, EnAccess, NRECA)	Certify OEM meters onto the open back end	Testing capacity; published connection standards

Enablers

Cost levers that cut across every pathway

Demand aggregation

Pools developer procurement into one order book, unlocking MVP-specific SKUs, bulk pricing, and OEM support presence, and giving local producers bankable orders. Aggregate demand is bounded by how fast the mini-grid market grows, the same constraint that kept meter volumes small. But growth still lowers cost two ways: bulk procurement gives developers negotiating power, and sustained local volume justifies in-country tooling and assembly, cutting import costs and keeping repairs local.

Who leads it:
DART or a procurement intermediary runs it (taking on capital and inventory risk); developers commit volumes; funders can anchor early orders.

Requires:
Alignment on the timing of orders and need.

Carbon Finance plus I-RECs

Metered consumption turns the meter from a pure cost into a revenue-bearing asset. Verified consumption data earns carbon credit and I-REC revenue, a share of which flows back to offset hardware and fees.

Who leads it:
Funders finance the verification via a carbon Monitoring, Reporting and Verification (MRV) framework that makes mini-grid data credit-worthy. Developers flag which sites and loads qualify. The meter stays standard, since verification builds on the consumption data the MVP already records.

Requires:
Verifiable consumption data.

Cross-subsidies

Meter suppliers providing national utilities with meters run a much larger, more profitable metering business line. Adding mini-grid meters to that line lets profitable utility-meter sales cover what mini-grid sales alone cannot (or the reverse: mini-grid meter suppliers expand into utility metering). Telecoms use the same logic, with city profits funding a rural-coverage levy.

Who leads it:
National utilities and regulators anchor the model; Nigeria's Rural Electrification Agency (REA) and Nigerian Electricity Regulatory Commission (NERC) offer a partial template; AMDA advocates for the framework.

Requires:
An MVP manufacturable on existing utility production lines (OEM adds a mini-grid SKU), or local producers able to meet utility specification, certification, and procurement requirements (local firm scales into utility volume).

Import duty and currency relief

High import duties and other charges can significantly increase landed costs; relief directly narrows the gap to the $20 target for imported and locally assembled meters alike. At sufficient volume, aggregation also creates leverage to negotiate local-currency terms, shifting foreign exchange (FX) risk on recurring payments off developers.

Who leads it:
AMDA and funders build the policy case from sector data; governments and rural electrification agencies grant relief.

Requires:
Structured industry advocacy, economic-impact evidence, and legislative budget alignment.

Local repair and support

A meter failure can strand a site for weeks awaiting an offshore replacement, when local repair could fix it in days, so a cheap meter without local support often costs more than a pricier one with it. Local repair keeps technicians and spare parts near the sites. It's needed under both supply pathways, delivered differently: under 2a, the firms building the meters are already in-country, so skills and parts sit close to the field; under 2b, international OEMs must be contracted to hold a support presence, regional in most markets, in-country where volumes concentrate.

Who leads it:
Developers or a procurement intermediary write support and skills-transfer terms into contracts; local firms (2a) or OEM in-country teams (2b) deliver them; trained local staff handle first-line repairs.

Requires:
Enough deployed volume in a market to justify a local support presence (roughly 25,000 connections), plus skills-transfer obligations written into meter supplier contracts.

Each enabler lowers cost or risk within paths 1 through 2b, and their impact compounds when combined. Demand aggregation is the gating enabler as both supply branches depend on it.

05

Next Steps

Next Steps

The Lab will help the sector pursue the most sustainable path for deploying the MVP. Our preliminary recommendation is to standardize around a low-cost meter, aggregate demand behind it, and deliver it through localized production. Several open questions remain that would strengthen this analysis and confirm the recommendation. With partners, we will explore:

- What the recurring cost of metering actually buys, through a feature-level cost-benefit assessment of the SteamaCo and SparkMeter platforms
- How the OMS is governed, funded, and priced once grant support tapers
- Whether the MVP needs a cloud-dependent meter at all — cloud dependence turned vendor collapse into a supply risk, and an offline design such as token-based STS or Near Field Communication (NFC) technology may deliver the MVP at lower cost and lower risk
- How funders, including DFIs, converge on standardized minimal reporting
- The point at which local producers reach economies of scale with a fully localized supply chain, and the duty relief, certification support, and patient capital that requires

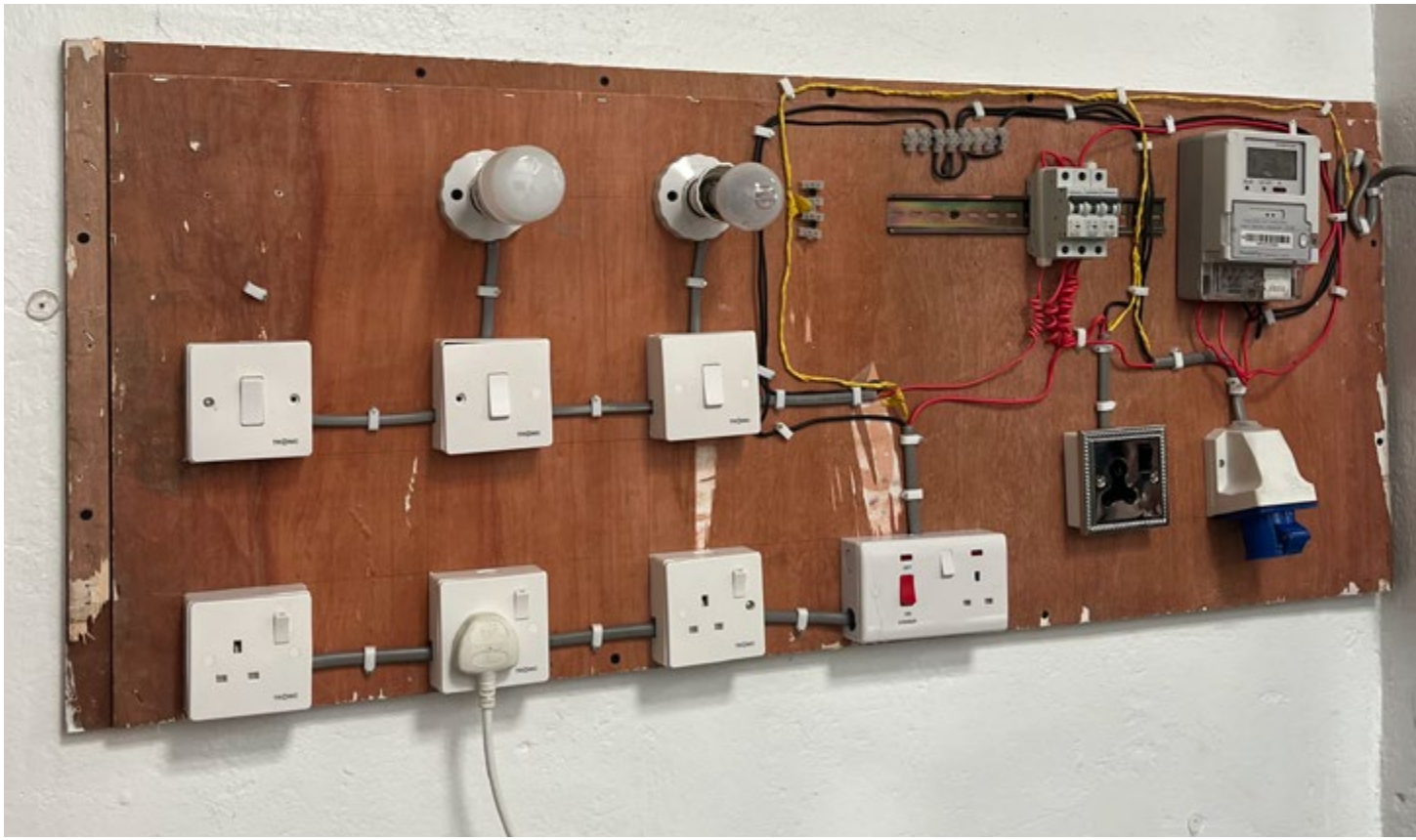


Image source: PowerPay

In parallel, the Lab is running field tests with PowerPay and PowerUp, two local meter suppliers, building on our multi-load metering work to assess how using AI to disaggregate loads could support time-of-use and type-of-use tariffs.

These are the Lab's current focus areas, but we recognize other pathways beyond this analysis should also be explored to help the sector reach the right answer as quickly as possible.

We invite collaborators to share insights and help advance research in this space. Please contact mini-gridslabs@crossboundary.com for collaboration opportunities.

Disclaimer

The Lab is supported by researchers from the University of Massachusetts Amherst, Rochester Institute of Technology, and Duke University, who support experiment design and analysis of results.

The Lab's Innovation Insight series provides ongoing, early insights on the prototypes so mini-grid developers, governments, and funders can act on the results as they emerge. All results and analysis in this series are therefore shared as actionable business intelligence rather than scientific evidence.

While this series is not intended to meet the standards of an academic paper, the Lab will publish more complete reports at the end of each prototype, and has partnered with University of Massachusetts Amherst, Rochester Institute of Technology, and Duke University to publish academic papers on certain prototypes.

Appendix

Where does cloud dependence come from?

Two communication architectures behind today's mini-grid meters, and what each costs per connection

A. Radio frequency (RF mesh or LoRa/LoRaWAN star)

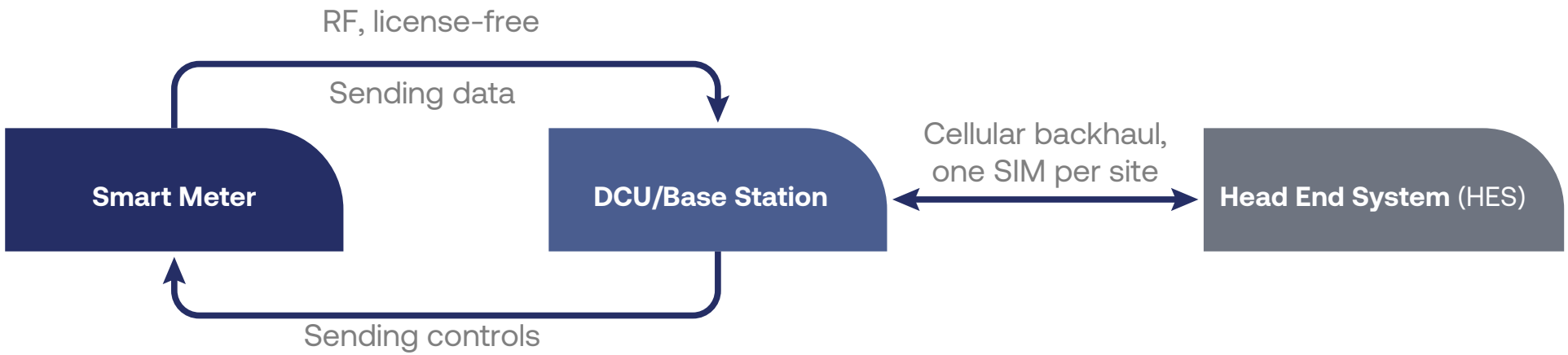
Cost per connection, USD	
Comm module inside meter (LoRa)	**$4.00**
Antenna, if not supplied with module	**$0.20 - $1.00**
DCU share, $450–$600 over 200 meters	**$2.25 - $3.00**
Total upfront	**$6.45 - $8.00**
Recurring	Data for one SIM per site

B. Cellular (2G/3G) (No DCU required)

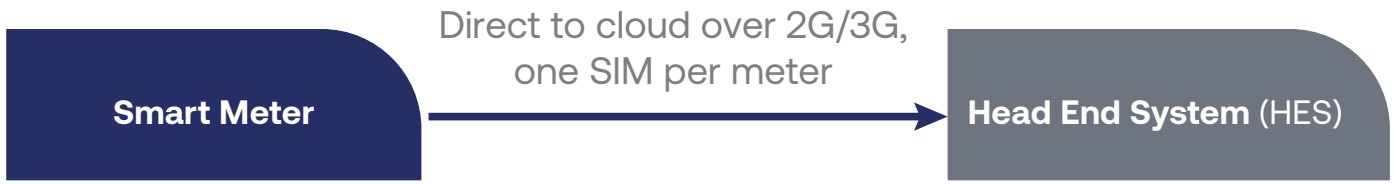
Cost per connection, USD	
2G module (SIM800L), by order volume	**$1.20 - $5.90**
2G subsystem integration	**$1.00 - $2.00**
DCU	**Not required**
Total upfront	**$2.20 - $7.90**
Recurring	Data for one SIM per meter

Notes: Figure excludes importation costs (customs, duties, freight) and excludes server or backend infrastructure costs, depending on network architecture.
Sources: OEM price data, Lab developer data

A. Radio frequency (RF mesh or LoRa/LoRaWAN star, via DCU/gateway)



B. Cellular (2G/3G) (No DCU required)



Neither architecture removes the cloud. RF concentrates the link in one DCU per site; cellular puts a SIM, and a monthly data subscription, in every meter.

Where in the system communication fails

- Meter to DCU, the RF link. Meters fail to communicate with the concentrator despite short distance and direct line of sight; resolution required signal-strength checks and reassigning the meter to a different core
- The DCU itself. Cores going offline and cycling on and off, traced to blown fuses, damaged AC/DC converters, and power fluctuation
- Backhaul to cloud. Wrong radio module shipped, faulty GSM modules, SIM cards installed incorrectly, and units with no active data subscription; low network coverage at remote sites
- The command path. Meters that log and respond to PING but not to ON or OFF commands, with the sender number the network transmits identified as a suspected cause
- Data handling at the meter. Meters fail to sync in low-network areas, and when data does sync it arrives lumped and cannot be disaggregated by time of use

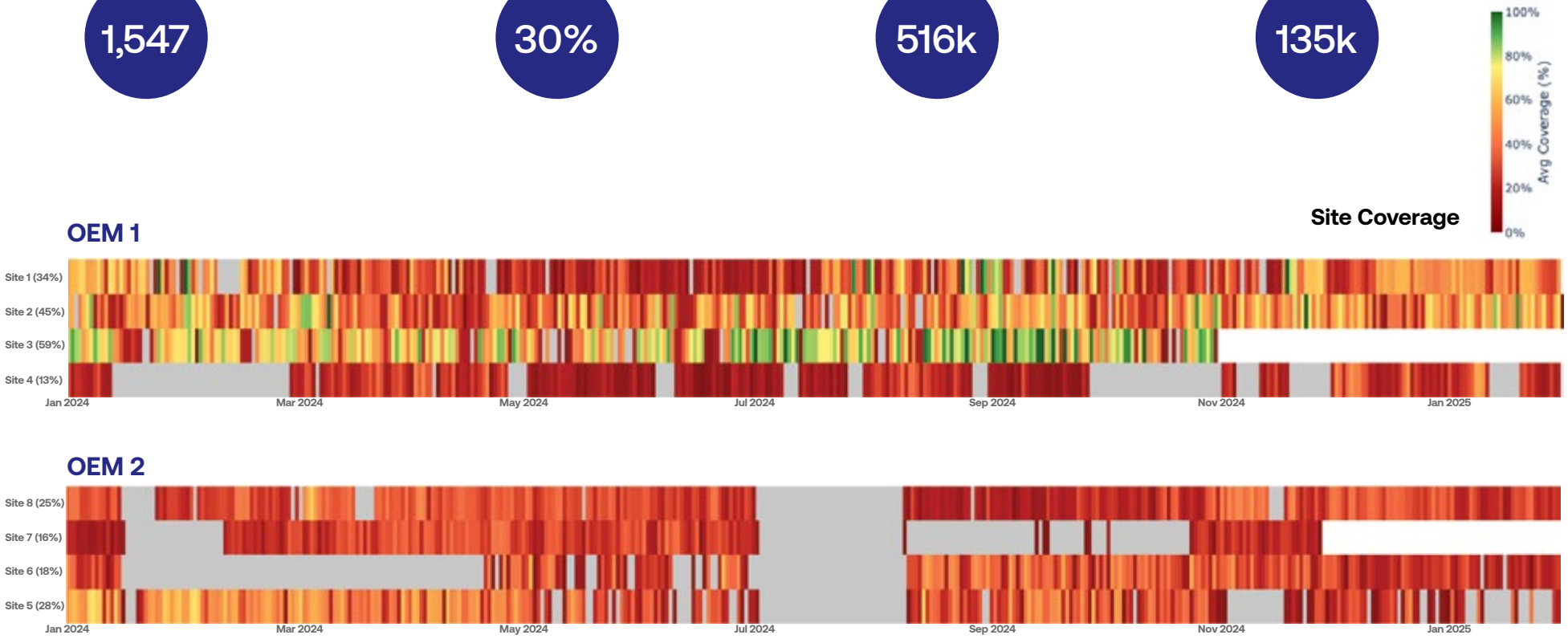
What the market's next meter should be built for

- Billing that keeps working offline, so a dropped link stops data flowing but not supply
- Local storage and buffering, so consumption is timestamped at the meter rather than at sync
- A control path that is verifiable and does not depend on SMS sender integrity
- An open meter-to-DCU protocol, so a cheaper processor does not lock future connections to one vendor
- A cellular module that can be upgraded as 2G and 3G are retired
- Meters per DCU sized to the site's density and terrain, not the datasheet maximum
- A communication architecture chosen per site (density, terrain, gateway placement, coverage, data frequency, power, maintenance capacity); no single technology suits every mini-grid

How does cloud dependence impact meter performance and reliability (1/2)?

Average site coverage across select Sierra Leone mini-grids from Jan 2024 to Jan 2025, %

Total meters	Average coverage	Total gap events	Delayed transmissions
1,547	30%	516k	135k



Assumptions: Coverage is measured against each meter's own active period, not the full dataset window. Expected daily readings are based on each site's confirmed cadence (e.g., 96/day at 15-min intervals, 24/day at 60-min). Daily coverage = actual ÷ expected readings × 100. Heatmap cells show the average coverage across all meters at a site on a given day. Heat map: white for inactive or decommissioned sites and gray for active sites that sent no data that day.

Meters record data, but cloud connections frequently lose it.

Across 1,547 meters at 8 sites in Sierra Leone, only 30% of expected readings reached the cloud. Failures happen constantly rather than occasionally. Meters fell below 80% coverage on 89% of their active days, and some sites sent no data at all for up to 96 days in a row.

Both OEMs state that their meters store readings locally when connectivity drops, and the 135k delayed transmissions show this happening. About 26% of missing readings eventually arrived in a burst once a meter reconnected. The rest are permanently lost.

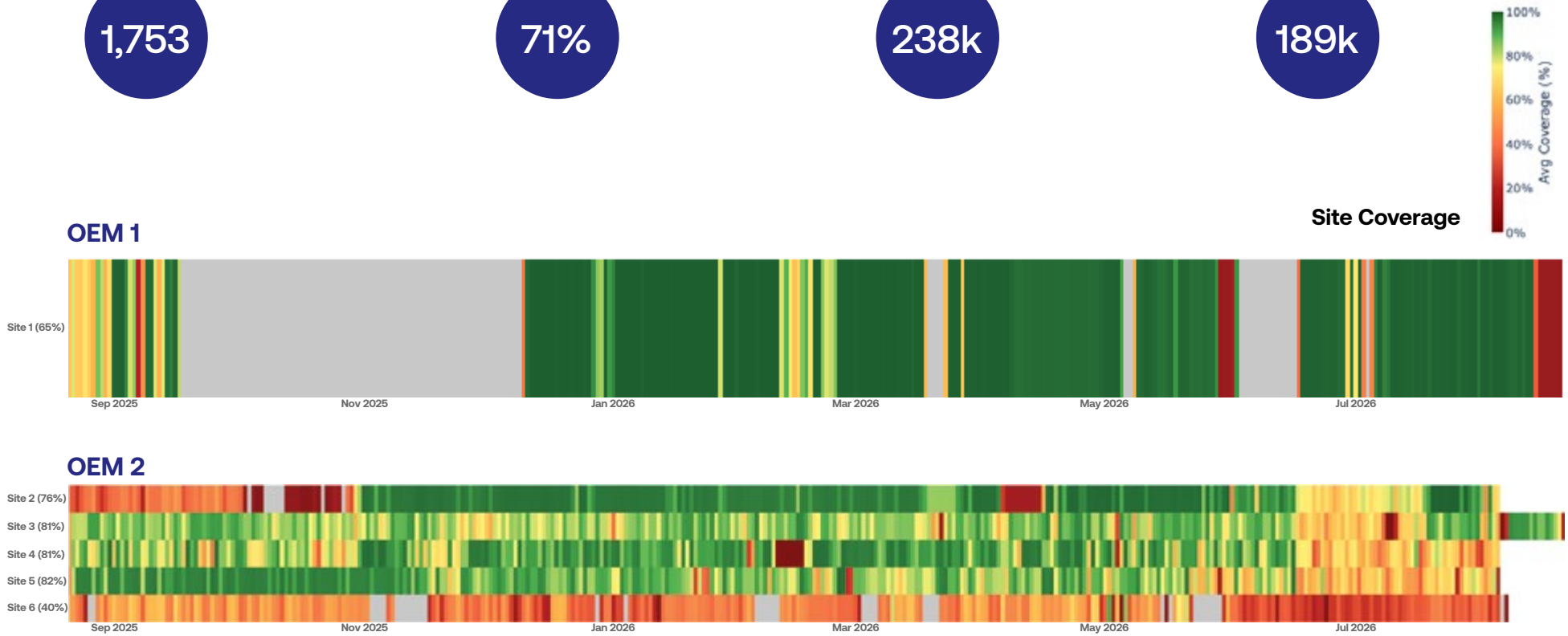
Performance depends mainly on the site. Site 3 averaged 59% and Site 4 averaged 13%, a difference of 4.5x, despite the same OEM and reporting interval. The two OEMs averaged 38% and 21%, which points to connection challenges rather than hardware issues. OEM 1 sites use a mesh network with a DCU per site, meaning a single backhaul failure takes the whole site silent simultaneously. OEM 2 sites support both direct GSM and DCU mesh depending on configuration, and the large grey blocks appearing across multiple OEM 2 sites at the same time suggest those sites are running on DCU mesh rather than individual modems.

The impact on revenue depends on where prepaid credit is held. In the cloud, a sync failure can let customers consume beyond their balance, leading to negative balances, abrupt disconnections or forgiven debts (p. 21). At the meter, as with STS, it costs visibility but not revenue. Either way, the operator's view of the grid is lost. Energy sold cannot be reconciled against energy delivered, so losses cannot be quantified, and load profiles are too incomplete for tariff design, site sizing, or measuring productive use.

How does cloud dependence impact meter performance and reliability (2/2)?

Average site coverage across select Nigeria mini-grids from Aug 2025 to Aug 2026, %

Total meters	Average coverage	Total gap events	Delayed transmissions
1,753	71%	238k	189k



Assumptions: Coverage is measured against each meter's own active period, not the full dataset window. Expected daily readings are based on each site's confirmed cadence (e.g., 96/day at 15-min intervals, 24/day at 60-min). Daily coverage = actual ÷ expected readings × 100. Heatmap cells show the average coverage across all meters at a site on a given day.Heat map: white for inactive or decommissioned sites and gray for active sites that sent no data that day.

Across 1,753 meters at 6 sites in Nigeria, 71% of expected readings reached the cloud, compared with 30% in Sierra Leone. Both countries use the same metering technology, so the difference comes from the mobile networks the meters depend on.

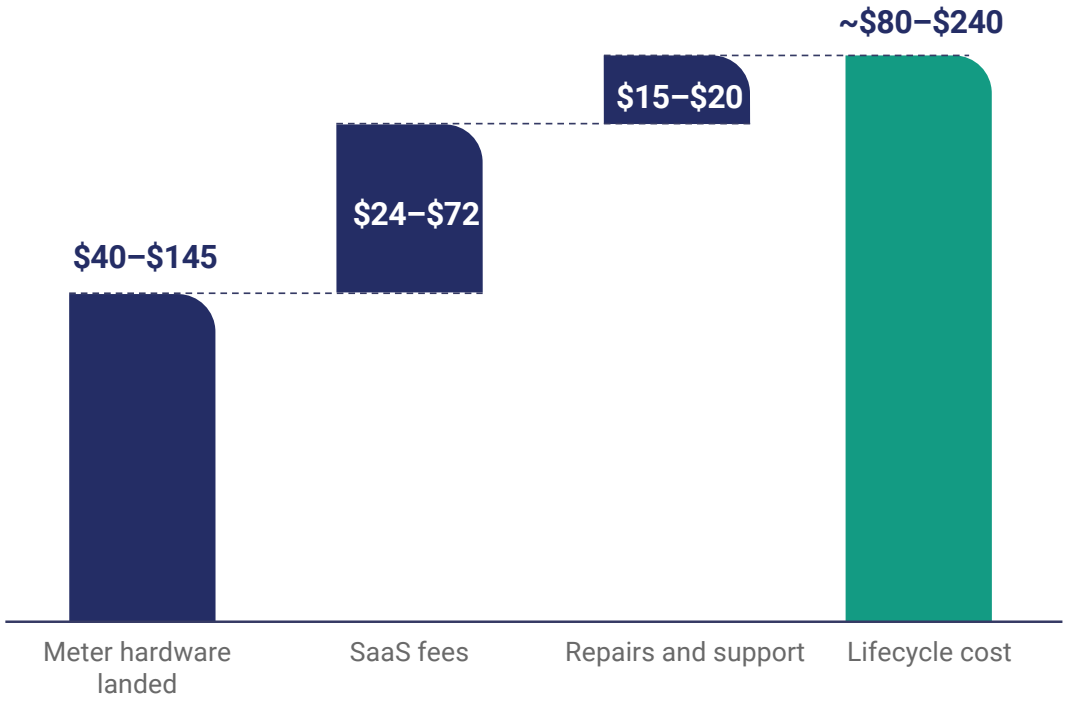
Failures in Nigeria happen in episodes rather than continuously, and poor performance is concentrated in a small number of sites. Site 1 averaged 65% while Sites 2 to 5 averaged between 76% and 82%. The episodic pattern is consistent with the OEM 1 mesh network architecture where a single DCU or backhaul failure takes the whole site silent at once and then recovers cleanly, rather than individual meters dropping in and out independently. For OEM 2 sites the more fragmented and independent gap patterns across sites suggest those sites are configured with individual GSM modems, which explains both the higher coverage and the more varied day to day patterns between sites.

There were 189k delayed transmissions against 238k gap events, a higher ratio than in Sierra Leone. About 80% of missing readings eventually arrived once meters reconnected, compared with 26% in Sierra Leone. Where connectivity returns quickly, most of the data is recovered.

At 71% coverage, consumption data is usable for billing and load analysis at most sites. The gap between the two countries suggests that data reliability is influenced by where a mini-grid is built, rather than just which meter is installed.

What does a meter cost over its life?

Illustrative lifecycle cost build-up per connection over 10 years, USD



Assumptions

Asset life: 10 years
Meter hardware is replaced at the end of the period, applying the 10-year replacement-capex asset life.

Hardware: $40-$145 landed per connection
Cost range across imported OEM meters and locally assembled meters, which excludes its share of the communication gateway.

SaaS fees: $24-$72 per connection
Using today's fees of $2.40–$7.20 per year (as described on pages 17 and 18).

Repairs and support: $15-$20 per connection
Estimated from two repair visits a year at $150–$200 per visit, spread across 200 meters, covering unit replacement, tripped breakers, enclosures, and antenna re-alignment. Meters are replaced rather than repaired in the field, since opening one voids its calibration for tariffed use. Meter failure can result in replacement of 5-25% of the site stock.

Notes: Estimate is undiscounted and excludes installation and integration labor at first deployment. Repair frequency and cost are Lab assumptions from developer interviews, not observed failure rates, noting most developers track general maintenance and repairs and do not isolate by asset-type.

Source: Developer and Supplier interviews. Hardware and SaaS from supplier build-ups and Lab field-test data.

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