Scaling Microgrid Deployment in Sub-Saharan Africa: Spotlight on the Role of Batteries

Eric Lockhart, National Renewable Energy Laboratory (NREL)

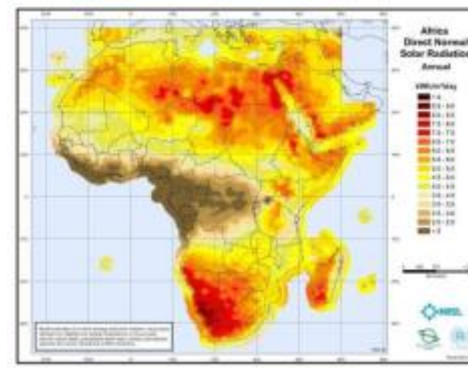
Power Africa Beyond the Grid Program Support Summary

- **Summary:** NREL is supporting Power Africa's Beyond the Grid Program with developing 8-10 million new electrical connections from mini and micro grids focused on implementing the QAF

- **Specific Support Areas**
  - Technical assistance to developers
  - Publication of reports to support micro-grid stakeholders with good practices
  - Support to government entities to develop policy, projects, and the enabling environment

- **See:** https://cleanenergysolutions.org/qaf for more information and reports

POWER AFRICA

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Quality Assurance Framework for Mini-Grids

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National Renewable Energy Laboratory

Rose Mutiso and Caroline McGregor
U.S. Department of Energy

Global LEAP

Quality Assurance Framework

- **Purpose:** Provide structure and transparency for mini/micro-grid sector, based on successful utility models, while reflecting the broad range of service levels required to meet the needs of various segments of the off-grid consumer base
- **Importance:** Help lay the foundation for successful business models in the mini/micro-grid space

Elements of a Quality Assurance Framework for Micro-grids

1. Define <u>levels of service</u>

- Tailored to different tiers of consumer need and ability to pay, including reasonable thresholds for:
  - Power quality
  - Power availability
  - Power reliability

2. Define <u>accountability</u> framework

- Provides defined assessment, monitoring and reporting protocol for operators to improve transparency and sustainability
- Clear process for verification service delivery through trusted information to consumers, funders, and/or regulators

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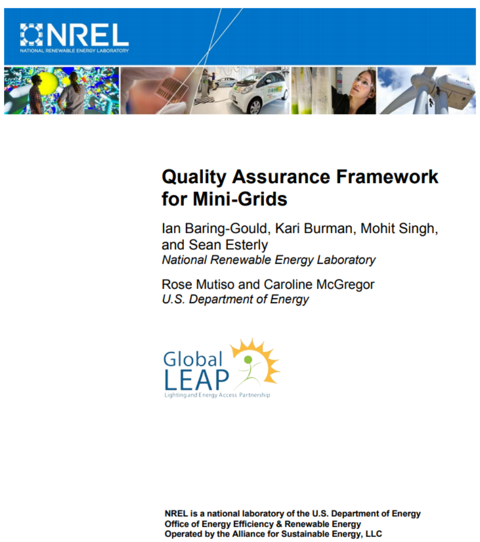
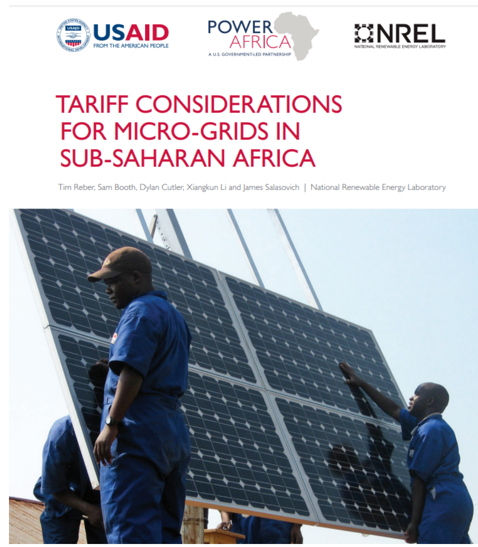
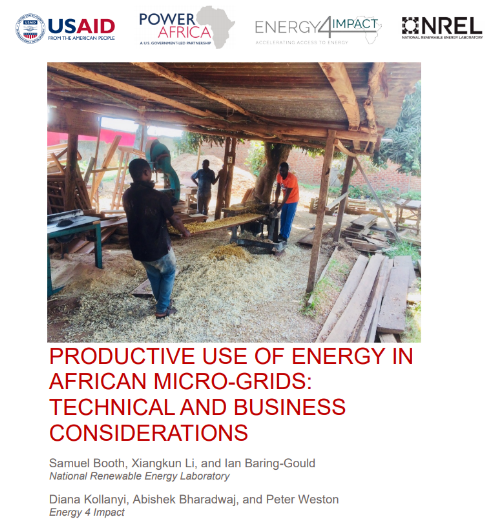
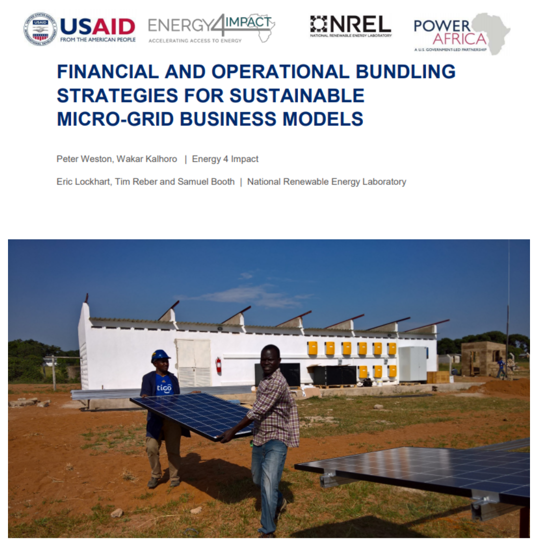
Other NREL Reports Supporting Power Africa









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Economics of Battery Selection and O&M

- **Question**: which battery and O&M approach leads to lowest lifecycle costs?
- **Motivation**: developers considering which batteries to use and how best to operate and maintain them
- **Audience**: developers, investors, regulators, policymakers, researchers
- **Conclusions**:
  – Li-ion batteries
  – Wood enclosures
  – HVAC depends on climate

COMPARATIVE STUDY OF TECHNO-ECONOMICS OF LITHIUM-ION AND LEAD-ACID BATTERIES IN MICRO-GRIDS IN SUB-SAHARAN AFRICA

Eric Lockhart, Xiangkun Li, Samuel Booth, James Salasovich, Dan Olis, James Elsworth, and Lars Lisell

National Renewable Energy Laboratory

Methodology for Novel Modeling Challenge

Thermal modeling

- **Inputs:** temperature for each location, impact of HVAC, heat from power system
- **Outputs:** temperature of battery over time, energy needs for HVAC

Battery degradation

- **Inputs:** thermal modeling outputs, battery characteristics
- **Outputs:** years of battery life for given set of assumptions

Techno-economic analysis

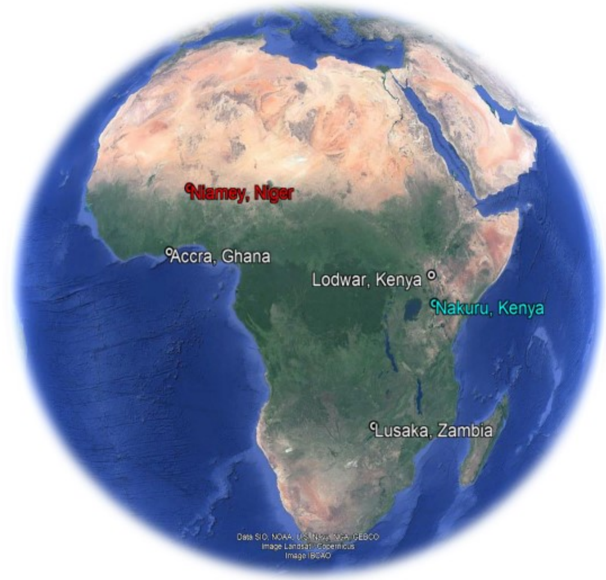
- **Inputs**: battery lifetime, cost assumptions, system dispatch
- **Outputs**: LCC for each scenario

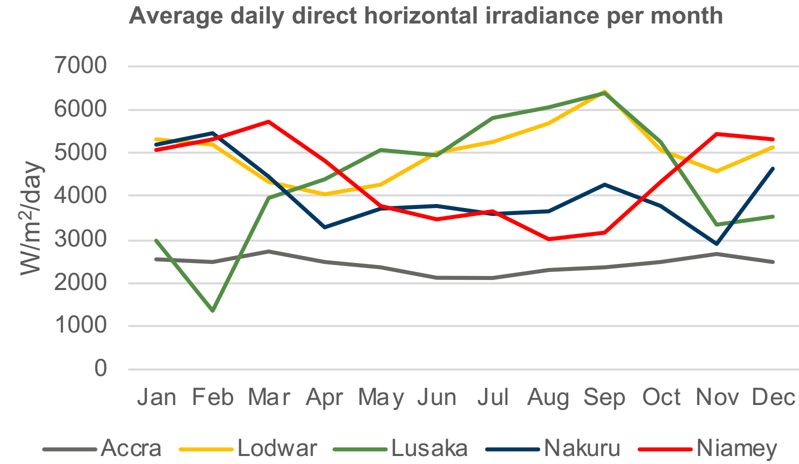
Modeling required new approach:

- Tool functionality development: integrating battery degradation
- Drawing on diverse tool suite, including OpenStudio and REopt
- Looked at scenarios across climate, HVAC, and construction options to get a comprehensive sense of cost drivers

Scenarios Modeled

- **Two batteries**: lead-acid and lithium-ion
- **Five locations**: Kenya (two locations), Zambia, Ghana, and Niger
- **Two load profiles**: community load profiles for a primarily residential customer demand profile and one that includes some limited commercial activity
- **Five heating, ventilating, and air-conditioning (HVAC) configurations**: air conditioner, active air circulation using two different fan configurations, direct evaporative cooler, and no HVAC
- **Four construction materials**: shipping container, wood, brick, and concrete for the enclosure housing the battery bank, inverter, and charge controller





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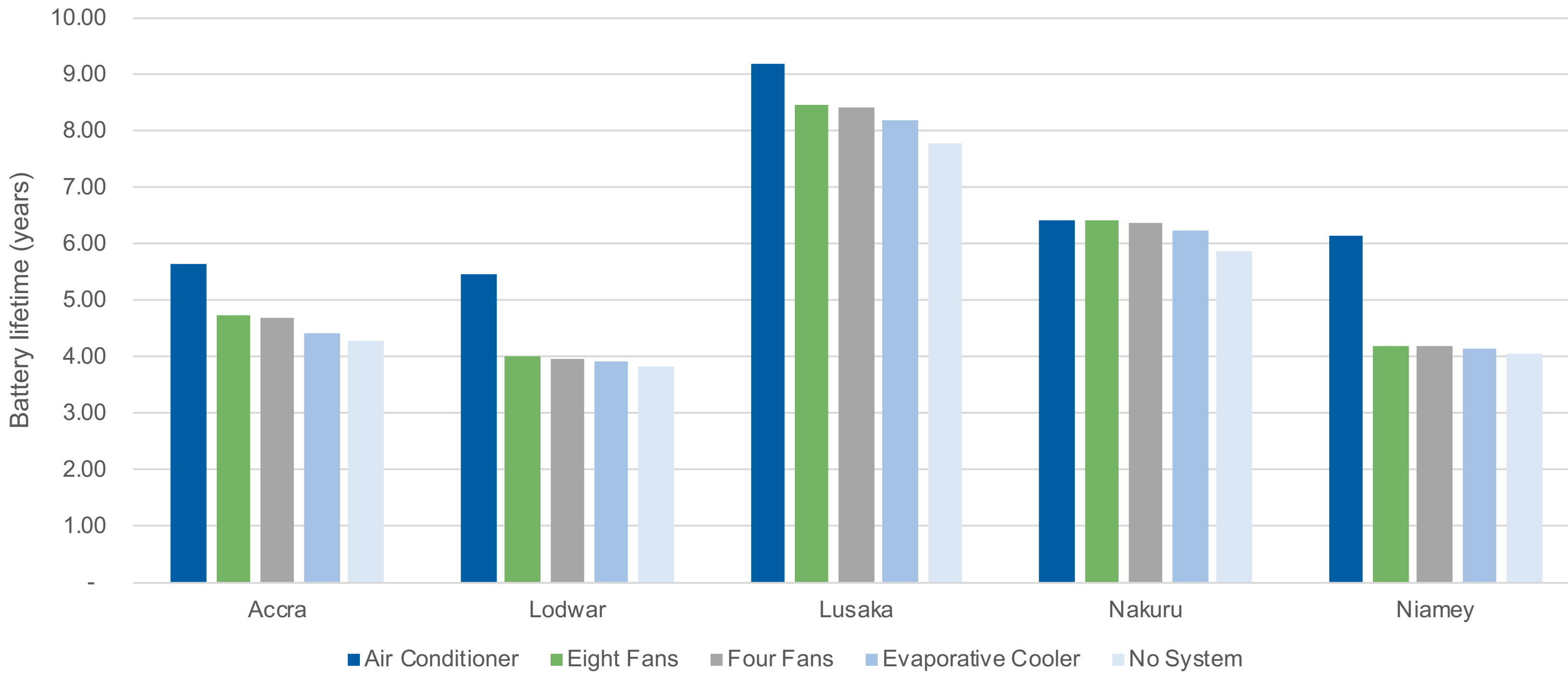
Battery Degradation Findings



Battery lifetime for lead-acid batteries with different HVAC configurations (commercial load profile, four fans, insulated, wood enclosure)

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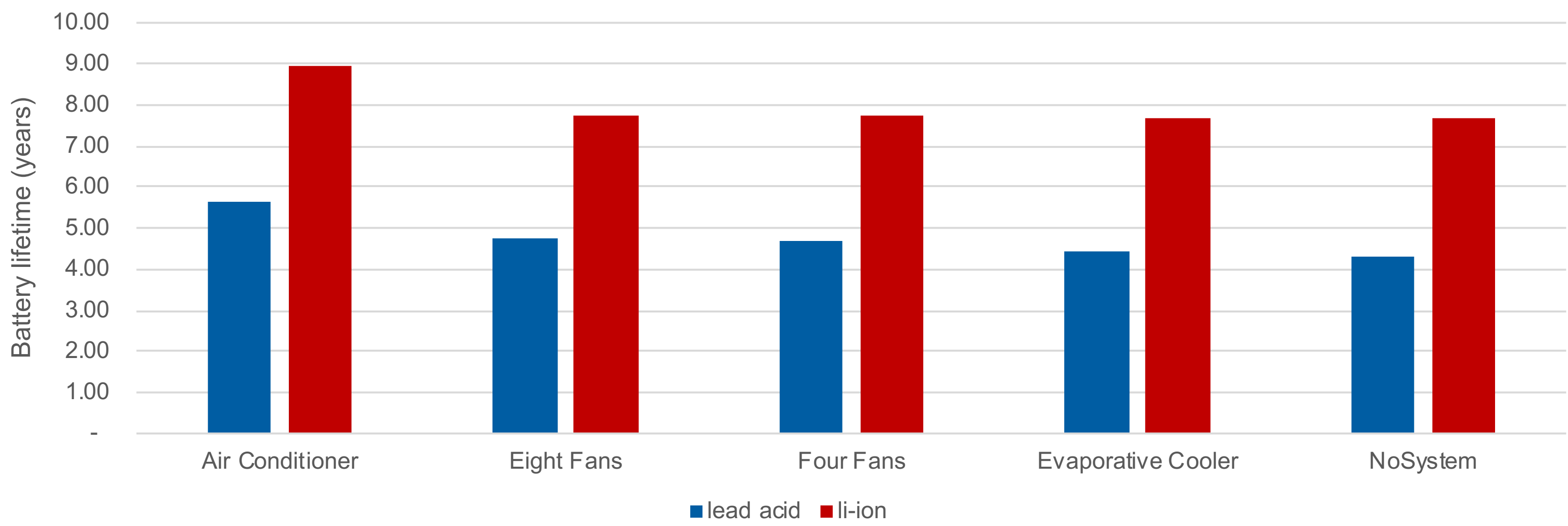
Battery Degradation Findings (cont'd)



Comparison of battery lifetimes between lead-acid and Li-ion batteries for different HVAC configurations (commercial load profile, insulated wood enclosure, located in Accra)

Lifecycle Cost (LCC) Analysis

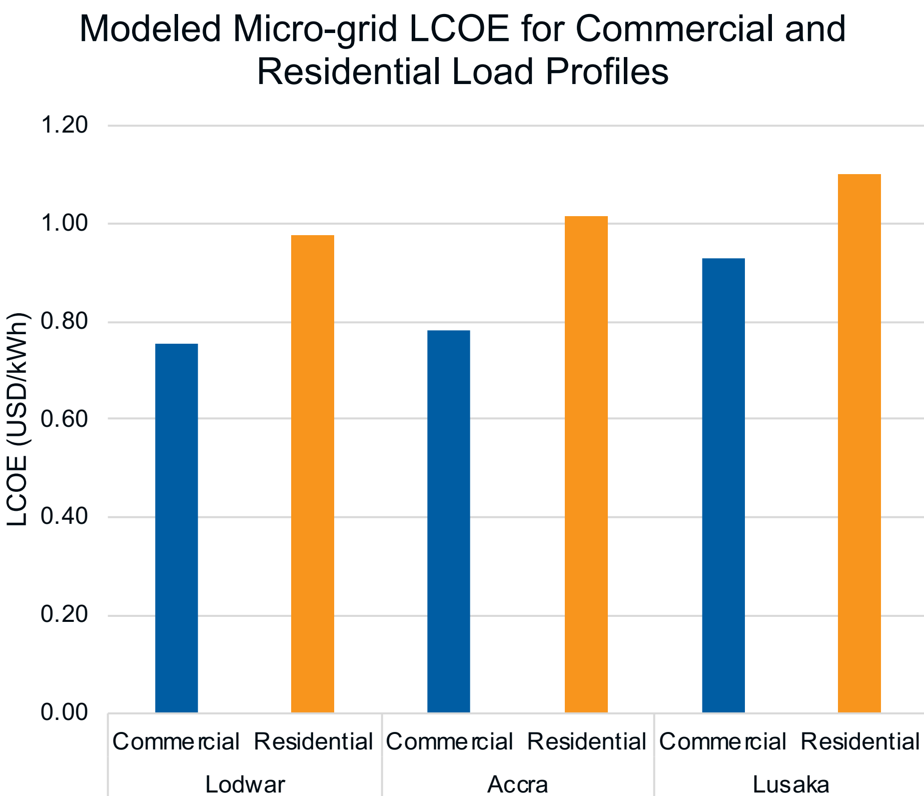
Table 4. Optimal Construction, Insulation, and HVAC Combination to Minimize LCC for Each Combination of Battery, Load Profile, and Location

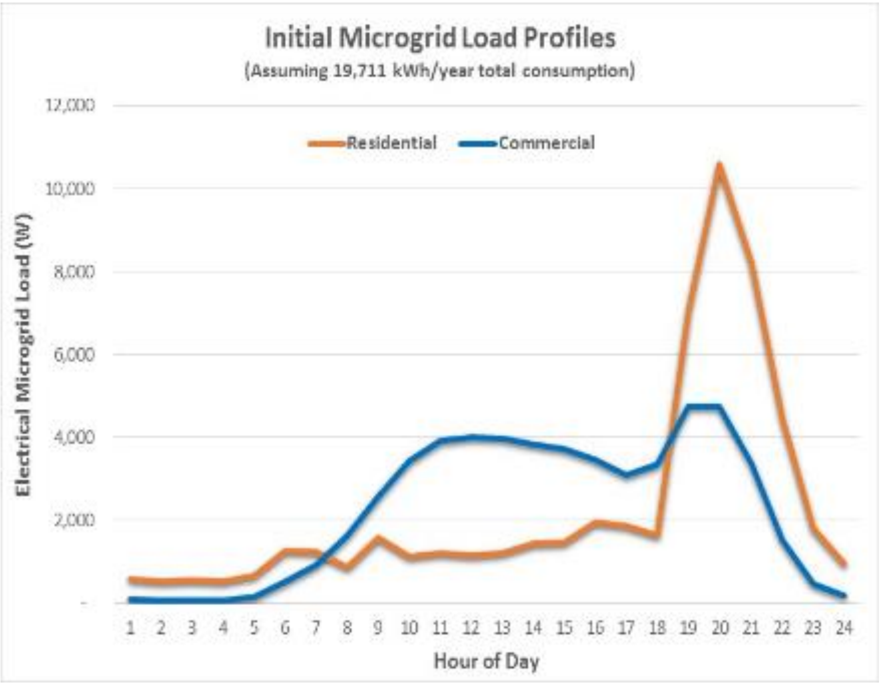
	Load Profile	Final LCC	Construction	Insulation	HVAC Type
Accra					
Lead-acid	Commercial	$119,172	Wood structure	Insulated	No system
Li-ion	Commercial	$110,806	Wood structure	Insulated	No system
Lead-acid	Residential	$150,129	Wood structure	Insulated	No system
Li-ion	Residential	$143,939	Wood structure	Insulated	Air conditioner
Lodwar					
Lead-acid	Commercial	$113,626	Wood structure	Insulated	No system
Li-ion	Commercial	$107,106	Wood structure	Insulated	No system
Lead-acid	Residential	$146,263	Wood structure	Insulated	No system
Li-ion	Residential	$138,536	Wood structure	Insulated	Air conditioner
Lusaka					
Lead-acid	Commercial	$140,176	Wood structure	Insulated	Four fans
Li-ion	Commercial	$131,621	Wood structure	Insulated	No system
Lead-acid	Residential	$171,358	Wood structure	Insulated	Four fans
Li-ion	Residential	$156,256	Wood structure	Insulated	Four fans

Drawing on thermal modeling and battery degradation modeling, assessed cost-optimal size, HVAC, building material, and dispatch for each location and calculated lifecycle cost for 25-year period:

- Lithium-ion batteries were always more cost-effective
- Though Li-ion batteries can manage higher temperatures, still were best paired with AC or fans for lifecycle cost savings in some settings

Cost reduction through load profile shifts





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Thank you

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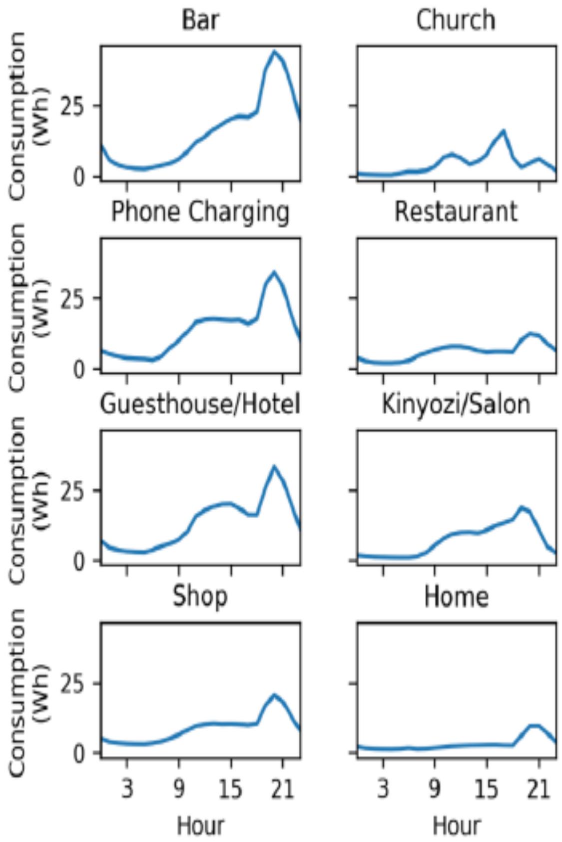
Case Studies of Stimulating Productive Use

Productive use = demand for electricity from small industry and businesses

Load Profiles



Business Case for Egg Incubator

VARIABLES	VALUES	UNITS
Size of incubator	100	eggs
Power rating of incubator	100	Watts (W)
Capital Cost	122	$
Amount of power consumed per day	2.4	kWh/day
Operational hours	24	hours/day
Operational days per month	21	days
Tariff	0.90	$/kWh
Cost of power	45	$/month
Avg. Expenses per month (including electricity)	83	$/month
Avg. Revenue of sales per month	125	$/month
Net profit	**42**	**$/month**
Profit Margin	**34%**	
Simple payback	**3**	**months**

Diversity of Viable Micro-grid Models

Mechanism of Project Initiation	Mechanism of Financial Backing	Mechanism of Cost Recovery	Mechanisms of Ownership
Tender / RFP • Utility concession areas • Direct project tenders by gov't	Subsidies • Connection subsidies • Production-based • Buy-downs • Grants/cash subsidies	Post-paid • Traditional tariff based on usage • Monthly flat-rate • Charged by device	Developer owned and operated (fully private) • Developer owns and operates MG assets for profit
Developer-driven • Identified commercial site • Could be public-private partnership	Concessionary Loans • Government- or donor-backed	Pre-paid • Pre-loaded power usage • PAYG/mobile money models	Gov't owned and operated (fully public) • Developer transfers assets to gov't
Donor-driven • Led by large donor or MDB investing in country	Private Investment • Equity investors (e.g. angel or impact) • Debt financing	Alternative revenue • Sell appliances to customers • Customers pay for charging services	Blended • Utility distribution, operator sells to MG • Gov't owns, private sector operates