Global Energy Alliance for people and planet

lightrock

Structuring For The Last Mile

Financing The Next Era of African Electrification

Source: GEAPP

With support from: The Rockefeller Foundation

Global Energy Alliance
for people and planet

lightrock

Part II: The Next Wave of Rural Electrification

Source: GEAPP

With support from: The Rockefeller Foundation

Charting a new path

Part I documented a sector at a structural impasse. Customers still without durable electricity access are poorer, more remote and harder to reach than those connected before them. The delivery models that served the first wave – grid densification, standalone PAYGO solar, isolated grids – have reached their limits. And while distributed renewable energy solutions will be the best fit for many of these remaining customers, financing costs are too high because the risks that drive pricing are being handed to small private sector companies that are least able to absorb them and which lack the scale and maturity to address these rural customers without a different approach.

The diagnosis points to another way forward. Fragmented, project-by-project delivery could be replaced by integrated service systems. Risk could be allocated to those best placed to carry it – governments, operators and financiers with each taking their share, to the degree they can bear it – rather than passed wholesale to the operator and ultimately to the household. And financing could be structured around sustained service delivery, not hardware deployment and connections.

The tools already exist. This paper draws on decades of work by regulators, development finance institutions and practitioners. Concessions with defined service obligations and universal coverage requirements have been used to deliver rural electrification, water, roads and telecommunications in some of the world's most challenging markets. Revenue settlement mechanisms allow governments to set affordable tariffs while ensuring operators recover their costs over time. Public-private partnerships can be structured so that demand, tariff and regulatory risk sit with governments who are better placed to carry them, while operational and performance risks sit with operators. And guarantees from institutions like The World Bank's Multilateral Investment Guarantee Agency (MIGA) can enhance bankability for infrastructure investors who have the appetite and scale the sector needs. What is new is the technology: a generation of distributed renewable energy solutions that are modular, proven and cheap enough to reach the customers that traditional grid infrastructure models never could. These technologies have matured outside the regulatory and financing frameworks that have historically delivered infrastructure at scale. Now is the time to bring them together.

Source: GEAPP

This section of the paper sets out how. It works through three interconnected design challenges that any program must get right simultaneously: defining and enabling the demand that will determine what gets built; designing least-cost systems flexible enough to grow as that demand evolves; and creating the regulatory and financial structures that attract the capital needed to sustain service delivery over time. Get any one of these wrong and the others unravel. Get all three right and the economics of reaching the last mile can change in more places, and more quickly, than the current trajectory suggests.

Meeting the electricity demands of the next customers

Demand in rural areas is genuinely difficult to predict. Consumption patterns are shaped by income levels, electricity pricing, agricultural cycles and the pace of local economic development. And electricity consumption in newly electrified rural communities typically starts at modest levels because electricity must compete with other essential expenditures. This means revenues rarely cover operating costs in the early years, as documented in Part I. Yet the absence of affordable electricity continues to constrain economic opportunity and human development, making rural electrification a development imperative even where the near-term economics are challenging. Breaking this cycle requires systems designed around actual demand rather than projected demand that are structured to grow supply as demand develops. Getting this right is the foundation on which everything else rests.

Household electrification is a public good

Achieving universal electrification means providing power to low-income households who likely won't be able to pay for the full cost of electrification. Many governments consider universal electricity access to be an obligation of the state. Last-mile electrification therefore becomes a social objective, requiring structured programs to reach those with the lowest ability to pay. As a public good, the level of service and the cost to the poorest consumers should be set by governments in response to policy priorities, ability to pay and available public funding, not left solely to the market to determine. Electrification of schools and health centers should be treated the same way: as a non-negotiable minimum, underpinned largely by state funding or guarantees, where budgets allow.

The populations most affected are typically rural, low-income households in smallholder agricultural communities. Experience from utilities and isolated grid operators shows that newly electrified households typically begin with modest consumption, prioritizing lighting, phone charging and small appliances. Electricity use may also fluctuate seasonally as household income varies.

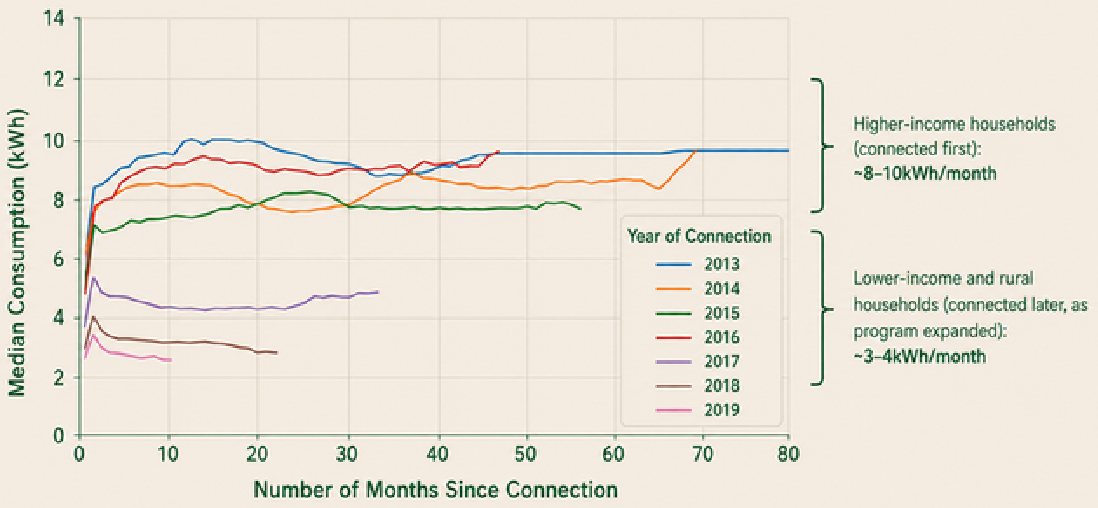
Because these households are highly price-sensitive, electricity consumption typically stabilizes at relatively low levels. This is a realistic starting point from which demand can grow, and it defines the minimum service level that meets core household needs while remaining affordable.[28]

Governments and system designers can use household consumption data and affordability benchmarks to meet customers where they are and define this minimum service level. Box 1 illustrates how data from Rwanda and Uganda can be used to estimate the level of electricity consumption and household expenditure that is consistent with an affordable basic service. It shows that more recent connections, usually for poorer and harder to reach populations, use significantly less electricity – both to start with and over time – than those who were connected earlier.

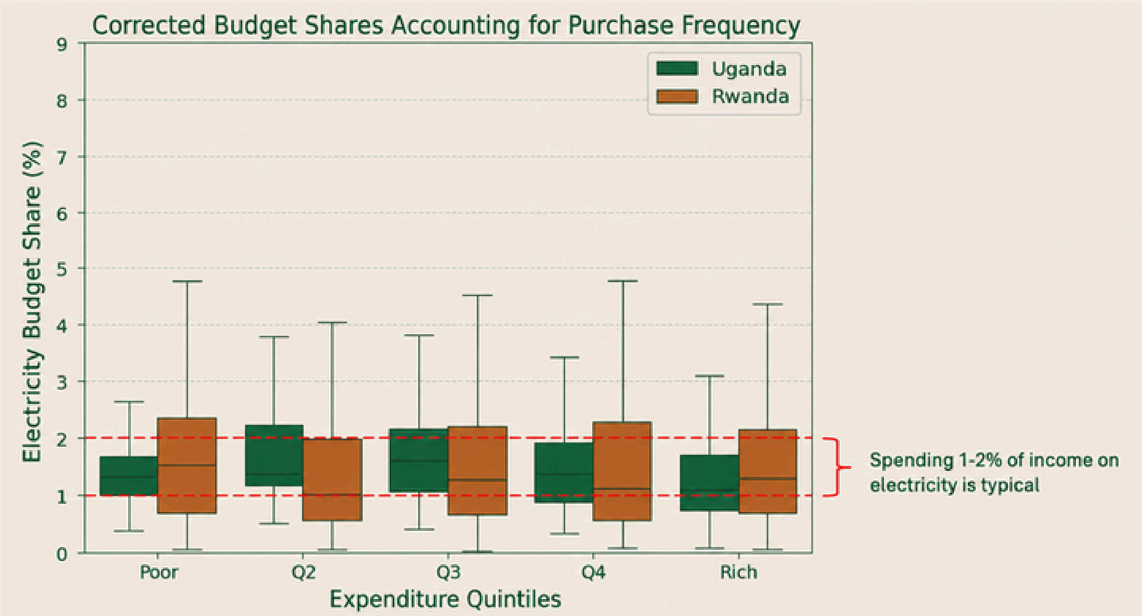
[28] Household electricity demand is sensitive to price but typically responds less than proportionally to tariff reductions. For example, consumption among newly electrified low-income households in Rwanda increased by about 30 percent when tariffs were reduced from $0.12/kWh to $0.06/kWh. CrossBoundary's Mini Grid Innovation Lab similarly observed consumption increases of just over 40 percent when tariffs in Sierra Leone were reduced from $0.70/kWh to $0.34/kWh. (Joel Mugyenyi et al., Energy Policy, 2025; CrossBoundary Innovation Insight: Harmonizing tariffs in Sierra Leone).

Box 1: Meet customers where they are: measured household data helps define realistic minimum electricity service levels

1. How much do people consume? Data from Rwanda[29] shows that the energy consumption of newly-connected, lower-income rural consumers in Rwanda settles at around 3-4 kWh per connection per month, with low-cost grid supply. In Kenya, the utility reports that rural consumers average 6 kWh per month.[30]



2. How much do people spend? Data from Rwanda and Uganda[31] suggest that low-income households typically spend around 1-2 percent of total household expenditure on electricity.



Together, these data points provide an empirical basis for defining a possible **minimum electricity service level and the public support required to deliver them**. National programs should calibrate these benchmarks using local income and consumption data. Appendix 4 illustrates how these assumptions were applied in least-cost electrification planning in Zambia.

[29] Joel Mugyenyi, Bob Muhwezi, Simone Fobi, Civian Massa, Jay Taneja, Nathaniel J. Williams, Vijay Modi, Post-connection electricity demand and pricing in newly electrified households: Insights from a large-scale dataset in Rwanda, Energy Policy, Volume 198, 2025.
[30] IOSR Journal of Economics and Finance, Assessing the Socio-Economic Determinants of Household Electricity Demand, Vol. 16, Issue 3, 2025
[31] Joel Mugyenyi, Vijay Modi, Survey bias and the poor: How survey responses overstate electricity spending, Energy for Sustainable Development, Volume 90, January 2026.

Where electricity is provided through national grids, this basic level of service has often been supported through lifeline tariffs. In distributed energy systems, the same objective can be achieved through standardized service packages that deliver a defined level of electricity at a predictable and affordable cost with simplified billing and collection systems that help to keep operating costs low. As technologies converge, consumers could receive equivalent basic electricity services, whether supplied through grid extension, isolated grids or standalone systems. This gives governments a common framework to define the cost of – and mobilize public funding for – minimum service obligations independent of the technology used to deliver them.

Over time, demand will grow as incomes rise and new appliances become accessible. However, the pace and scale of this transition remain impossible to predict and designing systems around optimistic demand projections has been one of the most consistent causes of failure for decentralized solutions. Electrification systems should therefore be designed to meet existing demand efficiently, while retaining the flexibility to expand as demand grows. This is discussed further in Section 2.

Box 2: Delivering a minimum electricity service: REAL Programme Catalyst and SolarAid's Light a Village pilot[32]

REAL Programme Catalyst is developing and implementing new models for foundational electricity services in low-income rural communities, working with multiple companies and delivery partners. Rather than selling individual solar home systems, the program aims to deliver a defined minimum level of electricity service to all households across participating villages. Households pay small, predictable service fees rather than purchasing equipment, with no downpayment (only the pre-payment of the first month's service fee). This removes entry barriers while keeping the focus on ensuring long-term system operations and high-quality customer service.

One example is REAL Programme Catalyst and SolarAid's energy-as-a-service pilot in Malawi, which provides households with a standardized bundle of basic electricity services – including lighting and phone charging – delivered through a local service provider responsible for installation and long-term maintenance. In August 2025, the pilot achieved **100 percent Tier 1 energy access** across Kasakula, a remote low-income community.

Pictured: Sadaya and Charity, the last household installation, Kasakula Malawi.

Productive use: electrification as a driver of development

While household electricity demand in rural areas may initially be modest, reliable electricity for productive uses such as agro-processing, irrigation, cold storage and retail businesses is critical. These activities increase incomes and grow the demand base that makes electrification systems financially sustainable over time.

[32] For more information, see Efficiency for Access: Mid-Term Review of the Light-a-Village Pilot, January 2026.

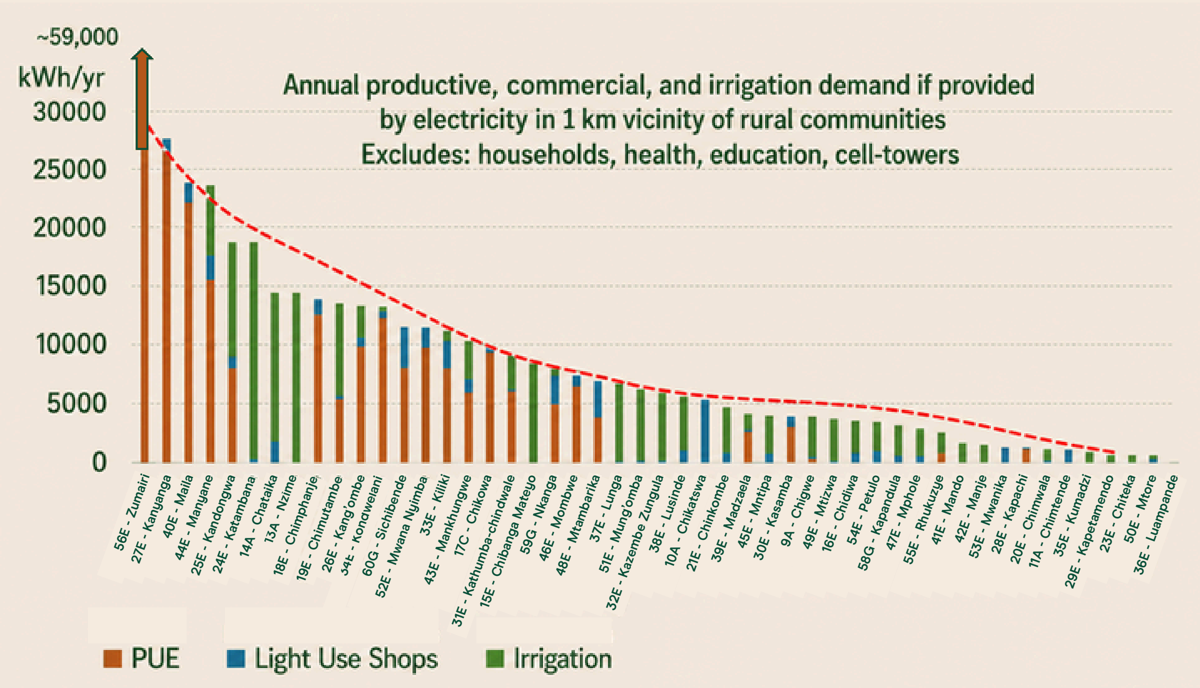
Designing systems that support productive use requires getting three things right: understanding latent demand, pricing electricity competitively and linking electrification with broader rural development programs.

First, productive electricity demand should be understood locally. While geospatial tools can identify potential demand clusters, they are rarely sufficient to estimate productive demand on their own. Accurate estimates typically require field-based surveys and engagement with local businesses, farmers and community institutions. Operators and planners therefore should invest in on-the-ground local demand assessment to identify anchor loads, seasonal demand patterns and opportunities for productive use.[33]

Box 3: Ground-truthing rural productive electricity demand in Zambia reveals large site-to-site variation and highlights the importance of on-ground studies to inform project design

The graph below shows estimated productive electricity demand for 50 communities in Zambia that were prioritized for electrification and initially identified through national geospatial planning as roughly equivalent mini-grid sites.[34]

Field surveys revealed a very different picture: productive electricity demand varied by two orders of magnitude across sites, ranging from less than 0.5MWh per year to more than 50MWh per year. In many of these sites standalone power solutions are likely to be more cost-effective than grids in the early years of electrification.



Source: *Data is from a program funded by the Rockefeller Foundation and executed by SEforALL.*

Collecting this ground-level data is relatively inexpensive but can fundamentally change electrification design and prioritization, enabling planners to match supply technologies to the actual needs of local economies.

[33] The raw cost of carrying out such surveying across – for example – the whole of Uganda, where 80,000 locations were visited by local teams on motorcycles, was just $800,000 (see qsel.columbia.edu).
[34] Data is from a program funded by the Rockefeller Foundation and executed by SEforALL.

Box 4: A demand-driven electrification approach by a successful local operator in Mali, expanding over time

The ACCESS SA experience in Mali illustrates what this looks like in practice. ACCESS SA has been working since 2005 to electrify communities in Mali and manage 29 concessions, reaching 135,000 people across the country. ACCESS SA works closely with communities to understand local demand patterns before designing and expanding systems. Concessions are negotiated directly with local municipalities before being formalized with the rural electrification agency, and communities establish Village Energy Committees to manage coordination with the operator.

This local engagement allows ACCESS SA to identify sites and deploy appropriately sized systems, and adapt to changing patterns of demand. For example, communities may collectively decide how to accommodate new productive uses – such as the addition of dozens of refrigerators for ice production – or adjust electricity schedules during periods of seasonal or religious demand such as early-morning cooking during Ramadan.

Pictured: ACCESS mini-grid in Finkolo Ganadougou village in the south of Mali, near the boarder with Côte d'Ivoire.

Second, in order to drive development, electricity should be priced competitively. In many unelectrified areas, businesses rely on diesel generation. With a diesel cost of $1-2 per liter and the low efficiency of small generators, that means electricity costs of $0.40-0.80 per kWh.[35] Electrification programs should aim to supply electricity well below diesel cost. Prices in the range of $0.15-0.20 per kWh – typical for grid-equivalent electricity in many African markets – can transform operating economics for existing businesses while unlocking latent demand for new ones.[36]

Third, electrification programs should be coordinated with broader rural development efforts. Affordable electricity alone does not automatically generate economic activity. Demand grows most rapidly when electrification is paired with complementary investments such as agricultural productivity programs; equipment financing; micro, small and medium-sized enterprise support; and improved access to markets. This pattern is consistently observed across empirical studies. When these enabling conditions are in place, energy access acts as a multiplier.

The current push to accelerate electrification under Mission 300 creates an opportunity to coordinate energy investments with economic development programs in a more deliberate way. The national energy compacts developed by governments demonstrate an ambition for electricity to drive economic growth, but most do not yet specify how electrification and sector programs will be aligned in practice. The World Bank has emphasized that infrastructure investments only create jobs at scale when linked to productive sectors such as agribusiness and manufacturing, a direction reflected in initiatives such as the AgriConnect program, but one that still needs to be operationalized at the country level. In Zambia, for example, major World Bank investments in rural electrification and agricultural development are being rolled out on parallel timelines, creating a concrete opportunity to link electricity expansion with irrigation, agro-processing and cold storage infrastructure.

[35] Storing and transporting diesel add to the price, especially in deep rural areas

[36] Here, the right-sizing of household demand described above becomes critical. Many projects offer unsustainably expensive power to productive users because they need to locally cross-subsidize the cost of overdesigned, expensive household connections.

Box 5: Aligning electricity and agricultural policy: solar irrigation under India's PM-KUSUM program

India's Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM-KUSUM) program shows what deliberate alignment between electricity and agricultural development can achieve at scale. The program links renewable energy expansion directly with agricultural irrigation by supporting the solarization of irrigation pumps and the development of distributed solar generation connected to rural electricity networks.

The scheme combines two complementary grid-integrated approaches. Under one component, farmers can install grid-connected solar plants on farmland near rural substations, with utilities purchasing the power. Under another, existing irrigation pumps are solarized either individually or through feeder-level solar plants that power clusters of agricultural pumps.

Evidence from implementation in Rajasthan State shows that aligning energy and agricultural policy can accelerate deployment and generate tangible benefits for farmers by allowing irrigation to shift to reliable daytime power that matches solar generation profiles. By early 2025 the program had added roughly 183MW of solar capacity and more than 12,700 solarized irrigation pumps. Surveys in Rajasthan found that 71 percent of farmers reported reduced cultivation costs and 57 percent reported higher yields after adopting solar-powered irrigation.

Reliable daytime electricity has also supported crop diversification and enabled small rural enterprises to operate more consistently.

The alignment also benefits electricity providers. Solar generation on agricultural feeders helps meet daytime demand locally while improving the performance of rural distribution networks, including through more stable voltage conditions and reduced strain on transformers during irrigation peaks.

Pictured: Solar power is creating more opportunities for women across rural households in Bansur, Rajasthan.

Enable efficient, least-cost delivery

Once governments and electricity providers have defined minimum service levels and assessed productive demand, the question becomes how to supply electricity at least cost.

Part I documented the consequences of delivering each technology through separate institutional channels, with none achieving the scale or density needed to bring costs down. With the remaining unconnected customers being the poorest and most remote, and public funding being finite, the cost of that inefficiency is increasingly hard to justify.

The new technologies make more efficient approaches possible. Solar panels, batteries and digital tools such as smart metering and PAYGO platforms have matured to the point where they can be integrated into national scale electrification programs, something that would have been far harder to achieve even a decade ago.

Design to meet current demand, and build in the flexibility to grow

Part I documented the consequences of designing systems based on optimistic projections of future demand: overbuilt infrastructure, unsustainable operating costs and providers locked into portfolios of loss-making connections. Distributed renewable energy now makes it easier to meet current demand efficiently while retaining the flexibility to grow as demand develops.

First, systems should be designed to meet current demand at least cost. This may involve deploying different technologies within the same service area, such as isolated grids for dense demand clusters and standalone systems for dispersed households or businesses. The Zambia analysis in Appendix 4 illustrates this concretely: in a cluster of 3,800 households, a least-cost design proposes standalone systems for 3,600 households and isolated grid connections for only 200 households where productive loads make shared infrastructure economically justified.

Second, systems must be built to grow. The modularity of distributed renewable energy technologies means generation, storage and distribution infrastructure can be expanded incrementally as demand grows. Operators with local knowledge can deploy the right blend of technologies to meet today's demand, while reacting quickly to expand when new businesses or economic development drive demand growth. For developers and utilities, staged investment reduces upfront capital requirements and better aligns investment with revenues.

For this to work, operators need the technical capabilities, financial agency and regulatory frameworks to make dynamic supply adjustments on the ground. Multi-technology models introduce new complexity, and project operators may need to develop new skills. Incentive structures should reinforce this: operators should be incentivized to meet new demand, not just minimum connection targets, and deliver those services in a sustained manner.[37]

Box 6: Leveraging technical and business model innovations for more modular deployment

Okra Solar is a mesh grid technology company that designs hardware kits and operational software for local energy developers, who deploy and operate the systems in off-grid communities. A mesh grid is topologically distinct from a conventional mini grid: instead of a central generator distributing power through heavy cabling sized for peak demand, small generation and storage units sit at or near each household and share energy with neighbors over short, low-voltage DC connections. Because local batteries serve peak loads and the network only needs to carry daily energy transfers between them, distribution costs are reduced and systems can be extended household by household as demand grows.

Source: OkraSolar

[37] There is generally an important role for electricity suppliers to help grow demand, for example through tariff structures, by deploying appliance supply and financing programs, or by partnering directly with larger business and off-takers

Okra currently has over 8,000 connected houses across sub-Saharan Africa, Southeast Asia and the Caribbean, with the majority in Nigeria and Haiti. A CrossBoundary case study[38] found mesh grids deployed 1.5 times faster and at 41 percent lower per-connection cost than conventional mini-grids. This cost advantage will be tested through Nigeria's $750 million Distributed Access through Renewable Energy Scale-up (DARES) program, which now includes funding for mesh grid deployment.

Source: OkraSolar

MOPO, a company operating in West and Central Africa, deploys battery solutions that allow electricity supply to expand gradually with demand. MOPO provides portable battery packs that households and businesses rent and recharge at local hubs powered by solar arrays. The battery packs range from small affordable batteries that deliver essential power for lighting, smartphone charging and small appliances, through to larger battery solutions that can power the vast majority of household and business appliances, including refrigerators, larger televisions, construction equipment and sewing machines. Customers typically pay daily in cash on a pay-per-use basis, eliminating the need for upfront deposits or debt financing. As batteries can be rented in bulk, swapped and redeployed across the network, customers get the amount of energy they need when they need it, and supply can grow incrementally as more units are deployed or additional hubs are installed.

MOPO is also experimenting with linking hubs to high-usage customers through a wired connection, creating pathways from portable energy services towards more permanent electricity systems that deliver larger amounts of energy as demand increases. The company is also piloting the use of batteries for e-mobility, allowing customers to use energy flexibly at home and to power electric two- and three-wheeler vehicles. Backed by a network of more than 550 hubs and 1,700 agents, MOPO operates across Chad, the Democratic Republic of the Congo, Liberia, Nigeria and Sierra Leone.

Source: MOPO

[38] CrossBoundary Innovation Insight: Mesh-grids, 2025

Give operators a defined service territory and a clear service obligation

The poorest and most remote communities will not be connected unless a provider has a clear obligation to serve them, and they cannot be served sustainably unless that provider can make the economics work. Doing so requires coordinating supply across adjacent communities; concentrating deployment, operations and after-sales service within a defined area so that fixed costs are spread across enough customers to be viable; and the portfolio as a whole operating without unsustainable demands on public funds. As Part I documented, the current "competitive free-for-all" in standalone solar markets inherently prevents geographic clustering and limits economies of scale so that costs remain high and after-sales service and collections are financially unviable. Delivering electrification at scale requires a model in which a single entity is ultimately responsible for ensuring that electricity services reach consumers within a defined geographic area. In practice, that entity may be structured as a partnership, consortium or joint venture comprising multiple operators with complementary roles and capabilities. This is not new. National and regional utilities have operated under scaled service obligations for decades, though lack of funds can limit actual network growth and service levels. The approach proposed here adapts that concept to the realities of distributed energy technologies and rural electrification, while also embracing principles underpinning infrastructure finance.

Only by blending geographical exclusivity with an obligation to serve, can we achieve universal energy access in a defined area. In some cases, it may be prohibitively expensive to require universal access immediately, but service territories and obligations can be used to unlock efficiencies in delivery and ratchet up to universal electrification step-by-step.[39] Under this model, governments designate technically qualified and capitalized electricity service operators – whether private operators or utilities – as responsible for defined geographic areas and obligated to provide services to households, businesses and public institutions within the territory. Operators could be given some degree of flexibility to deploy a cost-effective combination of electrification technologies, depending on local energy needs and public sector priorities.

Box 7: Exploring multi-technology deployments in Madagascar

The MOOKA initiative is testing an integrated electrification model that combines solar home systems with mini grid infrastructure within the same geographic clusters, allowing them to reach customers that would otherwise be unviable for the mini grid. The program brings together MOON, a solar home system as a service solution provider, and ANKA, a mini grid developer, to coordinate deployment across rural communities in southern Madagascar. Under their model, households receive rapid access to basic electricity services through solar home systems delivered using an energy-as-a-service model, while mini grids provide higher-capacity electricity for productive uses, businesses and community infrastructure.

By combining these technologies within a single operational framework, the approach allows electrification systems to match different levels of demand across a service territory while avoiding the inefficiencies of deploying each technology in isolation. The first deployment in the Atsimo-Andrefana region has connected approximately 2,000 households, with plans to expand to up to 100,000 households across Madagascar. The program operates through a shared asset ownership structure, with infrastructure held by a joint asset company while ANKA acts as the system operator. This structure enables coordinated planning of generation, distribution and service delivery as electrification expands.[40]

Pictured: A remote household beyond the mini-grid's area now has access to energy thanks to a solar system operated under an Energy-as-a-Service model by the mini-grid operator.

[39] This approach is fundamentally different to models in which private companies receive subsidy for electrifying only the highest-paying consumers, which risks making it even harder to reach the next wave, as subsidies will have been spent, cross-subsidies lost and operational efficiencies reduced
[40] REAL Programme Catalyst, 2026, Why Energy-as-a-Service works for the hardest to reach.

Service obligations should be paired with exclusive or priority rights within the service area, otherwise operators cannot plan or invest with confidence. Exclusivity does not prevent households from using other energy sources, but it ensures that the designated operator is responsible for delivering electricity services and is the focus of public subsidies and support. In return, governments set clear expectations for service within the concession area, for example requiring operators to connect a defined percentage of households within a specified time period, and to meet minimum standards for reliability and service quality.

Service areas that meet a minimum viable scale have benefits beyond spreading fixed costs across a larger customer base. Larger service territories reduce transaction costs, ease the regulatory burden on governments that may otherwise face the challenge of overseeing dozens or hundreds of small operators, simplify and lower the cost of financing, and provide more meaningful investment opportunities to infrastructure investors. Service areas that are too small and remote, without some type of aggregation, may never be financially viable.

Before designating an operator, governments can define a basic electrification plan for each service area (summarized in Table 3), giving operators clarity on demand conditions, service expectations and the broader infrastructure context in which they will work.

Table 2: Selected elements of a basic electrification plan, to be defined for an area to be assigned to a designated operator

Criteria	Description
Service area	Clearly defined geographic service areas, identifying the communities to be served.
Service levels	Minimum level of household service and performance standards for non-household consumers.
Productive demand assessment	Field-based assessments of productive demand, including businesses, seasonal demand patterns and peak loads.
Public institution requirements	Electricity needs of, and obligations to, public institutions – such as school, health centers and administrative buildings.
Demand growth opportunities	Potential for future demand growth, including links with rural development partners and programs.
Grid infrastructure mapping	Existing and planned grid infrastructure, including capacity and expansion timelines.
Service performance and maintenance	Maximum downtime and response to faults.

The shift from the current landscape of subsidies for technology-specific initiatives toward service-oriented electricity systems means operators are accountable for ongoing delivery of reliable electricity, not for deploying a particular technology.

It also requires a different approach to bankability. Developer-led distributed energy models typically rely on selecting the most commercially viable sites, but a provider responsible for an entire service territory must connect the dispersed and the poor alongside the relatively better-off. Long-term concessions, predictable revenue streams and risk-sharing arrangements can make area-based service provision attractive to investors. This requires frameworks that ensure risks are appropriately identified, allocated, mitigated and priced across stakeholders. In many contexts, a phased and incremental approach to market development may also be required, particularly where the objective is to mobilize private capital at scale. Such structuring can achieve the minimum viable scale of deployment that drives operational efficiency and unlocks private capital. Section 3 sets out ways to build those structures.

Box 8: The importance of understanding operational costs in rural electricity systems

Although capital costs for electrification technologies are now relatively well understood, far less data is available on the operating costs of providing ongoing electricity services in rural areas. In dispersed rural markets, these operational costs can represent a significant share of total system costs, particularly when customer densities are low. Many electrification programs have historically underestimated these costs, contributing to the financial challenges faced by rural electricity providers.

Better data is needed on the full range of operational costs associated with rural electricity systems, including operations and maintenance, revenue collection, system replacement and customer service in remote rural areas. These costs may vary significantly across countries and regions, depending on factors such as technology mix, population density, terrain and climate conditions, operational model, selection, repair costs, product maturity, standards and actual operational lifetimes.

Addressing these gaps will require projects that are willing to experiment and publish full cost structures for providing ongoing electricity services using different combinations of technologies. This type of data will also be critical for building regulatory capacity within countries, enabling regulators to better understand the costs and returns associated with local electricity system operators.


Source: GEAPP

Create financing structures to allocate risk and lower the cost of capital

Even the most efficiently designed service territory will not attract or sustain investment without predictable long-term revenues grounded in a long-term service obligation. Part I demonstrated how the reliance on capital subsidies – without the cross-subsidies and long-term public support mechanisms needed to sustain operations – has repeatedly undermined well-designed systems: revenues fall short, service degrades, investors retreat. We must now move from one-time capital subsidies toward financing structures that give operators the obligation and incentive to maintain and expand service, alongside revenue streams which ensure that the full cost of electricity service delivery is recovered over time.

Ensure long-term service is fully funded

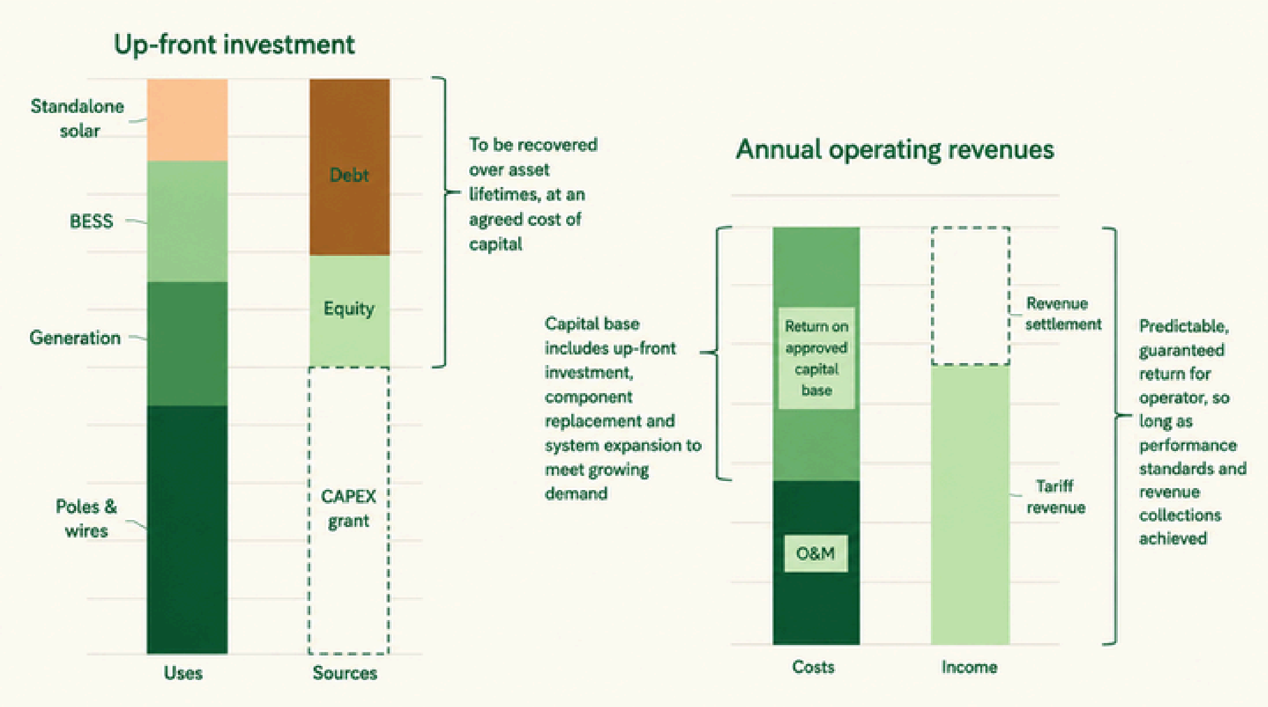
Cross-subsidizing rural customers[41] from a small, cost-sensitive urban and industrial consumer base is rarely feasible in the early phases of a comprehensive electrification process, and achieving financial stability without external support typically takes many years. A well-designed mixed-technology approach may substantially reduce overall cost, creating fiscal space for cross-subsidy and ongoing operational support. In the interim, programs need a financing mechanism that allows affordable tariffs while ensuring the full costs of service delivery are recovered, likely through a combination of customer revenue and subsidy.

The core question then becomes how to structure and finance the subsidy to cover the additional costs of service delivery over and above customer revenue.

[41] According to UN World Urbanisation Prospects and UN World Population Prospects, the 31 countries with Energy Compacts under Mission 300 are around 58% percent rural (931M people, of which 389M urban)

Different options and approaches exist, and must be considered in terms of local relevance, incentive structures, implementation complexity and risks that might affect bankability. One approach is to use a revenue settlement mechanism that covers the difference between the regulated tariff, and the operator's regulated cost base (see Figure 14). Under this model, the operator charges consumers the government-regulated tariff and delivers against defined service standards. The government or a designated agency then settles the difference between tariff collections and the agreed cost of service provision, subject to performance verification.[42]

Figure 14: Sources and uses of funding for a distributed renewable energy operator in an example model using a revenue settlement mechanism to fund the operations of an isolated grid and solar home system concession.



This approach has several advantages. It aligns operator incentives with service delivery rather than hardware deployment, since revenue depends on maintaining service quality, not just installing systems. It allows tariffs to be set at affordable levels for consumers while ensuring operators can cover their costs. And it creates the kind of predictable, long-term revenue stream that can underpin infrastructure financing. However, it requires the government to take on key risks and reserve financing for payments, just as it would for a utility.

The approach depends heavily on the capability of national regulators to validate cost structures, carry out reconciliation and ensure timely payments to operators. This capacity cannot be assumed. Building it should be planned as an integral part of electrification programs from the outset, with support for cost benchmarking, performance monitoring and payment systems. Revenue settlement mechanisms also need to work within regulatory regimes that explicitly address risks, including eventual grid interconnection, non-payment or regulatory disputes.

Other approaches have been tested. For example, the International Finance Corporation (IFC) Scaling Mini-Grid program designed minimum revenue guarantees for private developers. These can be useful de-risking tools but do not on their own create the ability to cross-subsidize, control tariffs or address the political risks associated with tariff-setting.[1] Power purchase agreements (PPAs), widely used in utility-scale generation, can also be adapted for providing power through isolated or rural grids. In practice, countries may adopt new or hybrid approaches that combine elements of several models.

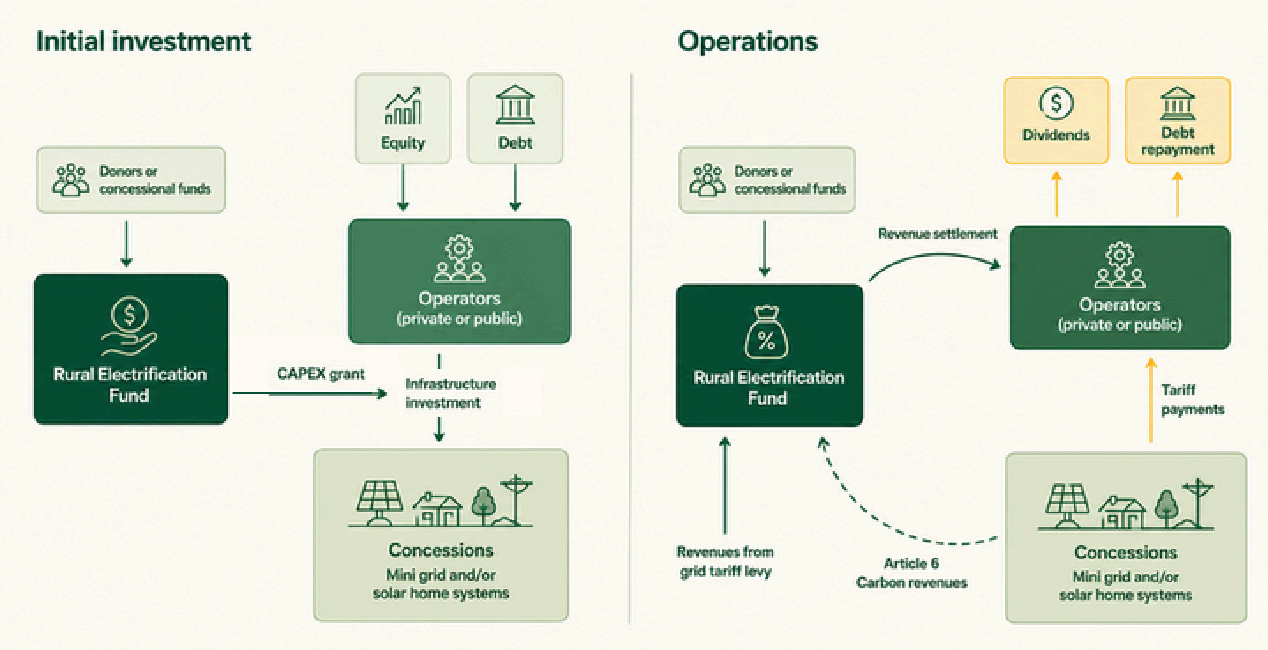
---

[42] Any country with a uniform tariff is doing some sort of cross-subsidization. This revenue settlement approach is used by countries including Brazil, Ecuador, and the Philippines for financing rural electrification, as well as in markets like Spain and France for harmonising tariffs in remote or hard-to-serve areas

[43] IFC's Scaling Mini-Grid templates are freely available for download

Even well-designed revenue mechanisms face a financing challenge over time. Major development partners, such as The World Bank, typically operate on relatively short project cycles of five years or less but their finance is critical for filling funding gaps. One approach is to use this funding – held in dedicated or escrow accounts where appropriate – to finance capital expenditure and the early years of operational incentives while building the domestic funding mechanisms needed for long-term sustainability (Figure 15).

Figure 15: Flow of funds between institutions, for the same example model as Figure 14 this time using a revenue settlement mechanism to fund the operations of an isolated grid and solar home system concession.



Structure investments that allocate risk appropriately

To attract private capital, rural electrification programs can be structured as public-private partnerships (PPPs), allowing governments to expand access while enabling developers, utilities and investors to finance and operate electrification systems as long-term infrastructure assets (even if they include some assets with shorter lives, which then need to be replaced). Operators are responsible for building, operating and maintaining electricity systems within defined service areas, while governments establish service obligations, regulatory oversight and the revenue support mechanisms set out in Section 3.1. So long as the scale is large enough, together these create the conditions for infrastructure finance, giving investors visibility over the full project lifecycle from capital investment and operating costs through to repayment schedules and service obligations.

Structuring electrification programs this way allows risks to be allocated between governments and operators in ways that reflect each party's capacity to manage them, including: their control over the likelihood of the risk occurring; their ability to manage the risk if it occurs: and their ability to absorb the risk at the lowest cost. Each context and use case will vary. However, governments are generally better positioned to absorb tariff risk and regulatory risk, while operators are better positioned to manage household payment default and performance risks.

Appendix 2 sets out a more detailed framework for risk allocation across the major categories that must be addressed, including demand, collection, performance and regulatory, tariff and government payment risks. PPPs can also be structured as build-own-operate-transfer (BOOT) models, with assets returned to government ownership at the end of the concession period. This ensures that infrastructure built through private investment becomes a public asset available for re-tendering or operation by a public utility.

Guarantees from entities such as the Multilateral Investment Guarantee Agency (MIGA) are critical to making projects bankable for infrastructure investors, particularly in addressing political risk and payment risk. Appendix 2 sets out the bankability conditions that investors will focus on, including the scale, term and predictability of revenue streams, the robustness of the contractual framework and the track record of the operator.

Box 9: Anzana's PPPs and project finance

Anzana (formerly Virunga Power) illustrates what a large-scale PPP for rural electrification can look like in practice. In Burundi, distribution infrastructure rather than generation is the binding constraint, so Anzana and the government have pursued a 25-year PPP to extend grid access to more than half of the population. The model consolidates what may otherwise have been multiple micro-utilities into a single national PPP concession to capture economies of scale and ensure uniform service standards. A 55,000-connection demonstration phase is underway, and a set of similar frameworks with ZESCO in Zambia and with provincial governments in the Democratic Republic of the Congo aim to achieve universal access in selected regions, with potential integration of distributed renewable solutions. Advantages of the model include:

Crowds in finance for the government's universal access goals. The long-term concession is structured to mobilize public-oriented grants and concessional finance, as well as development finance institution (DFI) funding and private commercial investment toward universal access, reducing pressure on national debt and the public utility while enabling large-scale expansion.

Accelerates electrification in dense, grid-appropriate geographies. In countries like Burundi, where grid extension is the least-cost pathway for most households, Anzana brings technical capacity, speed and project management capabilities that are difficult for constrained utilities to match.

Creates a unified national framework that avoids fragmentation. By moving from provincial pilots to a nationwide contiguous concession to complement the public utility, the approach enables consistent service standards, tariffs, economies of scale and portfolio-wide cross-subsidization.

Integrates distributed solutions into a grid-first strategy. Although centered on grid expansion, the model allows for partnerships with future-proofed mini grids to stimulate demand and enhance system value.

Incorporates demand generation efforts. Anzana brings experience in demand generation to a grid-connected environment. In their initial pilot, for example, they are incorporating an e-cooking trial.

Improves tariff stability and long-run financial viability. The PPP embeds mechanisms like periodic re-benchmarking of the cost of capital, drawing on lessons from other historical African private utility models to ensure affordability while maintaining operator sustainability as risk declines over time.

Ground electrification plans in national financial planning

Achieving universal electrification requires planning and financing at a national level rather than through small, isolated projects. This allows governments to understand the total cost of delivering electricity services across both grid and off-grid systems, and to develop long-term strategies that give operators and investors the coordinated framework they need to make long-term commitments.

With demand mapped and supply costs increasingly well understood, governments can model the financial requirements of universal electricity access. This allows policymakers to test different delivery models, service levels and investment pathways, and make explicit the trade-offs between public funding, tariffs and private investment.

Regulators can also move beyond attempting to make tariffs cost-reflective at the level of individual households or communities, which is economically impossible in most rural settings. Instead they can aim for cost recovery at the level of the national electricity system across both on and off-grid systems, adopting the rural-urban cross-subsidy that is typical in many markets. In most countries this will take many years. Affordable electricity is fundamental for urban and industrial growth, as well as rural development, and therefore public funds and concessional finance will be critical to bridge the gap between today's situation and a sustainable long-term equilibrium.

This integrated financing model draws heavily on the principles laid out in the Integrated Framework for Electrification, developed by the African School of Regulation (ASR), the Global Commission to End Energy Poverty (GCEEP) and MIT/IIT-Comillas Universal Energy Access Lab, as further detailed in Appendix 3.

The example of Zambia in Appendix 4 demonstrates how existing grid tariff levies can be used alongside up-front development partner support to fully fund the extension of universal, affordable and sustainable access across a whole country.

The principle behind Anzana's model in Burundi and the Zambia example is the same: universal electrification becomes financially viable, not by making individual projects more attractive to investors but by building the systems within which projects can be structured as infrastructure rather than risky bets. The three design elements outlined in this paper are interlocking components of that system, and they only deliver when built together.

From architecture to implementation

The model set out in this paper is grounded in frameworks and financing structures that have worked in different contexts around the world. But architecture on paper is not the same as systems on the ground. Moving from architecture to implementation will require confronting a set of challenges that are as much political and institutional as they are technical or financial. Acknowledging the following challenges helps to set a roadmap for where deliberate effort will be required:

- **Institutional and regulatory capacity.** Service-based or publicly procured electrification systems require stronger regulatory capability than most current distributed energy subsidy programs. Revenue settlement mechanisms, concession oversight and performance monitoring depend on institutions that can validate cost structures, reconcile payments, verify service delivery and enforce standards. In many countries these capabilities exist within traditional grid-based power systems but have not yet been extended to distributed energy systems. Building them could be treated as a core component of electrification programs from the outset, not an ancillary activity.

- **A role for local companies.** Larger service territories and bankability requirements will favor experienced operators, and there may be few or no local companies with the requisite experience today. However, barriers will likely be lower for distributed energy providers and service providers, opening up opportunities for local companies and employees who will be vital for local operational capacity and long-term sustainability. Designed correctly, the first wave of service territories could create a raft of new partnerships and opportunities for local companies to grow, operate at new scale and develop their own capacity, for example by acting as engineering, procurement and construction or regional service providers.

- **Sustained fiscal commitment and availability of funds.** Universal electrification for low-income rural populations requires ongoing public support. Development partner funds may be available during the few years of a project cycle, but governments must be able to commit to the financial plans that allow for ongoing revenue flow (for example, funds from the tariff levy). Here, the roles of MIGA and other guarantee providers become essential, in supporting and guaranteeing these longer-term revenues, and making projects bankable.

- **Funder alignment around national frameworks**. Fragmented development partner programs have been a major driver of the project-based landscape that helped to popularize the new technologies. Implementing this next stage of market development requires development partners to align around national electrification frameworks and service-area planning rather than funding isolated projects tied to particular technologies or delivery models. The Mission 300 compact process provides a platform for this alignment, but sustained coordination will be necessary to translate it into coherent national programs that operators and investors can act on.

- **Measurement, learning and course correction.** Rural electrification programs must be designed as adaptive systems rather than fixed project pipelines. Demand growth, operating costs, technology performance and the pace of local economic development are all difficult to predict in advance. Programs need mechanisms to monitor whether systems are delivering durable outcomes, tracking service reliability, revenue adequacy and actual electricity use, not simply connection counts. Governments and development partners should require transparent reporting and structured review as conditions of program approval, building the evidence base that allows the whole sector to learn and improve over time.


Source: GEAPP

The hundreds of millions of people still without electricity cannot wait for perfect conditions or another cycle of fragmented pilots. Distributed renewable energy technologies are mature, regulatory and financing models exist, and the scale of ambition is creating the opportunity to bring them together. What it requires now is the collective will to act on it, by all stakeholders:

- **Governments** can structure scaled market opportunities, treat them as core national infrastructure, and share the risks that markets alone cannot carry.
- **Concessional financiers** can direct subsidies toward sustained service rather than hardware and use their balance sheets to crowd in private capital by helping absorb the risks that hold it back.
- **Operators** can work with governments as partners, unlocking the scale and bankability the sector has lacked.
- **Investors** can approach this as an emerging infrastructure asset class, where past underperformance reflected how the sector was structured and financed, not the technology or the people in it.

Source: GEAPP

Appendix

Appendix 1: Summary of electrification programs and PPPs that demonstrate principles in practice

The principles described in this paper have all been tested and demonstrated in practice. Table A1 summarizes how an electrification program might be assessed against them. Table A2 shows how each of the examples cited in the boxes in the main text demonstrates at least two of these principles in practice.

Table A1: Assessment criteria for electrification programs against the seven principles in this paper

Universal household supply	Does the program mandate a minimum level of supply that should be available to all households, at a determined cost?
Productive use program alignment	Does the program guarantee supply of electricity to support agriculture and business, at tariffs that are consistent with growth and economic development (i.e., much better than diesel), and in close alignment with local demand and other rural development programs?
Least-cost initial supply and growth	Does the program guarantee that initial demand will be met (by any blend of technologies), while ensuring the operator is empowered and incentivized to rapidly provide for increasing demand?
Service territories with performance obligation	Does the project define service obligations in a given area, that will guarantee outcomes, such as universal access? And is this balanced with exclusivity or certain rights within the area?
Guarantees of operational revenue	Does the project guarantee ongoing revenues that will maintain the incentives to provide high performance over time, and provide some resilience to currency, tariff, or demand risks?
Structured investment with allocated risk	Is the project large enough, long enough, with predictable returns, and the right operator? Are project risks properly considered and shared between the government and the operator?
National financial planning	Does the project fit within a national financial plan for long-term scale-up of electrification?

Table A2: Examples cited in this paper, and principles demonstrated in each

	REAL/ SolarAid *Malawi*	**ACCESS Energie** *Mali*	**PM-KUSUM** *India*	**MoPo** *Various*	**OKRA** *Nigeria*	**MOOKA** *Madagascar*	**Anzana / Weza** *Burundi*
Universal household supply							
Productive use program alignment							
Least-cost initial supply and growth							
Service territories with performance obligation							
Guarantees of operational revenue							
Structured investment with allocated risk							
National financial planning							

Appendix 2: Selected criteria for risk and bankability in PPPs

As described in Section 3.2, sharing of risk is critical for the design of an effective PPP. Table A3 provides an example of how common risks might be considered in a rural electrification concession that follows the principles laid out in this paper.

Table A4 summarizes some of the key criteria that will be considered in assessing the bankability of a project that seeks to raise private capital to deliver rural electrification.

Table A3: Example of risk distribution in a rural electrification concession

Risk	Approach
Demand risk	**Shared.** Government underwrites the initial demand risk, especially from residential consumers (as defined above). As demand grows, the operator is incentivized to expand the system but will take a higher portion of the demand risk.
Collection risks	**Operator.** It is the operator's responsibility to collect payments from customers.
Performance risks	**Operator.** It is the operator's responsibility to maintain system performance and meet service standards. Their revenues and returns will fall if they fail to meet these performance levels.
Regulatory risk	**Government.** The appropriate government agencies define concession boundaries, duration, grid interaction and other key factors.
Stranded asset risk	**Concession agreement.** The concession area can be affected by regulatory change (allowing competing operators) or grid extension. The PPP or concession agreement addresses this directly to provide pre-agreed buy-out formulas, grid encroachment protocols, transition agreements and clear rules on what happens at the end of the concession term.
Tariff risk	**Government.** Tariff risk includes affordability, willingness to pay and the political pressure that can be generated by having non-uniform tariffs. To address this, the tariffs will be set and regulated by national agencies. The developer is simply responsible for collecting the set tariffs.
Government payment risk	**Concession agreement and guarantee structure.** The government will generally make payments to the operator through a revenue settlement mechanism. To achieve project bankability, these payments can be guaranteed by an entity like MIGA.
Company failure risk	**Government.** In some cases, even with well-structured concessions and experienced providers, companies may fail. There must be a mechanism to avoid these failures leading to large numbers of people losing access to electricity, or to infrastructure deterioration. Governments should ensure that a "provider of last resort" exists, with the capabilities to take over the operations of the concession, with public backing, under pre-defined conditions.

Table A4: Key bankability criteria for rural electrification concessions

Criteria	Considerations for bankability
Revenue streams	Following initial investment, returns on the project will come from a combination of tariff revenue and a revenue settlement mechanism. Government ownership of the tariffs – and hence any local political pressure around electricity costs – will be important.
Term	Longer-term projects will be easier to finance: a typical project term may be 20 years. Note that this can be aligned with the expected lifetime and depreciation of the physical infrastructure.
Scale	Any project needs to reach "minimum viable scale", in other words, it needs to be a large enough transaction that the costs of PPP development and deployment do not unduly burden the project. Increasing scale also has a major impact on operational efficiencies and cost of supply. Small-scale projects and clusters will not be viable.
Political risk	A rural electrification concession will be founded on a long-term agreement with the government, possibly including a flow of funds to support the operations of the concession. A strong political risk guarantee will be critical for the project financiers. In many cases, MIGA guarantees are likely to be the most suitable instrument.
Service obligations	The government will set out service obligations, such as quality or universality of supply. These requirements on the operator may increase their costs. As such, they need to be clearly agreed and properly costed.
Track record	A rural electrification concession will be operated by an entity that needs to demonstrate the organizational and technical capabilities for serving millions of people over long time periods with low costs. Larger companies with strong track records (for example, holders of distribution concessions in other countries) are more likely to be able to demonstrate this skillset.
Financial returns	The overall expected return on capital in the project will be the main investment criteria for the financier. In addition, there should be clear and effective mechanisms in place for regulators to review and approve ongoing capital investments in a timely way, to allow the operator to effectively serve the region ("grow with demand").

Appendix 3: An introduction to the Integrated Framework for Electrification

ASR's Integrated Framework for Electrification (IFE) provides a structured approach – a basket of best regulatory, institutional and financial practices – for designing electrification programs capable of delivering universal access (SDG 7) in a way that is financially viable and compatible with long-term power-sector development. The framework has been developed over several years through the work of ASR, the MIT/IIT-Comillas Universal Energy Access Lab and GCEEP, and has informed country-level analysis and implementation discussions in Madagascar, Rwanda, Uganda and Zambia, as well as relevant Latin American experiences.

Delivering universal access imposes four essential requirements on any national electrification program:

- **Least-cost**, so that the total funding gap to be closed is the smallest one compatible with meeting the access target. This requires an integrated techno-economic plan that considers grid extension, mini grids and standalone systems together, rather than as separate technology silos.
- **Scalable**, so that the program can reach every customer and not only those the market would serve on its own. The total expenditure required to electrify an entire country is of a magnitude that public resources and concessional finance alone cannot cover. Scalability is what allows mobilization of the private capital needed at the required volume.
- **Sustainable**, so that access is permanent – an ongoing service governed by a regulated tariff, rather than a one-off project that collapses once the support from the initial funding proves inadequate to maintain affordable tariffs. This requires a financial plan under which the sector eventually reaches stability, with the efficient cost of service covered by regulated tariffs without external subsidies (targeted social tariffs or lifeline rates for vulnerable customers remain compatible with this). Reaching that point typically takes longer than reaching universal access itself.
- **Customer-oriented**, so that access translates into economic development and growing demand. Without productive use, appliance access and local economic activity, demand stagnates, affordability does not improve and sustainability becomes unreachable.

As a practical toolkit, the IFE operationalizes these principles through three questions that any national electrification program must answer:

- **What must be done, where and at what cost?** A least-cost integrated techno-economic plan specifying which technology serves each customer, the resources required and how the system evolves until universal access is achieved.
- **Who will do it and under what regulatory and business model?** Someone must be responsible for serving every customer in a defined geographic area – normally a utility, concession or a PPP with a universal-service obligation. Specialized grid, mini grid and standalone providers can operate within the same national strategy; no single company needs to deploy every technology in every territory. The model must also be able to attract private capital, since public and concessional funding alone cannot cover the volume required.
- **How will it be paid for over time?** An integrated financial plan covering all electrification modes, combining regulated tariffs, efficient cost-of-service remuneration, viability-gap funding, public and concessional support, and cross-subsidization where appropriate – designed to reach financial sustainability within the timeframe the country's circumstances allow.

Several conclusions in this paper have drawn on the IFE and the broader workstream on integrated electrification: the move beyond technology-specific projects; the distinction between affordable customer tariffs and the operator's efficient revenue requirement; the importance of scalability to mobilize private capital at the volume required for universality; and the recognition that financial stability is achieved over the necessary period of time rather than instantaneously. In this sense, the IFE should be understood not only as a toolkit, but as one of the analytical foundations for the integrated, service-based and financially sustainable electrification model proposed in this paper.

Appendix 4: A plan for least-cost electrification concessions in Zambia

This section is drawn from a pilot program, under development by the Zambian Rural Electrification Authority, working with partners including The Rockefeller Foundation, SEforALL, Global Energy Alliance, ASR and Columbia University to demonstrate universal, sustainable access by applying the principles laid out in this report (albeit at a smaller scale than is proposed in the bankability assessment in Appendix 2).

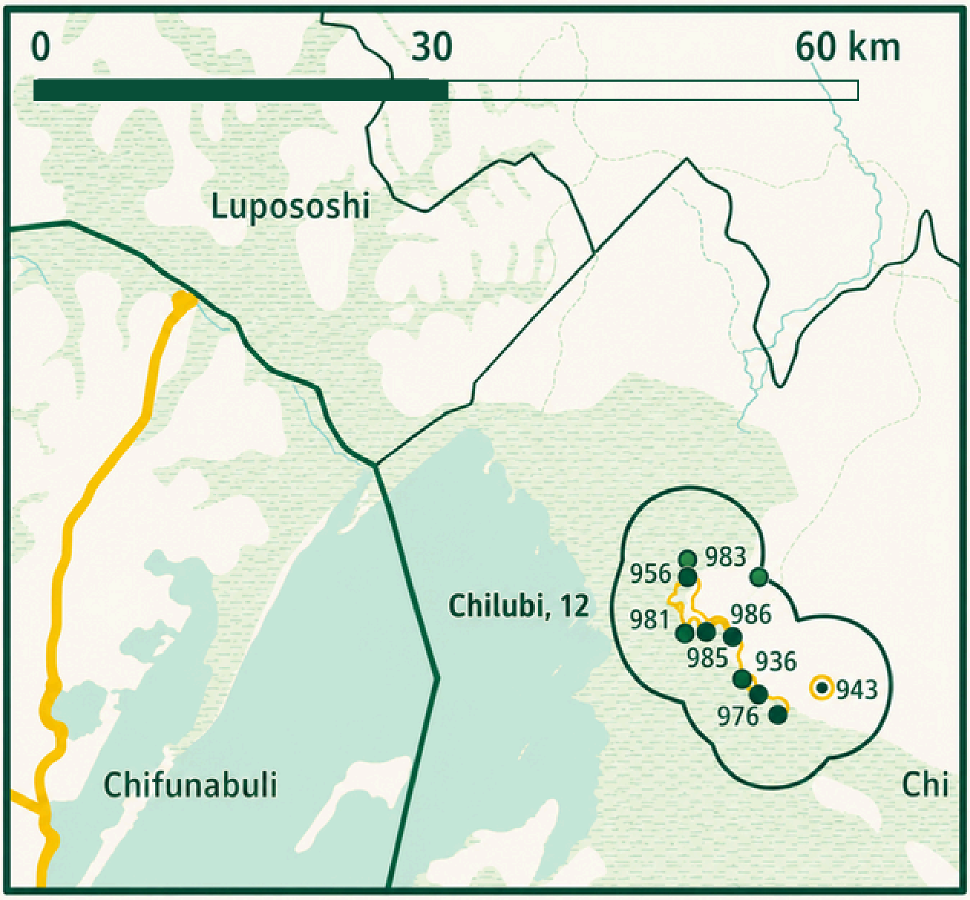
The data shown here provides a worked example, referencing a potential site under the pilot program and showing how it can achieve universal access, reaching 100 percent electrification in a short period of time, in a manner that provides for long-term sustainability of access, including growth over time.

While it will require customization based on geographic spread and density, this model is in principle scalable to the whole country under existing mechanisms and frameworks with concessional support in the initial stages of build-out.

Introduction: demonstration site

The site-specific worked example uses data from Chilubi, in Zambia's Northern Province. The national Rural Electrification Master Plan (REMP) uses geospatial mapping to identify unelectrified buildings across the country, designating larger clusters as potential mini grid sites. Chilubi has 12 proposed mini grid sites within a small area. By adopting a five kilometer radius around these sites – as proposed by the Rural Electrification Agency (REA) – a Universal Access Cluster pilot site has been defined.

Figure A1: Map showing Chilubi cluster, designated REMP sites and the proposed 5km concession radius



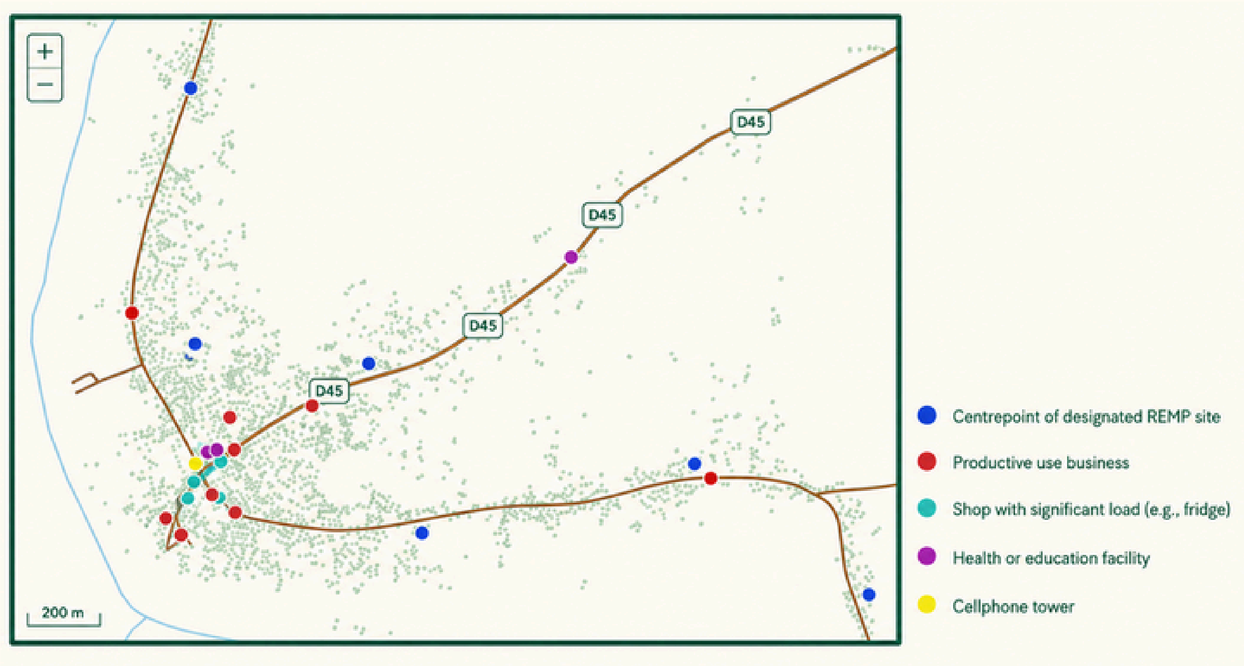
Universal household supply

- Drawing on affordability, demand and rural aspirational expectations, this plan proposes to provide universal access for every household at the level of around 3kWh/month.[44] This level is low compared to long-term aspirations for demand but represents a major step up for almost all unelectrified, rural households.
- This energy service can be provided through a grid connection, an isolated grid or an equivalent 50 Watt-peak/150Wh solar home system.[45] In all cases, the energy is provided as a service with reliability expectations over the full concession period.
- The plan would need to meet affordability criterion for households even in the poorest provinces of Zambia. We assume an affordability threshold of 12 Zambian Kwacha ($0.60)[46] each month for energy services.
- Chilubi cluster includes approximately 3,800 households to be served in this manner.

Productive use program alignment

- Detailed surveys have been carried out in the prospective sites, including geo-location of all existing productive uses, to identify the annual demand that must be met to effectively serve all the current businesses in the area.
- A clear clustering of larger businesses and loads (Figure A2) shows significant existing demand and likely potential for economic growth, as diesel is displaced and new businesses can open with lower costs.
- Through close partnership with the Zambia Agri-business and Trade Program (ZATP), opportunities are being identified to work with local farmer cooperatives to help them access matching funds for increasing productivity and output, for example by buying new equipment. Alongside the upcoming availability of low-cost electricity, this can provide transformative outcomes for local producers.
- For this pilot, tariffs for productive users will be capped, for example at around $0.20/kWh.

Figure A2: Map showing Chilubi cluster and identified productive loads (note: in making residential demand estimates, rooftop structures were adjusted to account for multiple rooftops representing a household).



[44] This draws on the demand analysis shown in the earlier sections of this paper

[45] Accompanied at minimum with LED lights, radio, and mobile charging.

[46] ZAMSTAT provides province level information on household incomes. Given the urban/rural income split, for Northern Pprovince one can estimate rural monthly income to be 1,525 ZMW. Further noting that the lower 80% percent earn about 30% percent of the income, we obtain 570 ZMW, which escalated for economic growth and devaluation gives us 800 ZMW for the lower 80 percentile rural demographic. Using the electricity share of 1.5% percent shown in Box 2, we obtain 12 ZMW per month for 80% percent of rural households to establish an affordability criterion.

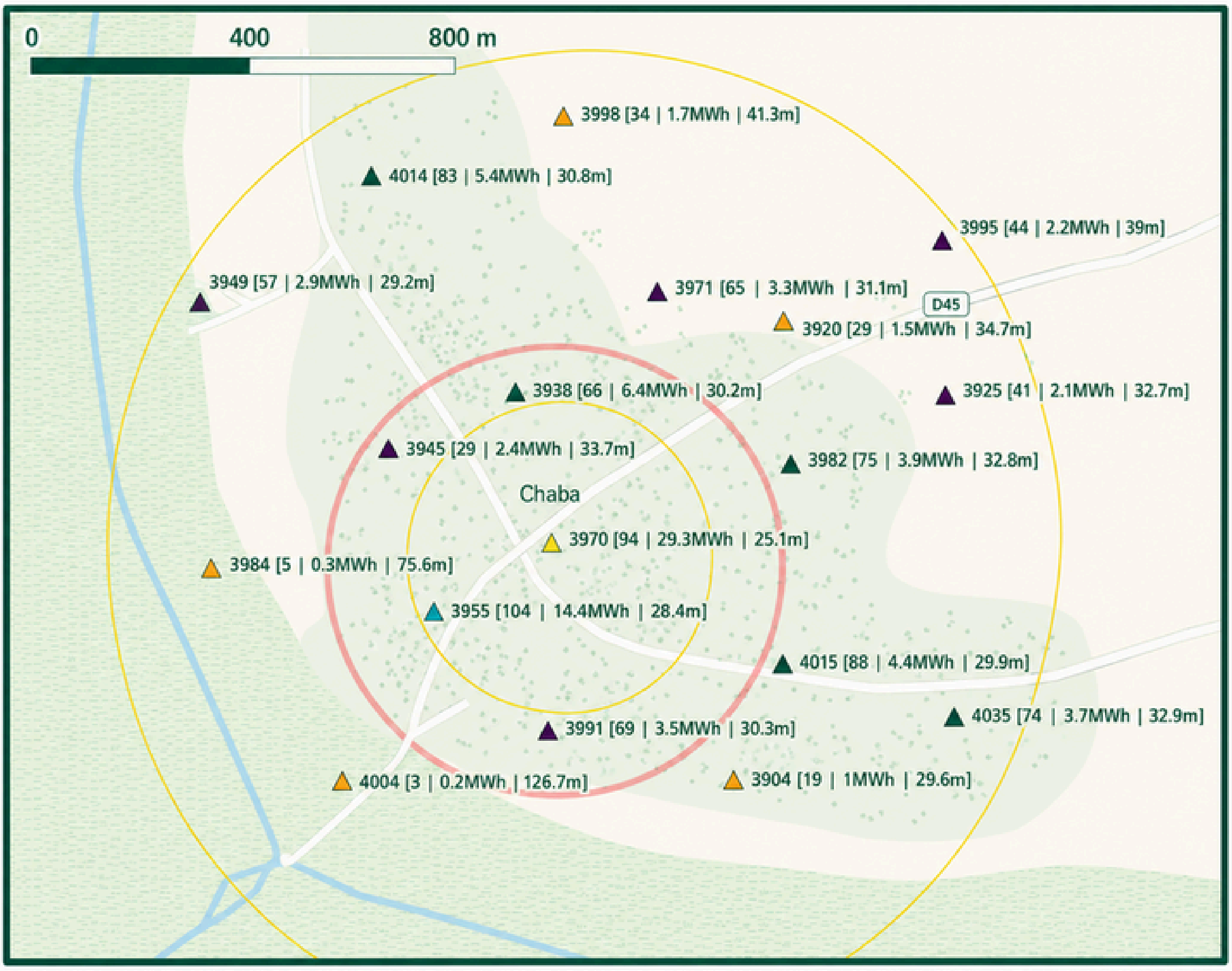
Least-cost initial supply and growth

- Standalone, starter solar home systems to meet household access will have an upfront capital cost of around $100. Should an upfront capital expenditure grant of $50 be made available, the annual system cost will be around $40/year per household, to cover the private provider returns on capital, servicing and maintenance, timely parts replacements, collections and ensuring stipulated performance standards are met.[47]
- For most households, these individual systems are almost always least-cost at low initial demands when compared to a mini grid or a grid connection, except where there are tightly clustered households with other loads present. The upfront subsidy requirement can be 6-8 times higher for a mini grid connection under current financing approaches, and the annual maintenance cost to the state will be closer to $80/household (so, nearly double) if household demands do not grow significantly.
- Mini grids or grids will be viable where there is a cluster of productive loads located near each other (especially where they have sporadic loads, seasonal loads or high peak demand that would make them more expensive to serve with standalone systems). However, the installation costs of mini grids and grids are highly sensitive to the average distance between dwellings because increasing the length of wiring and number of poles quickly drives up cost per connection.
- As an initial marker, a collective load of 20MWh/year in close proximity can be used as a broad marker for viable, least-cost mini-grids.[48] Figure A3 shows that there is only one location in Chilubi cluster that can be viably served by a mini grid. Combining the areas under the pink ellipse in the graph, it is possible to reach a 55MWh load with limited wiring costs.
- From this, the first-order, least-cost design for Chilubi will include a single mini grid connecting the largest productive loads and around 200 households. The remaining 3,600 households will be served by standalone solar systems. (The project operators will, of course, deliver their own least-cost configurations.)
- All the systems will be designed for modular expansion with increasing load to cater for new demand that may emerge once the area is electrified.

---

[47] These are first-order cost estimates, that will be refined as the pilot starts implementation. The true, measured cost structures for O&Moperation and maintenance are of particular interest.
[48] A thorough least-cost analysis involves more detailed costing and understanding of load diversity.

Figure A3 – Map showing Chilubi cluster, with the electricity demand and metets of wire per connection for each possible electrification node (shown in triangles). Only the middle, yellow node (ID 3970) has high enough demand to justify mini grid or grid electrification. The pink ellipse shows the sum of two adjacent nodes (ID3970 and 3955) with a combined 44MWh load and limited wiring costs, reaching 200 customers.



Service territories with performance obligation

- A concession agreement will provide a single operator with exclusive access to national electrification subsidies within the site boundaries, subject to them achieving electrification goals (for the pilot: >90 percent household and productive use electrification within two years) and performance standards, including reliability of service and modular expansion.
- For larger concessions, the operator will bid for the sites in an open tender, under which they will compete on least-cost system design and the lowest cost of capital, as well as demonstrated capabilities.
- The operators will be likely to include partnerships with local engineering, procurement and construction contractors, and mini grid and solar home system companies to build the required skill base for managing these concessions.
- For the pilot sites, REA will work with partners and philanthropic funding to run an accelerated procurement process with established players in the Zambian market, aligned with the need for rapid demonstration of the project principles.

Guarantees of operational revenue

- The operator will be provided with a revenue settlement mechanism to cover the difference between the cost of supply (including cost of capital) and the expected revenue throughout the pilot period. This may be combined with some upfront grant funding from time-limited sources, such as World Bank programs.

- In the long term, the Rural Electrification Fund – which pools funds from the rural electrification levy on the tariff and from development partners such as The World Bank – will be expected to provide this revenue settlement funding. However, as this is currently outside the scope of the fund, the pilot will be supported by philanthropic funds from project partners.
- For the Chilubi cluster and the assumptions shown above, the topline project financials are as follows:
  - $360,000 for standalone solar, of which 50 percent ($180,000) will be provided as a capital expenditure subsidy, by an existing World Bank-funded program, Accelerating Sustainable and Clean Energy Access Transformation (ASCENT).
  - $240,000 for a mini grid to meet 44MWh of load through 200 connections, of which 50 percent ($120,000) will come from the ASCENT subsidy program.
  - The operator will thus deploy $300,000 of private finance at the start of the project and additional capital through the project lifetime to increase the system capacity to meet demand.
  - Tariff revenue (assumed $0.60 per household per month and $0.20/kWh for larger users)[49] will initially bring in approximately $34,000 per year for the operator.
  - To cover operational expenditure costs and meet an 11 percent weighted average cost of capital for the operator, the revenue settlement required over a 10-year concession period[50] would be around $40 per year per household for the standalone solar systems, and $88 per year for the mini grid connected systems. This is a weighted average of $42.50 per household per year.
- This revenue settlement mechanism is a robust way to deal with the uncertainty of future demand. If demand stays low, the operator will continue to have a small concession with limited losses. The operator has a strong incentive to increase demand, as this can increase the total capital investment in their project, and hence total returns. And increasing demand increases efficiency and reduces the unit cost of electrification, meaning the subsidy requirement per connection will in turn reduce.
- This mechanism also works well with grid extension alongside standalone solar and mini grids, where there is a locally available distribution network (although this is not proposed for the initial pilot).

Structured investment with allocated risk

- For delivering at scale, these concessions will be structured through formal PPPs, under Zambia's regulatory framework. A model is being developed that can be followed for such projects. In parallel, the national mini grid regulatory framework is being updated.
- The pilot sites, with their small scale and ability to deploy philanthropic funding, will move more quickly by working under the existing and evolving mini grid regulatory framework.

National financial planning

- A long-term goal should be financial sustainability across the country's electricity system. After an initial subsidy from The World Bank, steady-state subsidies from a revenue settlement mechanism are likely to be around $40 per user per year in deep rural areas for the defined levels of rural access (3kWh), and only slightly higher where mini grids are deployed.
- For Zambia's current, unelectrified population of approximately 2.3 million households, the cost of a nationwide revenue settlement mechanism for all unelectrified households would cost under $100 million per year, under these estimates. However, some of these households will be electrified by the grid, and operational expenditure costs are likely to fall as operators reach scale, potentially reducing the required revenue settlement.

---

[49] These figures are illustrative, pending tariff discussions with the regulator

[50] The concession period for the pilot is still under discussion. Shorter periods, such as 10 years, are likely to be more appropriate for solar home systems that may change dramatically over time. But longer concession periods are likely to be more favourable for large concessions with multiple technologies and significant loads.

- The utility, ZESCO, has a three percent tariff levy to fund rural electrification. Its 2024 revenue was $1.6 billion,[51] but is projected to grow sharply as demand and tariffs increase over time. The existing three percent levy, if it were evenly applied across all of ZESCO's income and fully disbursed to electrification projects would provide $46 million per year.
- Thus, current funding flows would cover around half of ongoing costs for full electrification, but future operational efficiencies and increasing tariff levies could close this gap.
- With some concessional support on initial capital expenditure (such as The World Bank programs and the existing Constituency Development Fund), Zambia could fund universal, sustainable electricity access entirely under existing mechanisms.

[51] ZESCO 2024 integrated report.