Are Mini-Grids Financially Viable at Scale? Lessons from Zambia

Session 6
May 22, 2026

University Partnership:

Agenda

1. Research Background & Objectives
2. Modelling Framework & Assumptions
3. Main Findings
4. Policy Implications & Future Research
5. Audience Q&A

Source: Beyond the Grid Fund for Africa (BGFA)

1. Research Background & Objectives

University Partnership:

Least-cost electrification plans rarely assess whether large-scale rollout is financially feasible under resource constraints

- Over 600 million people remain without electricity access, driving renewed efforts toward SDG7 through national and regional electrification planning
- These plans are increasingly informed by sophisticated least-cost geospatial models like OnSSET, which identify whether grid-extension, mini-grids, or standalone solutions are most cost-optimal for electrifying specific rural communities
- Yet they often overlook differences in cost of capital between modes and countries, end-user affordability, and the feasibility of large-scale implementation under fiscal and financial constraints
- Mini-grid viability literature also remains heavily focused on site-specific pilot studies, rather than the feasibility of scaling planned pipelines

This study aims to assess the financial feasibility of mini-grid deployment at both project and portfolio levels in Zambia

Main Objective: To identify the operational and financial conditions under which mini-grids can be financially sustainable and scalable within resource constraints.

Project-level objectives:

1. Identify the optimal project financing structure of representative mini-grid while operating within identified resource constraints
2. Examine how different tariff levels, productive use of energy (PUE) uptake, and macro conditions interact to shape financial sustainability and consumer affordability

Portfolio-level objectives:

1. Compare total financing requirements (both capital and operational) against identified national budget and concessional finance envelopes under different operational and price conditions
2. Identify policy and regulatory actions to bridge identified funding gaps

Zambia is a particularly timely and policy-relevant case as part of the first cohort of countries participating in Mission 300

- Mission 300 is an initiative by the World Bank and African Development Bank that aims to connect 300 million Africans to electricity by 2030, effectively halving the access gap
- As one of the first participating countries, Zambia will be receiving US$200 million of grant funding via the ASCENT programme over the delivery period 2025-2030 to meet universal access by 2030 from a current rural access rate of 34%
- The Government of Zambia (GRZ) has committed to contribute US$250 million from the national budget over the same period, positioning mini-grids as a key electrification solution by launching its 1,000 Mini-Grid Presidential Initiative
- The Rural Electrification Authority (REA) recently launched an update of its Rural Electrification Master Plan (REMP), which identifies the least-cost electrification pathway for universal access

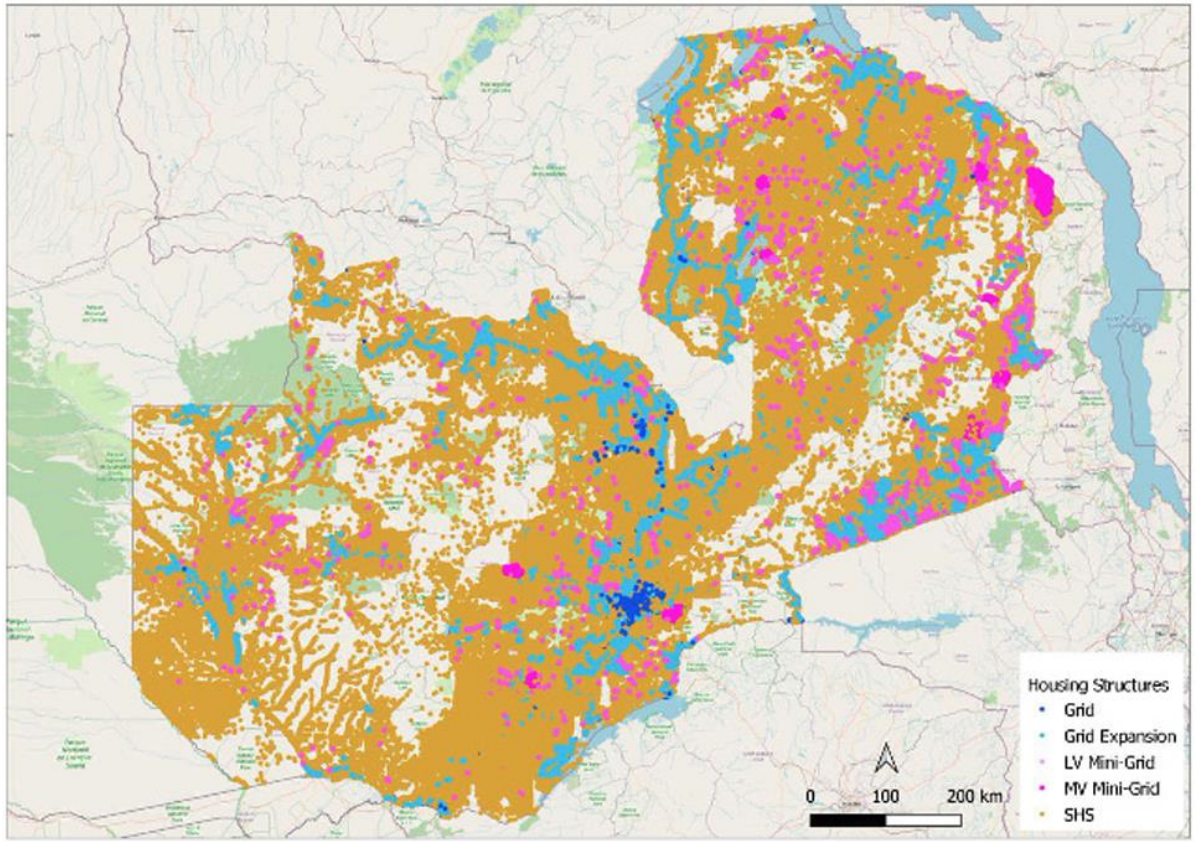
This makes Zambia a salient case for examining whether stated policy ambitions are matched by sufficient financial and institutional resources

2. Modelling Framework & Assumptions

University Partnership:

Techno-economic inputs used in the analysis are based on OnSSET outputs underpinning the 2026 REMP update

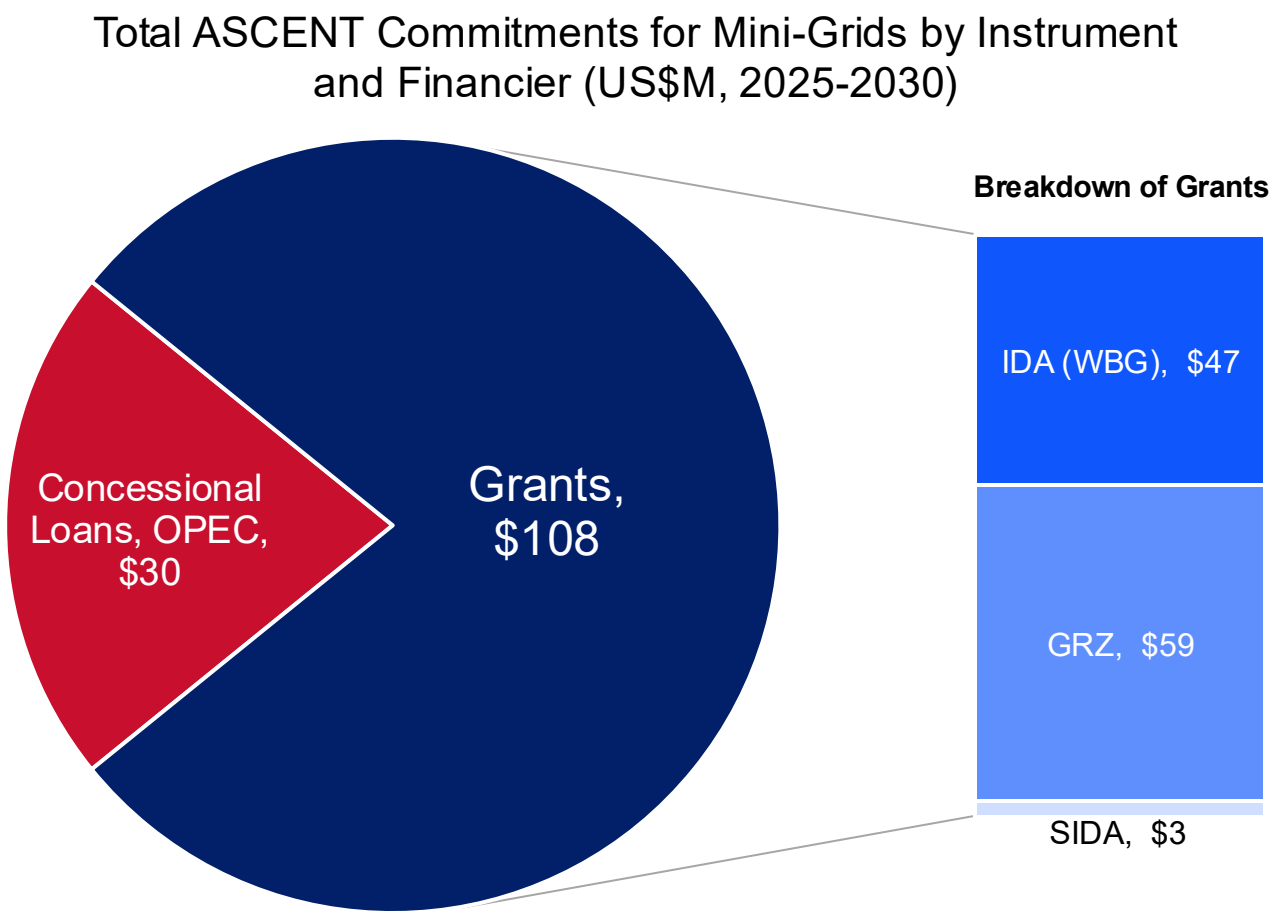
Zambia's Least-Cost Electrification Pathway



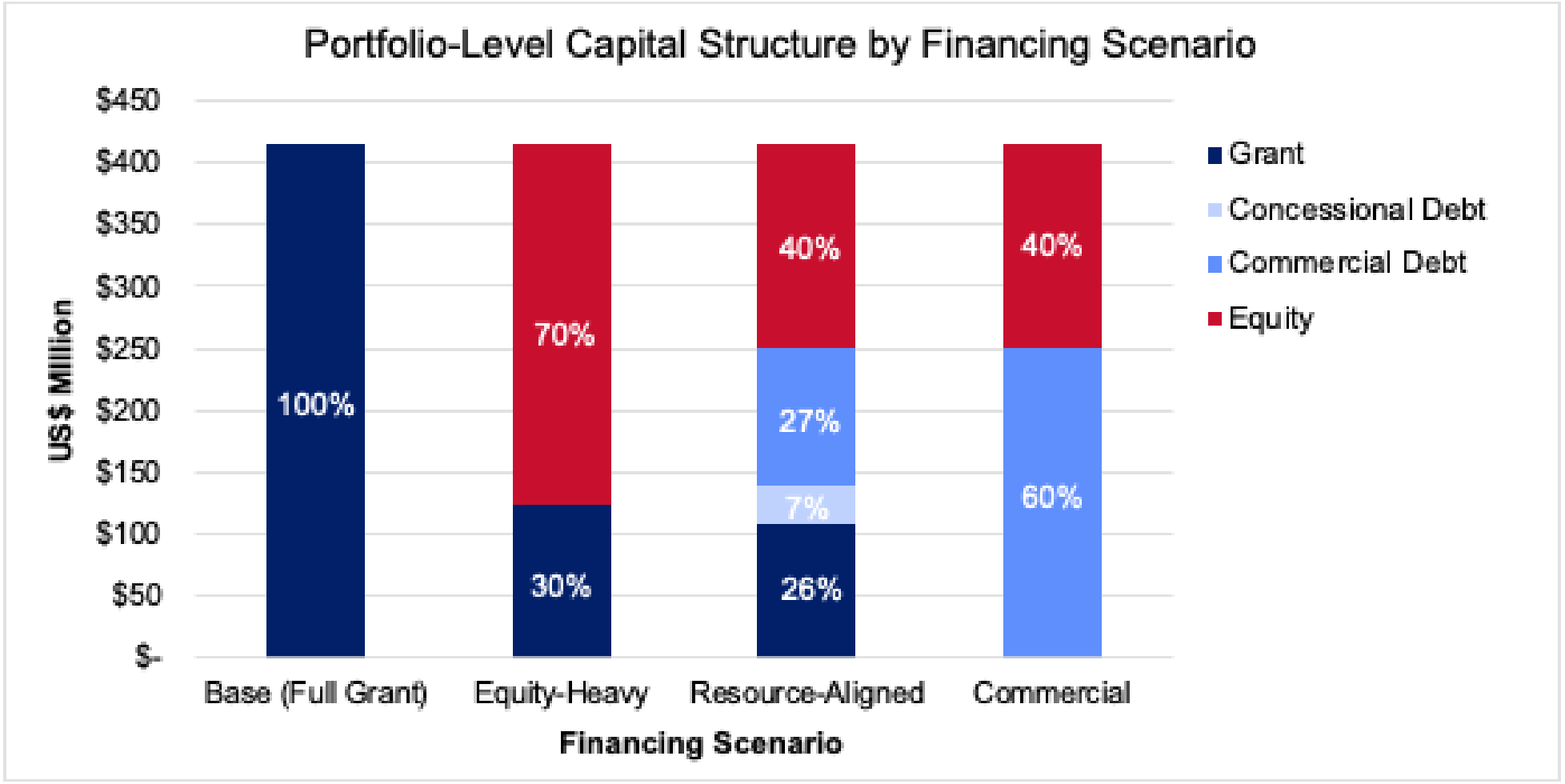
Source: Updated REMP (REA, 2026)

- A portfolio of **1,421 LV solar-battery mini-grids** are identified as the least-cost electrification solution
- Cumulative investment needs amount to **US$415 million** across 2025-2030
- Based on the average cost and operational characteristics of these planned projects, a representative 76kW system is modelled at the project-level
- Results are then re-aggregated to the portfolio level and compared against resource availability

An estimated US$108.4m in grant and US$30m concessional debt financing are earmarked for mini-grid investments under ASCENT across the deployment period to 2030



Four financing scenarios were examined



Three sensitivities were tested on the distribution of consumer demand, tariff levels, and load factor (proxy for PUE)

Sensitivity	Units	Residential	Commercial
1. Consumer Demand Share			
Residential Heavy	%	90	10
Even Split	%	50	50
Commercial Heavy	%	10	90
2. Load Factor (LF)			
Low	%	10	35
Medium	%	20	45
High	%	30	55
3. Tariff Level			
Affordable	ZMW/kWh	3	7
Observed–Low	ZMW/kWh	15	13
Observed–High	ZMW/kWh	25	22.5

Current average rural demand shares based on field data

Current observed industry averages (ESMAP, 2022)

HH affordability benchmark (5% of income) and price of diesel (Anker Research Institute, 2025; Ahmed et al, 2019)

Current competitive tariff ranges for operational mini-grid (Lemaire, 2023)

Tariffs were assumed to increase at a nominal rate of 8% p.a. (BoZ's inflation target), and exposed to S1) historic average depreciation rate 9.8%p.a. or S2) zero-depreciation

3. Key Findings

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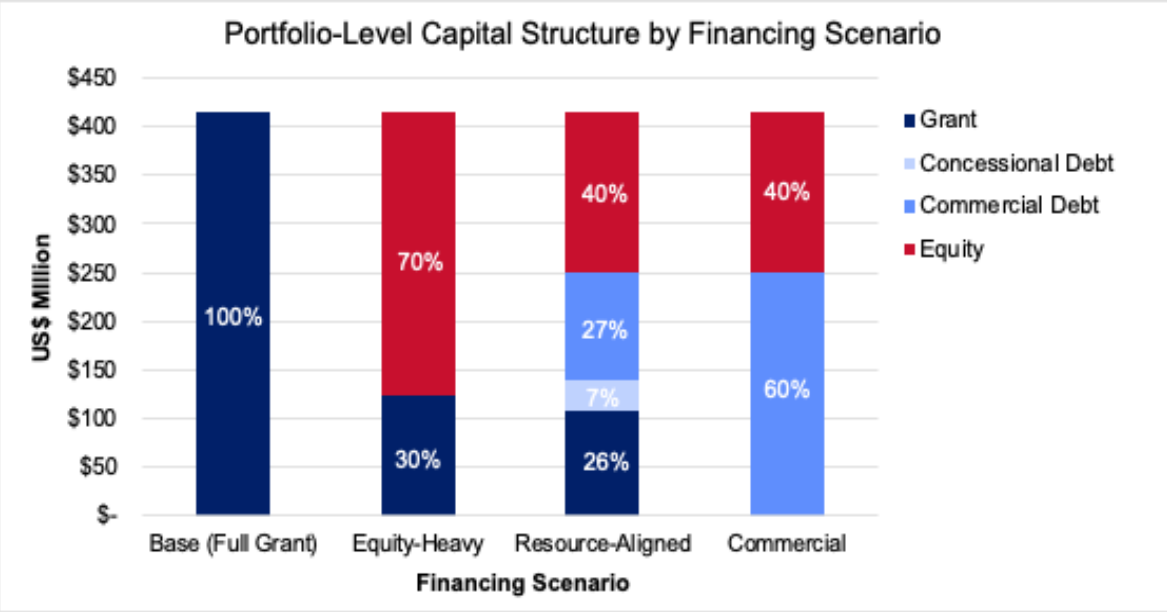
Continued reliance on predominantly grant- and equity-based financing models is insufficient to support full MG rollout



If mini-grids were to be fully grant-funded, existing resources would only be sufficient to fund **371** of the **1,421** (26%) planned projects

- Committed funding under ASCENT would meet ~33% of capital investment needs, with remaining 67% requiring private sector mobilisation (equivalent to **US$277 million** across 2025-2030)
- This highlights the need to distribute scarce concessional resources strategically across the pipeline to de-risk and catalyse private finance

Even with capex fully grant-funded, revenues under most sensitivities remain insufficient to cover opex

Heatmap of Cumulative Operating Cost Recovery Ratio (CRR) by Sensitivity

Residential Share	Tariff Sensitivity	Low LF	Medium LF	High LF
90%	Affordable	0.07	0.12	0.16
	Observed - Low	0.25	0.45	0.66
	Observed - High	0.42	0.76	1.10
50%	Affordable	0.19	0.26	0.33
	Observed - Low	0.42	0.61	0.80
	Observed - High	0.71	1.04	1.37
10%	Affordable	0.31	0.40	0.49
	Observed - Low	0.58	0.77	0.95
	Observed - High	1.01	1.32	1.64

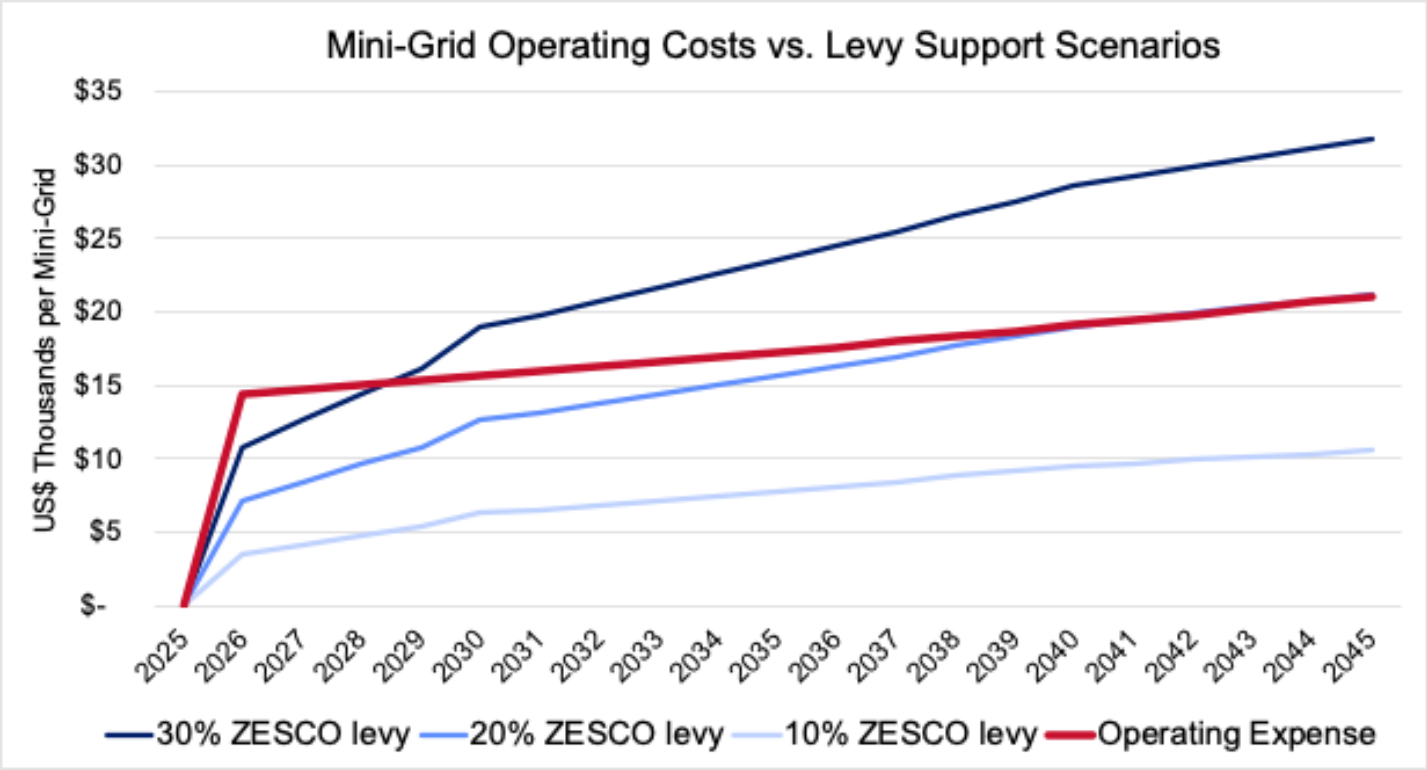
Achieving full cost-recovery without subsidies would require tariffs that substantially exceed affordability benchmarks

Cost-Reflective Tariffs Without Operating Subsidies by Sensitivy (ZMW/kWh, 2025)

Residential Share	Tariff Consumer	Low LF	Medium LF	High LF
90%	Residential	59.66	32.90	22.71
	Commercial	54.24	29.91	20.65
50%	Residential	34.76	23.86	18.17
	Commercial	31.60	21.69	16.52
10%	Residential	24.52	18.72	15.14
	Commercial	22.29	17.02	13.76

- Residential affordability benchmark: ZMW 5/kWh
- Commercial competitive benchmark: ZMW 7/kWh

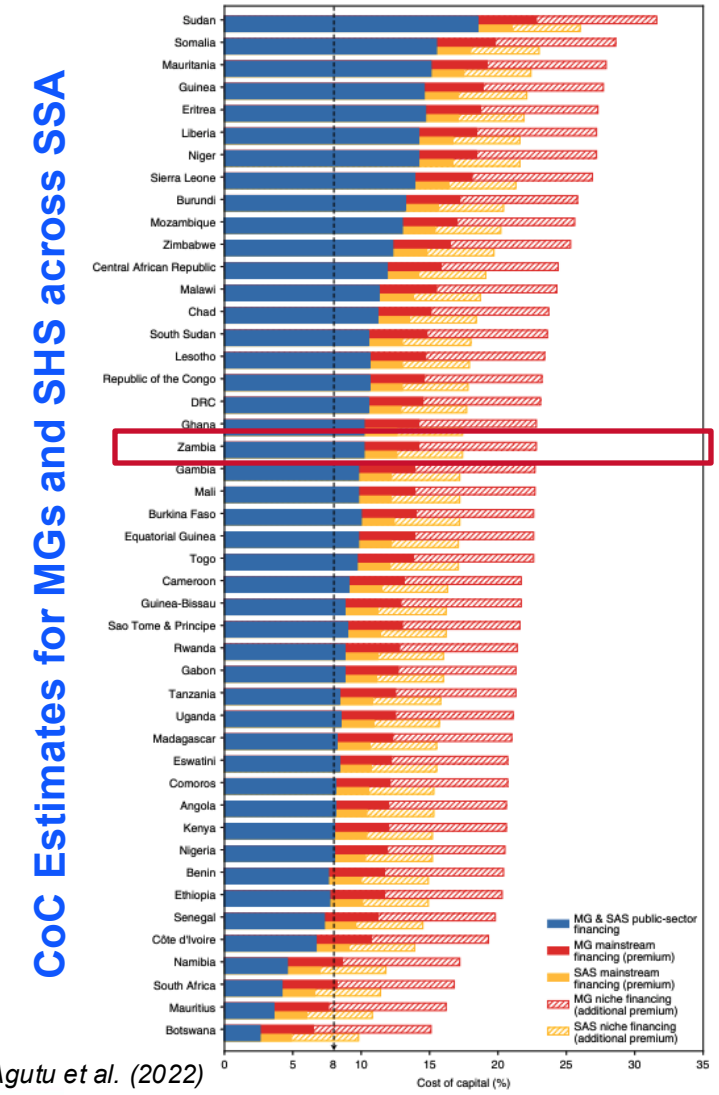
In Zambia, an existing domestic mechanism provides a potential vehicle for supporting ongoing operating costs



Maintaining affordable tariffs would require operational support up to 20% of levy proceeds, or 0.66% of electricity revenues for fully grant-funded systems

- The existing Rural Electrification Fund is partly funded by a 3% levy charged to grid-connected customers, which is used to provide capital support for mini-grids, while O&M responsibilities are typically deferred to private operators or communities
- However, there is scope to direct some of levy proceeds towards consistent O&M support

For financing structures involving debt and equity, feasibility is measured by the ability to generate sufficient investor returns



Agutu et al. (2022)

- In these cases, operational cost recovery becomes a necessary but not sufficient condition for feasibility
- Recognising that equity investors are residual claimants and therefore repaid only after all debt obligations have been satisfied, the relevant financial feasibility metric is the Economic Modified Internal Rate of Return (**EMIRR**)
- This is compared against the Cost of Equity **(CoE)** benchmark, with **EMIRR** ≥ **CoE** indicating financial feasibility

Two benchmark scenarios are examined to capture the transition towards increased mini-grid deployment:

Scenario	MG Market Maturity	Estimated CoE Benchmark
Niche	Nascent, status quo	24.7%
Mainstream	Mature, potential future	17.3%

With 9.8% historic currency depreciation, EMIRRs fall short of meeting investor benchmarks, except under most optimistic conditions

*Heatmap of Realised EMIRRs by Financing Scenario and Sensitivity**

			Niche			Mainstream		
Financing Scenario	**Residential Share**	**Tariff Sensitivity**	**Low LF**	**Medium LF**	**High LF**	**Low LF**	**Medium LF**	**High LF**
Equity Heavy	90%	Affordable	17.7%	18.6%	19.3%	11.9%	12.6%	13.2%
		Observed - Low	20.2%	21.5%	22.4%	13.9%	15.1%	15.9%
		Observed - High	21.4%	22.7%	23.6%	15.0%	16.2%	16.9%
	50%	Affordable	19.6%	20.2%	20.8%	13.4%	14.0%	14.5%
		Observed - Low	21.3%	22.2%	22.8%	15.0%	15.7%	16.3%
		Observed - High	22.6%	23.4%	24.1%	16.0%	16.8%	17.4%
	10%	Affordable	20.6%	21.2%	21.7%	14.3%	14.9%	15.3%
		Observed - Low	22.1%	22.7%	23.2%	15.6%	16.2%	16.6%
		Observed - High	23.4%	24.0%	24.5%	16.8%	17.3%	17.8%
Resource-Aligned	90%	Affordable	11.3%	12.7%	13.8%	7.2%	8.4%	9.3%
		Observed - Low	15.3%	17.8%	20.8%	10.6%	12.7%	14.9%
		Observed - High	17.5%	21.9%	23.7%	12.5%	15.7%	17.2%
	50%	Affordable	14.2%	15.4%	16.4%	9.7%	10.7%	11.6%
		Observed - Low	17.5%	20.2%	22.2%	12.5%	14.4%	16.0%
		Observed - High	21.5%	23.5%	24.5%	15.4%	17.0%	17.9%
	10%	Affordable	16.1%	17.3%	18.2%	11.4%	12.3%	13.0%
		Observed - Low	19.8%	22.0%	23.1%	14.1%	15.8%	16.7%
		Observed - High	23.4%	24.4%	25.2%	16.9%	17.8%	18.5%
Commercial	90%	Affordable	0.0%	0.0%	0.0%	0.0%	2.5%	5.8%
		Observed - Low	11.3%	15.1%	17.1%	8.1%	10.8%	12.4%
		Observed - High	14.6%	17.9%	20.0%	10.4%	13.1%	14.8%
	50%	Affordable	8.3%	11.6%	13.2%	6.7%	8.3%	9.3%
		Observed - Low	14.6%	16.7%	18.3%	10.4%	12.1%	13.3%
		Observed - High	17.6%	19.7%	22.0%	12.8%	14.4%	16.6%
	10%	Affordable	12.8%	14.4%	15.5%	9.1%	10.2%	11.1%
		Observed - Low	16.5%	18.0%	19.2%	11.9%	13.1%	14.1%
		Observed - High	19.6%	21.5%	23.9%	14.3%	16.3%	17.5%

*Assuming subsidy availability equivalent to 30% of levy proceeds

In the absence of currency depreciation, viability significantly improves, especially with increase in PUE activities

*Heatmap of Realised EMIRRs by Financing Scenario and Sensitivity**

			Niche			Mainstream		
Financing Scenario	**Residential Share**	**Tariff Sensitivity**	**Low LF**	**Medium LF**	**High LF**	**Low LF**	**Medium LF**	**High LF**
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		Observed - High	22.5%	23.9%	24.8%	16.2%	17.5%	18.3%
	50%	Affordable	20.6%	21.4%	21.9%	14.5%	15.2%	15.7%
		Observed - Low	22.5%	23.4%	24.1%	16.2%	17.0%	17.7%
		Observed - High	23.8%	24.7%	25.3%	17.4%	18.2%	18.8%
	10%	Affordable	21.8%	22.4%	22.8%	15.6%	16.1%	16.5%
		Observed - Low	23.3%	24.0%	24.4%	16.9%	17.6%	18.0%
		Observed - High	24.6%	25.2%	25.7%	18.1%	18.7%	19.2%
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		Observed - Low	18.6%	21.7%	23.5%	13.6%	16.0%	17.5%
		Observed - High	21.2%	24.1%	25.4%	15.7%	18.0%	19.1%
	50%	Affordable	17.3%	18.8%	19.8%	12.5%	13.7%	14.6%
		Observed - Low	21.2%	23.2%	24.3%	15.7%	17.2%	18.1%
		Observed - High	23.9%	25.2%	26.1%	17.8%	18.9%	19.7%
	10%	Affordable	19.5%	20.9%	22.1%	14.3%	15.5%	16.4%
		Observed - Low	23.0%	24.2%	24.9%	17.1%	18.0%	18.6%
		Observed - High	25.1%	26.0%	26.6%	18.8%	19.6%	20.1%
Commercial	90%	Affordable	0.0%	0.0%	11.3%	0.0%	0.0%	7.3%
		Observed - Low	15.8%	19.3%	21.1%	11.4%	14.4%	16.0%
		Observed - High	18.9%	22.1%	24.3%	14.0%	16.7%	18.3%
	50%	Affordable	13.4%	16.0%	17.5%	9.3%	11.6%	12.9%
		Observed - Low	18.8%	20.8%	22.4%	14.0%	15.7%	17.0%
		Observed - High	21.7%	24.0%	25.3%	16.4%	18.1%	19.1%
	10%	Affordable	17.1%	18.6%	19.7%	12.6%	13.8%	14.8%
		Observed - Low	20.6%	22.1%	23.4%	15.5%	16.7%	17.7%
		Observed - High	23.8%	25.2%	26.0%	18.0%	19.0%	19.7%

*Assuming subsidy availability equivalent to 30% of levy proceeds

4. Policy Implications & Future Research

University Partnership:

Summary of key conclusions and their policy implications

1. Across many rural contexts, subsidies remain essential for reconciling tariff affordability with operating cost recovery.

- Development partners and governments should consider integrating operating support into financing windows, including cross-subsidisation mechanisms where appropriate.

2. Higher levels of productive use can substantially improve operational recovery and investor returns, while easing pressure on tariffs and reducing subsidy needs.

- Deployment strategies should explicitly incorporate PUE development – such as agro-processing, refrigeration and clean cooking stoves – and ensure sufficient commercial users.

3. Stable and enabling regulatory frameworks, tariff transparency, and stable FX rates collectively improve investor confidence and accelerate mobilisation of private finance.

Limitations and Future Research

This study demonstrates the analytical value of assessing electrification plans under explicit financial and operational constraints, though several limitations should be acknowledged.

1. **Examining the distribution of financial performance over different types of mini-grids** instead of a single, representative one could provide more understanding of technical trade-offs in different settings.
2. **Incorporating cost of capital differences across electrification modes in OnSSET**, instead of considering it ex-post
3. **Reflecting greater realism and context-specificity in PUE**, instead of basing load factor assumptions off industry-wide benchmarks
4. **Considering other market-based solutions to bridge the viability gap** instead of continued subsidy reliance

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www.climatecompatiblegrowth.com

Contact Information: v.foster@imperial.ac.uk or ginny.ip23@imperial.ac.uk