20 BY 20 | A Design Charrette To Achieve 20¢/kWh By 2020

ROCKY MOUNTAIN INSTITUTE

RURAL ELECTRIFICATION AGENCY

ENERGY • EMPOWERMENT • EFFICIENCY

In partnership with:

The Rockefeller Foundation · Virgin Unite · GEF · UNDP (Empowered lives. Resilient nations.) · Schneider Electric (Life Is On)

Image courtesy of Jörg Böthling

This pre-read document serves three purposes

- Provide general event, venue, and logistical information to charrette* participants
- Ground conversations in a common framework and provide a clear understanding of current minigrid challenges
- Seed the conversation regarding solutions with initial thinking for participants to consider

** A charrette is a working session that brings diverse stakeholders together to overcome complex problems in tangible and practical ways. The process includes open conversation, cross-cutting rapid idea generation and testing, and structured facilitation.*

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Executive summary

Executive Summary (1 of 3)

Context:

- **Electricity is a critical enabler of economic development**, with additional benefits for health, education, gender equality, and overall quality of life. Yet one billion people in emerging markets lack electricity access.
- **Billions of dollars** and commensurate time have been invested in the promise of electrification, but **success has been lagging aspirations.**
- Minigrids can play a **critical role in powering economic development** (e.g., grain mills, irrigation, computers, carpentry, welding, and small shops) in areas where the grid does not reach or is unreliable.
- Serving these customers is a **multi-billion dollar market opportunity**, but profitable business models still need to be proven. **A profitable business model** will allow minigrids to scale rapidly and achieve the necessary impact while serving these customers sustainably.

Executive Summary (2 of 3)

Current challenges:

- **$0.60/kWh is the typical cost of service of a well run minigrid today**, but much higher cost, up to $1.00/kWh, is not uncommon.

- The cost of service of minigrids must be reduced to compete with alternatives, such as **small petrol and diesel generators ($0.35–0.70/kWh)**, and also to fit within **customers' ability and willingness to pay (typically $1-5/week).**

- Both **upfront and ongoing system cost** must be reduced, as well as the time and expense of **project development**. Companies can do more to **stimulate customer demand** and **improve system capacity utilization** to further reduce costs.

- **Unpredictable grid extension** and **unclear or unsupportive policies** further increase risk and drive up cost (e.g., import delays and fees).

- As these costs are reduced, the **availability of financing must increase and cost of financing must be reduced** accordingly to scale business models.

Executive Summary (3 of 3)

Unlocking the opportunity:

- Initial analysis suggests the cost of minigrid service can be reduced by more than 60% from $0.60/kWh to near $0.20/kWh by 2020 by addressing six key areas:

Cost reduction area	$/kWh saved	% of $0.60/kWh
1. Reduced hardware cost	$0.11	18%
2. Efficient load management	$0.08	13%
3. Effective customer engagement	$0.06	10%
4. Efficient project development and O&M	$0.05	8%
5. Affordable financing available	$0.03	5%
6. Supportive and enabling policy	$0.03	5%

- We will test and refine these ideas by creating a business model for three representative market segments: large under-grid, large off-grid, and smaller off-grid with subsidy.

- Program design options to support the business models and accelerate cost reductions will also be developed.

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Charrette format and logistics

The charrette will answer three critical questions about minigrid business models and what is needed to accelerate market growth

Objectives

Over 50 experts and industry leaders will be working together to answer three critical questions:

- How can we reduce costs and improve customer engagement so that minigrids can reach **a profitable and scalable business model in the next 3–5 years**?
- What **size and type of funding** is required to accelerate progress, and what **program design** is needed to apply these funds most effectively, while preserving **competition and innovation** and driving towards cost reduction and other business model improvements?
- What are the **next steps** and who are the **partners** for immediate action?

Goal:
Target to achieve $0.20/kWh cost of service by 2020

Outcomes and the value proposition for participants

- Identify and refine the largest cost reduction opportunities
- Co-create innovative business models for three market segments
- Explore partnership and investments opportunities
- Collaborative program design with government and funders

RMI is convening the charrette with the generous support of the Nigeria Rural Electrification Agency, The Rockefeller Foundation, Virgin Unite, the Global Environment Facility, UNDP, and Schneider Electric.

Pre-competitive collaboration across diverse stakeholders is the key to success

Participants

Global supply chain:

ABB
Schneider Electric
SPARKMETER
ODYSSEY

Off-grid companies:

arnergy
EM-ONE Energy Solutions
OFF-GRID ELECTRIC
Community Energy Social Enterprise Ltd
RUBITEC POWER RUBITEC SOLAR
rensource
Solarmate Engineering Limited
M-KOPA SOLAR
PowerGen Renewable Energy
HUSK Powering Possibilities
powerhive
STARSIGHT
AYO Tropical Technology
GV

Development partners, foundations, and investors:

ACUMEN
POWER for ALL
giz
WORLD BANK
THE ROCKEFELLER FOUNDATION
gef
Breakthrough Energy
MacArthur Foundation
Shell Foundation
HELIOS Investment Partners
THE ABRAAJ GROUP
All On
AIIM
ESMAP
USAID From the American People

Government:

NERC
REA Rural Electrification Agency

Outside expertise:

ITT Institute for Transformative Technologies
California Clean Energy Fund
CARBON TRUST
PENTAGON PARTNERS Legal Practitioners
IHS Towers of strength
CROSSBOUNDARY
Babban Gona
McKinsey&Company

What is *pre-competitive collaboration*?

- An early stage in the development of a commercial product or concept, during which potential competitors collaborate for collective benefit
- There is a successful track record of this type of collaboration in the pharmaceutical, communication, and solar industries

Agenda

	Tuesday	Wednesday	Thursday	Friday
Arrive	11:00-12:00	8:30	8:30	8:30
Start	12:00	9:00	9:00	9:00
Morning	Arrive at Venue Location: **Orchid Hall**	**Develop Cost Reduction Strategies** Within breakout groups participants will explore ways to address specific cost reduction challenges (e.g., hardware costs or customer acquisition) Location: **Orchid Hall**	**Design Sustainable Business Models*** In new breakout groups, teams will develop business model for specific market segments applying the insights from the previous day Location: **Orchid Hall**	**Teams Finalize Presentations** Location: **Orchid Hall** **Present Business Models, Programs, and Roadmaps to Senior Leaders** (11:00 -13:00) **Closing**
Lunch	12:00-13:00	12:30-13:30	12:45-13:30	13:00-14:00
Afternoon	**Welcome & Introduction** **Create Shared Understanding of Challenges** Articulate the existing situation and key challenges that need to be addressed to achieve 20¢/kWh by 2020	Continued work on cost reduction strategies	Continued business model work from morning session and begin to develop presentations to share with invited guest on Friday **Design program to accelerate progress with donor funding** Breakout group to explore what new model of funding is needed to support these kinds of initiatives	**Senior Leader Meeting** 14:00-16:00 17:00 Depart Venue
End	18:00	18:00	18:00	
Evening	**Hosted Dinner 18:30** Locations: **Iris Hall** Facilitators will support a round of discussions over dinner to get to know fellow participants	**Networking Dinner 19:00** Location: **Orchid Hall** Participants will be invited to take advantage of a hosted space for networking	**Open Time** This evening will be left open for additional work time or networking	

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Logistics

Location

Hotel: Eko Hotel & Suites

Address: Plot 1415 Adetokunbo Ademola Street, PMB 12724, Victoria Island, Lagos, Nigeria

Phone: +234 1 277 2700

Website: https://www.ekohotels.com/

Map: [Click here]

Meals

- There will be coffee, tea and some snacks each morning in the main conference room, so please make sure to eat breakfast before arriving.
- Lunch will be provided in the main conference room Tue through Fri.
- Dinner will be provided on Tuesday and Wednesday nights.
- Dinner will not be provided on Thur night. Participants are open to choose from one of many restaurants at Eko Hotel or elsewhere.

Transportation

- For airport pick-up/drop-off or getting around Lagos please only use transportation you coordinate through the Eko Hotel or secure transportation used by your company.
- Note: For those that provided flight itineraries by February 22nd RMI will coordinate your airport pick-up/drop-off and will send that information to you by Thursday March 1st.

Registration & Security

- Registration begins outside of Orchid Hall on March 6th at 11am, and will be available throughout the charrette.
- For general safety, security guards will be outside of the conference room entrance. You will need to your name badge in order to access the conference room.
- Please keep your belongings with you at all times.

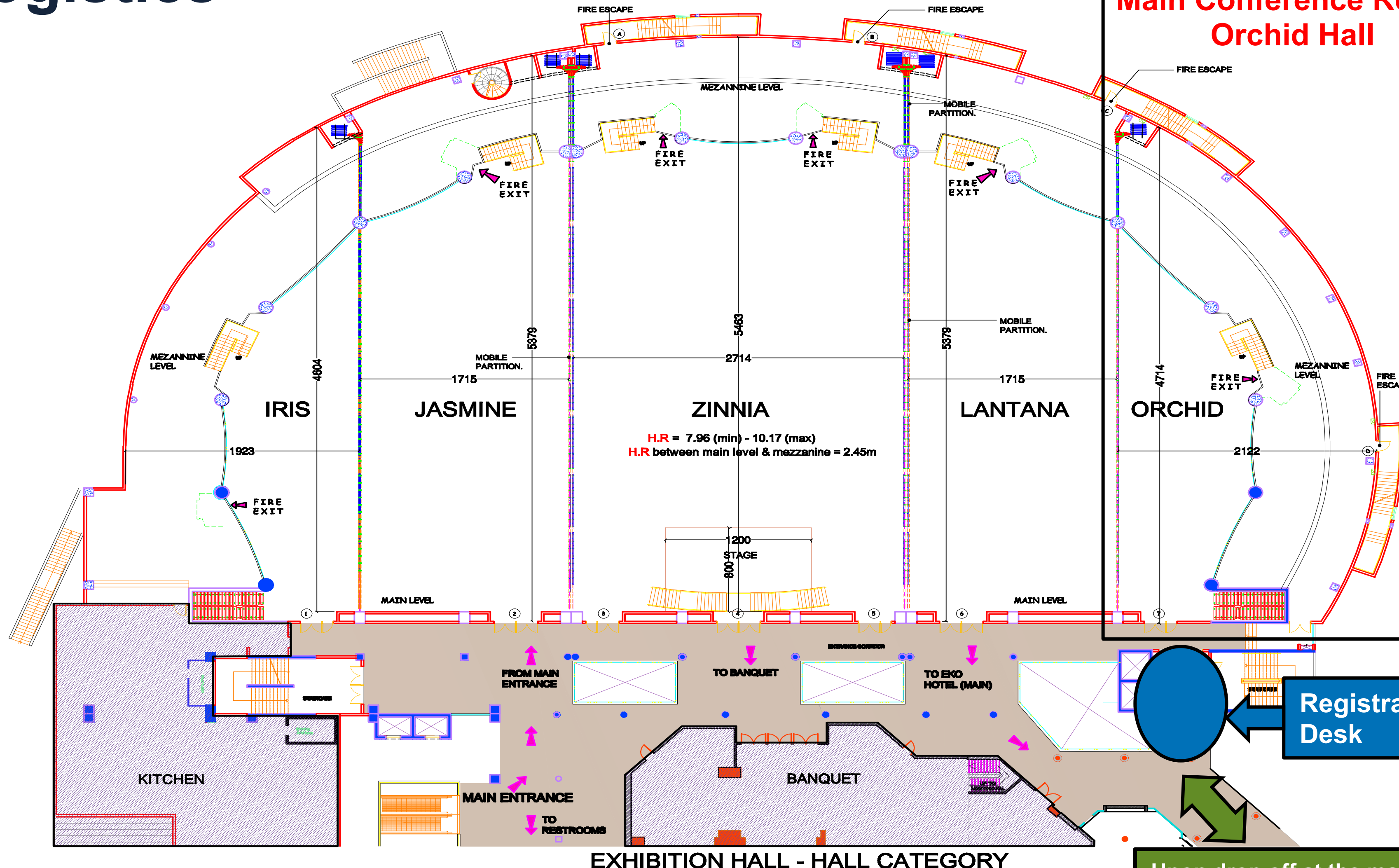
Contacts

Any further questions, please contact:

Callie Sasser
Phone: +234.902.592.2627
WhatsApp: +1.941.929.6029
Email: csasser@rmi.org

Josh Agenbroad
Phone: +234.909.959.2461
WhatsApp: +1.505.307.2066
Email: jagenbroad@rmi.org

Logistics



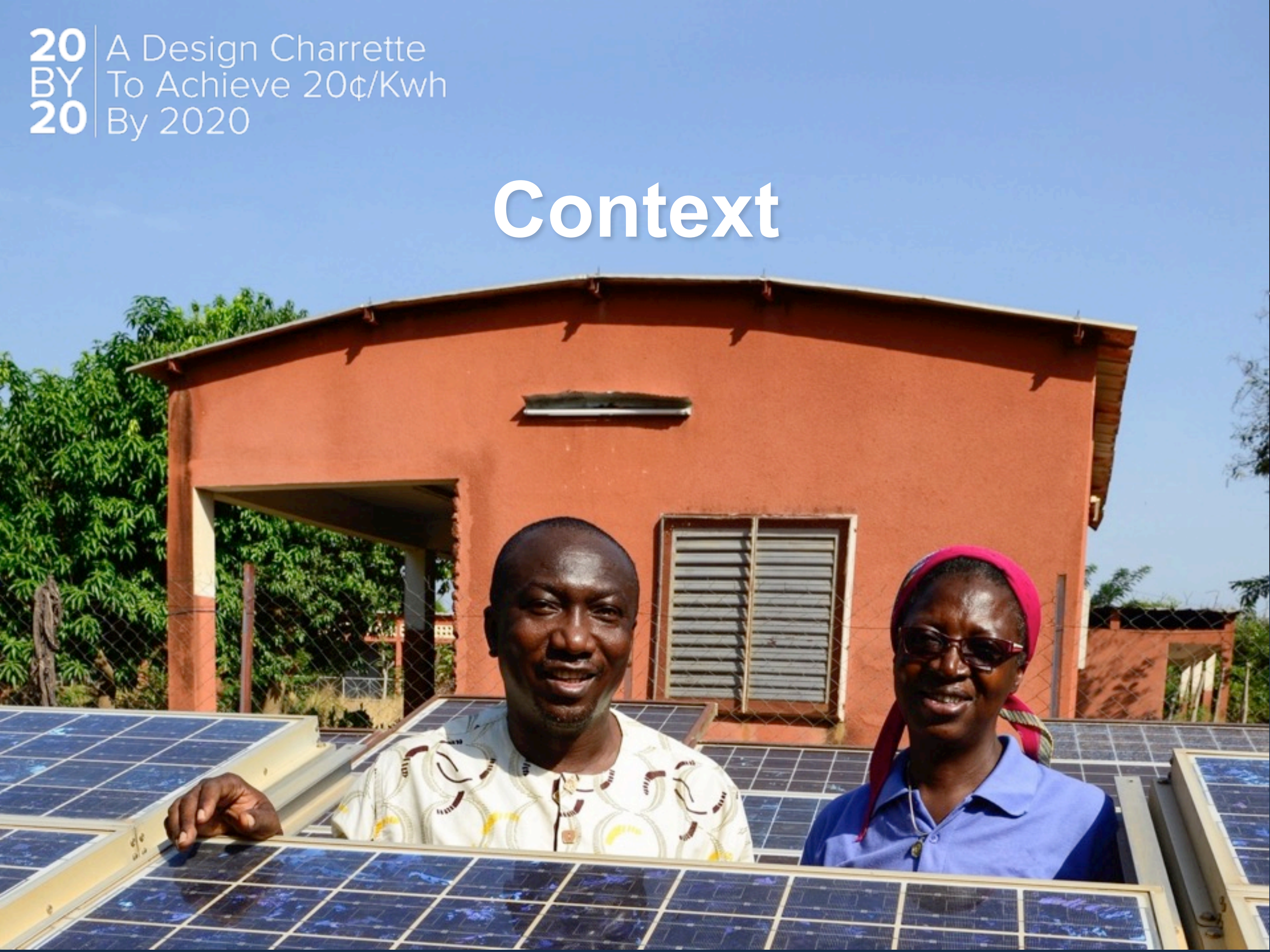
Main Conference Room: Orchid Hall

Registration Desk

Upon drop off at the main entrance to Eko Hotel, take the walkway to the left, you will end up here, Orchid Hall.

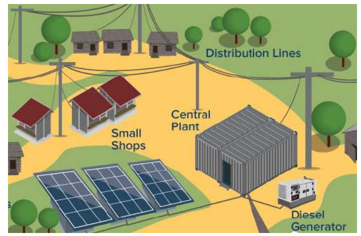
RURAL ELECTRIFICATION AGENCY

Context



Minigrids have a critical role to play in providing power to homes and businesses

Minigrids can serve productive-use loads underpinning economic development



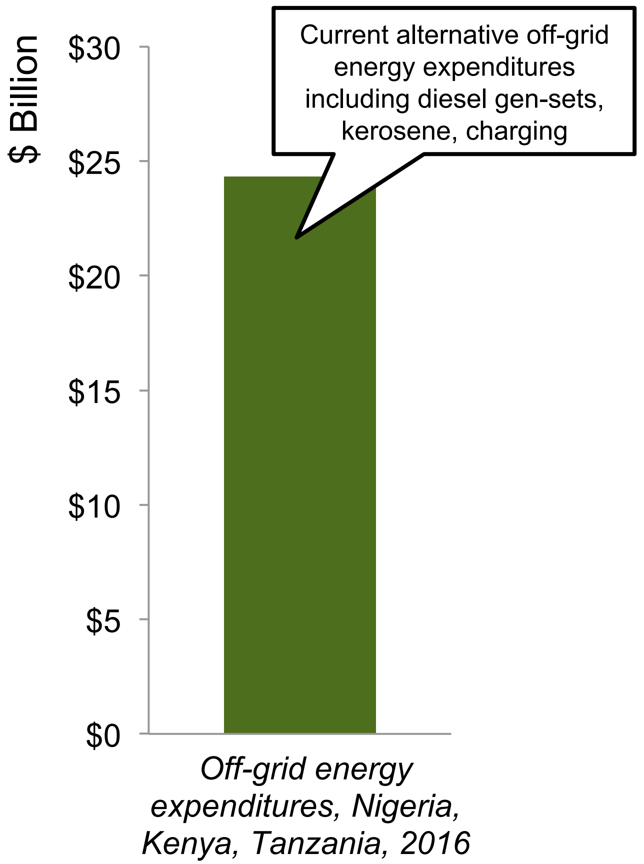
	Solar home system (tier 1)	Minigrid	Grid extension	Alternative energy or no energy
Cost per customer	$6 to $12/month for basic services	$6-$10/month for basic service	$0.74 to $12/month for basic service	Typically, costs are $25/ month for customers with a petrol generator or $35/month for diesel. Costs are $11/month per customer using energy substitutes (including torches, kerosene, candles, or cell phone charging)
LCOE*	$2/kWh or higher	$0.50-$1.00/kWh	$0.15-$1.00/kWh, if including cost of grid extension	
Can it serve productive loads?	Currently only small and medium enterprises	Yes	Yes	
Time to deploy	Fast	Fast	Slow	
Least-cost role	Providing energy access to isolated residential customers	**Providing energy access to remote or underserved villages with significant load**	Either for those near existing grid, or very high loads that are farther from the grid	None

*Levelized cost of electricity

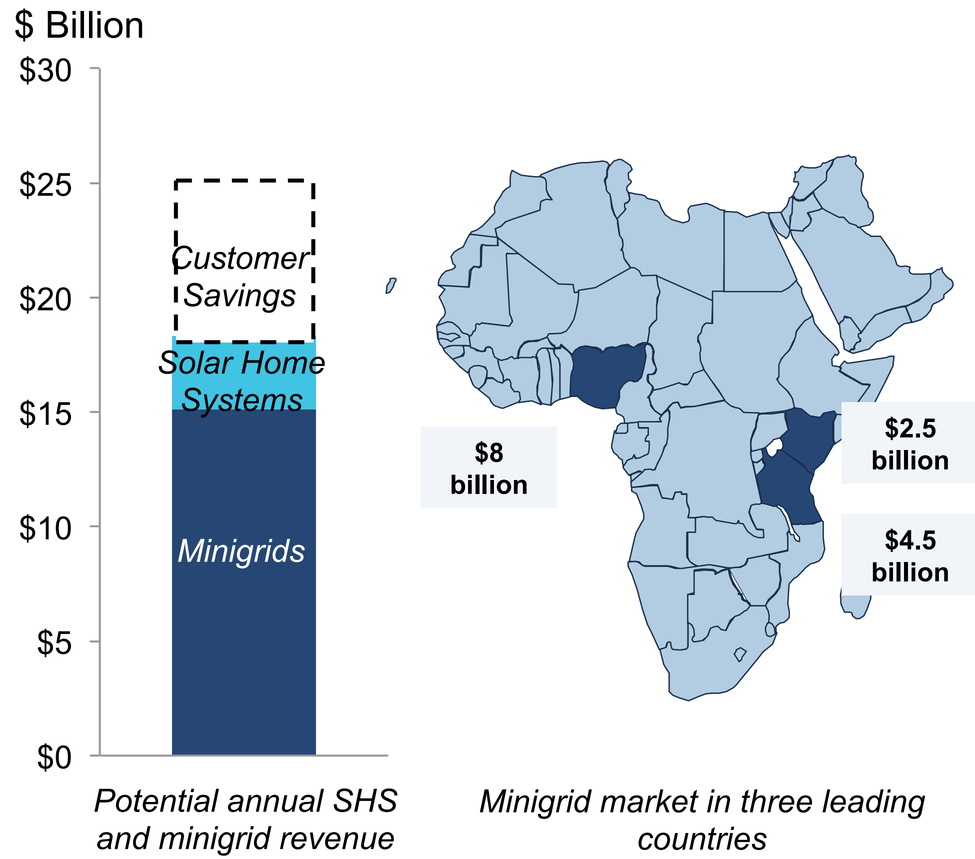
Source: RMI industry interviews and analysis, field visits to un-electrified villages

A profitable minigrid business model is a multi-billion dollar market opportunity

$24 billion spent currently on off-grid alternatives in three leading markets



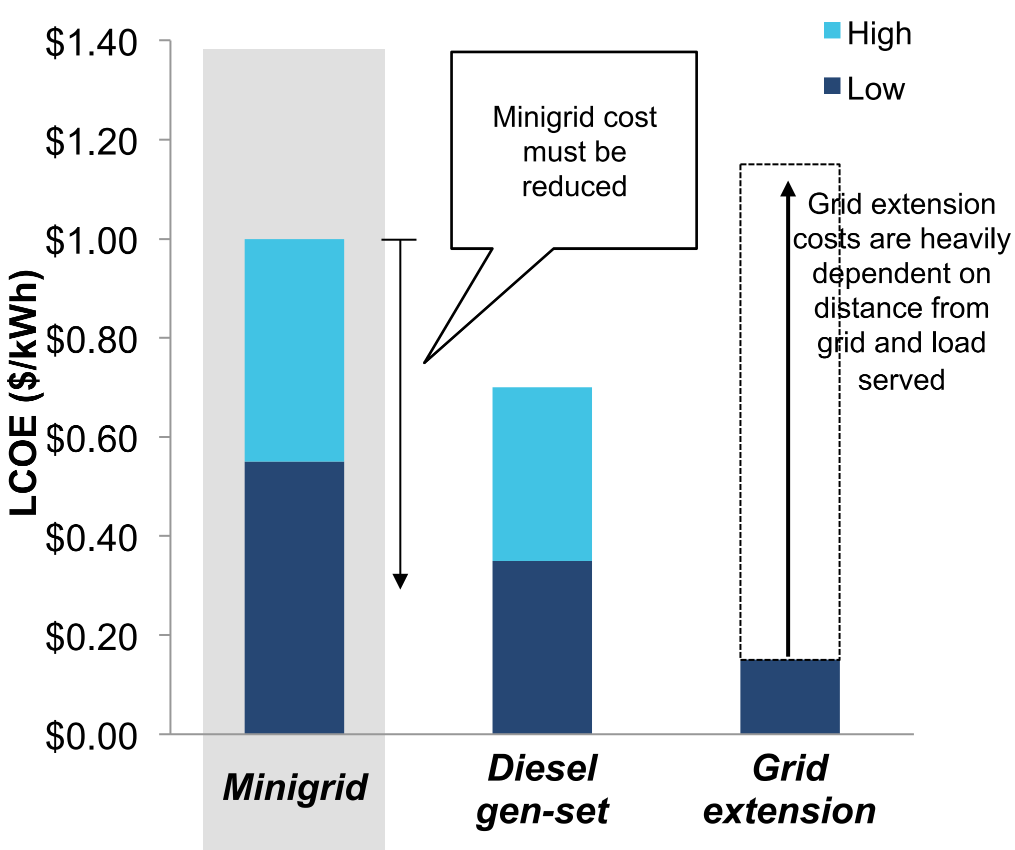
Capturing just 60% of these expenditures is an $18 billion market opportunity



Source: RMI, analysis from "Energy Within Reach" and internal analysis; potential minigrid market based on percentage of population without grid electricity with the ability to pay for over $6/month, SHS for those with less than $6/month ability to pay

Minigrid cost of service must be reduced to compete with alternatives and fit within customers' ability and willingness to pay

Minigrid cost comparison with alternatives



- Over $400M investment in minigrid pilot projects has proven technical feasibility, but not economic viability
- Current minigrid cost of service of $0.55–1.00/kWh must be reduced in order to compete with alternatives such as diesel gen-sets, and to fit within customers ability and willingness to pay
- Cost reduction will help gain government support – at current costs minigrids must charge poor rural customers more than the oft subsidized grid tariff enjoyed by wealthier urban customers

Source: RMI analysis and field visits

Nigeria is a promising market and a good test case for developing a profitable minigrid business model that scales

Nigeria is an attractive market for testing and scaling minigrids

- Nigeria has the **largest population and GDP** in Africa with significant rural economic activity
- **14 GW served by small petrol and diesel generators**
- Nigerians already spend **$14B annually on off-grid power** from small generators
- There are **85 million people** underserved and/or unconnected to the grid, which is an enormous investment opportunity
- The market is large - installing **1,000 minigrids each year for the next 10 years** would only serve 20% of the current off-grid population

Some Nigeria data and experience will ground the conversation, but insights are transferable

- The range of **community and economic structures** in Nigeria is **very broad** ranging from nomadic to agricultural to large cities near and far from grid
- **Hardware and O&M** cost reductions are broadly **transferable**
- The **government's experience** with developing and applying minigrid policy is **common** across sub-Saharan Africa
- The details of **community engagement** and **customer acquisition** may be location-specific but general **approaches are transferable**

Source: RMI Analysis and "Captive Power in Nigeria," from the Africa-EU Renewable Energy Cooperation Programme.

Challenges

There are four categories of barriers to profitable and scalable minigrid business models

1 **Cost is high**

- Overall **cost of service** is determined by both upfront and ongoing cost, and can be measured by calculating the **overall levelized cost of electricity** (LCOE)
- **Upfront cost** includes hardware, project development, and construction
- **Ongoing cost** includes O&M, fuel, customer engagement, and system losses
- **Policy and finance** also affect cost, additional considerations are noted below

2 **Capacity utilization is poor**

Cost of service increases further for minigrids with poor utilization, including systems that are oversized with slow customer acquisition and/or high peak loads in the evening

3 **Financing is expensive or unavailable**

Increased access to finance is required for scaling successful business models, but current rates are high and increase further with foreign exchange risk

4 **Policy is unpredictable or unsupportive**

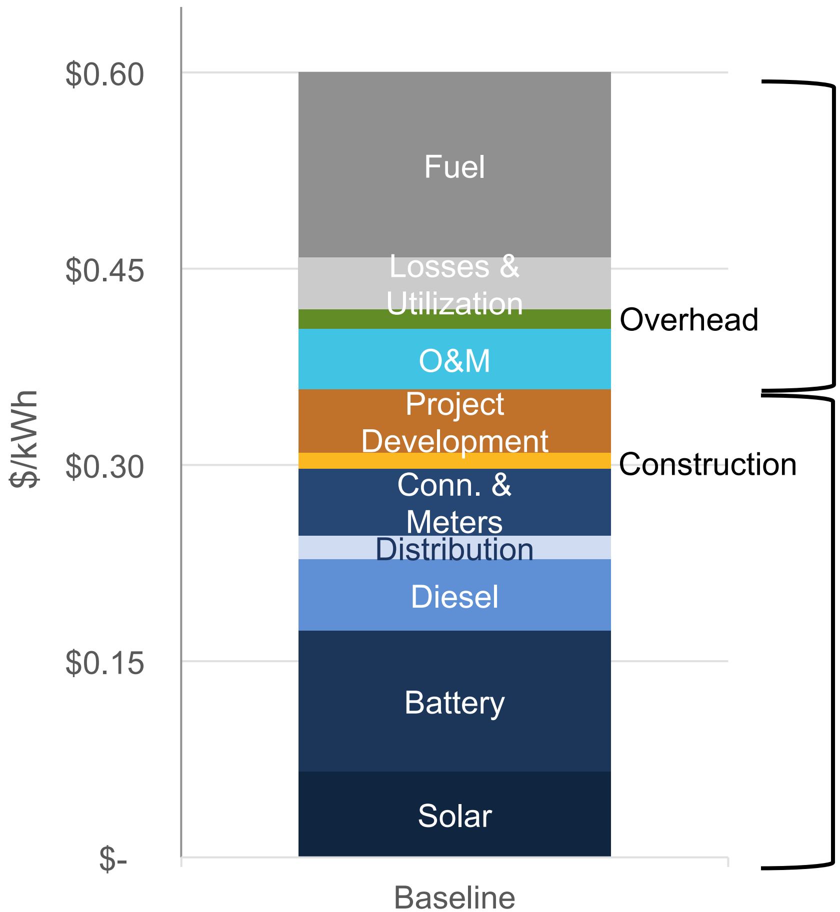
Key considerations include tariff setting, licensing, taxes, import duties and delays, subsidies, and grid extension and interconnection

1

Cost is high

$0.60/kWh is the typical levelized cost of service for a well run minigrid today

Cost of service from a minigrid (LCOE $/kWh)



Ongoing costs (42%):
-Fuel: 24%
-O&M and overhead: 10%
-Losses and lower capacity utilization: 7%

Upfront costs (58%):
-Capex: 48%
-Project development and construction: 10%

System characteristics

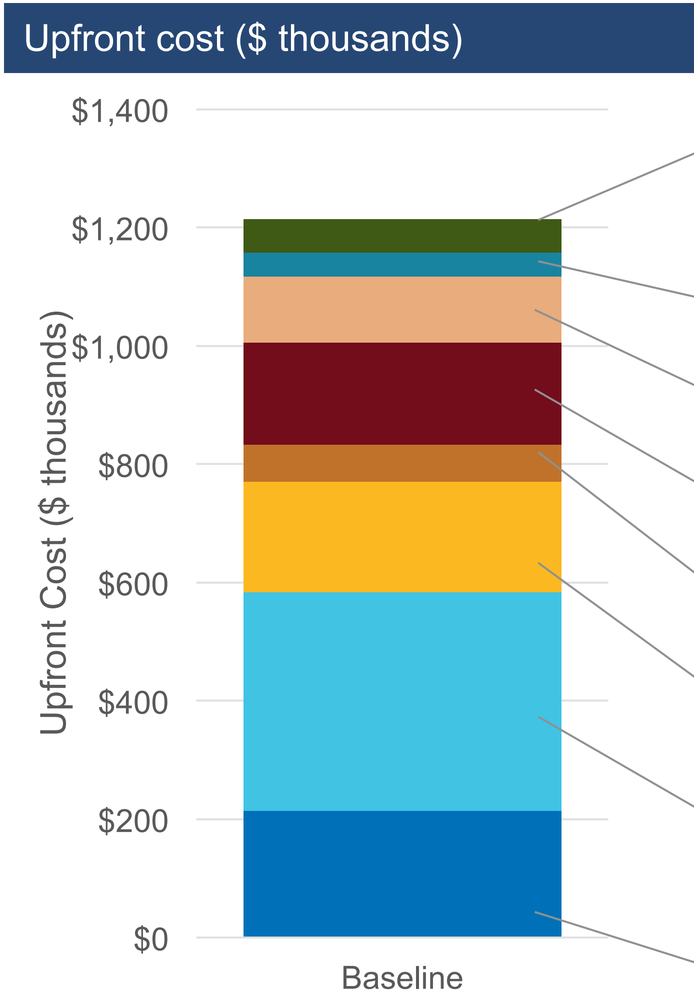
Peak load: 200 kW
Annual consumption: 500,000 kWh/yr
Assumed uptime: 24 hrs
Number of connections: 1,200

Solar array: 200 kW
Diesel generator: 225 kVA
Battery size: 860 kWh Pb-acid
Distribution network: 4 km

System lifetime: 20 years
WACC: 13%

Source: RMI analysis. See appendix for detailed assumptions.

Upfront cost can exceed $1M for a solar diesel hybrid minigrid with 200kW peak load ($6/W)



Upfront soft costs (5%):

- Predevelopment costs include labor to select sites and perform initial customer engagement
- Engineering labor is calculated for system design, construction supervision, and financial modeling
- Site delays are calculated as captive capital and idle labor

Construction and installation costs (3%) for all components based on labor cost and time estimates

Duties and fees (9%): include customs duties and VAT for imported capex except solar

Connections (weighted average of 1/3 phase of $49/conn.) **and meters (14%)** (weighted average of 1/3 phase of $95/conn.) capex

Distribution capex (5%): Low voltage 1/3 phase distribution at $1,550/100m

Diesel capex (15%): $1,050/kW includes generator, housing, and replacement (8 yr) cost

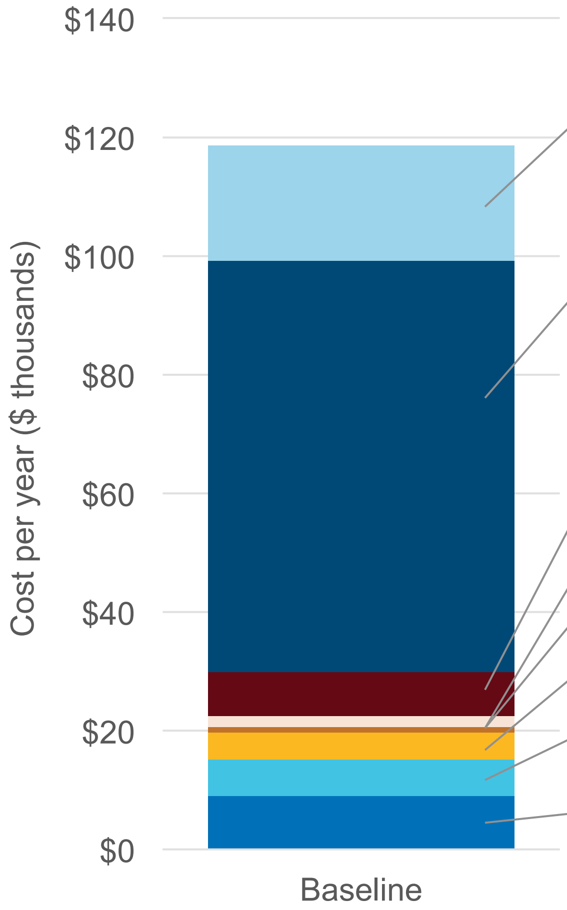
Battery capex (30%): $390/kWh for lead-acid batteries, housing, and replacement (5 yr)
Battery inverter cost: $175/kW

Solar capex (18%): $1,020/kW includes module, inverter, racking, foundation and balance of systems. Graph includes spare parts for all capex and sub-distribution for all generation

Source: RMI analysis. See appendix for detailed assumptions.

Annual cost for operation, customer service, and overhead can exceed $100,000 or $0.24/kWh

Ongoing cost ($ thousands)



Losses and capacity utilization (16%): Include overcapacity due to customer undersubscription and technical losses from parasitic loads such as inefficient AC cooling for batteries and power electronics

Fuel (58%): Fuel priced at $0.80/L inclusive of logistics for fuel delivery at $0.10/L

Income taxes (6%): Includes a 30% corporate income tax

All other overhead (2%): Includes corporate office rental, company insurance, and contingencies

Other staff overhead (1%): All other staff including an accountant and driver

Management overhead (4%): Includes a local executive and management staff

Customer relations (5%): An onsite representative to handle customer acquisition, retention, and technical training

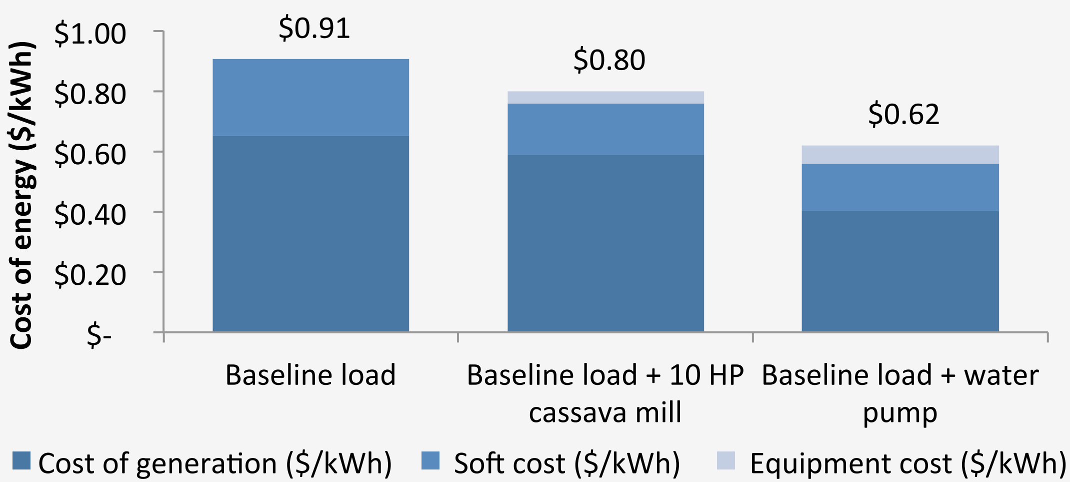
Local operations management (8%): Includes an operations tech on site, the cost to dispatch engineers twice per year, as well as 2 guards to maintain basic security

Source: RMI analysis. See appendix for detailed assumptions.

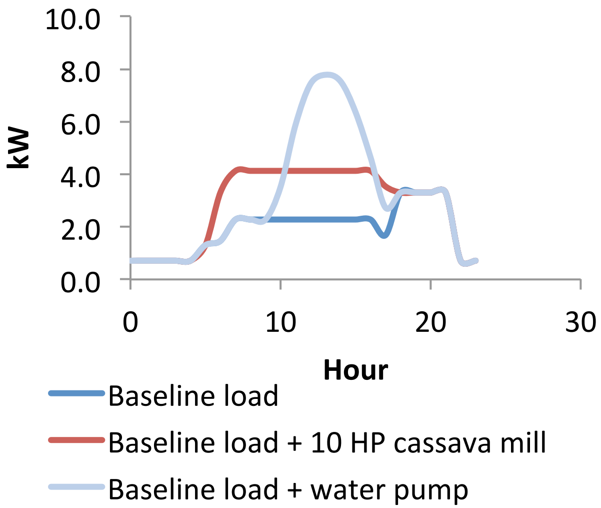
Cost of service further increases for minigrids with poor capacity utilization

Effect of demand stimulation on cost of energy in a sample rural East Africa village

Cost is reduced after demand stimulation



Load profile before and after demand stimulation



- In this example, adding a cassava mill for $0.04/kWh **lowers the cost of energy by $0.11/kWh (12%)**. Adding a flexible water pump for $0.06/kWh **lowers the cost by $0.29/kWh (32%)**
- For minigrids of all sizes, **load shapes that dictate a large system design but under-utilization of low-cost daytime solar assets lead to high costs**

Source: RMI analysis, field data

High interest rates and/or unavailable financing increases cost and slows market growth

Low Availability of Finance	• Minigrid companies **struggle to secure equity, concessional or commercial debt, and credit enhancements** • Existing minigrid companies are **unable to scale up their operations** because of the longer payback times of minigrids and difficulty in obtaining other finance • **Smaller companies are unable to enter the minigrid market** because of the lack of finance
High Cost of Finance	• Minigrid developers who take on more expensive debt must **pass on those costs to their customers.** Commercial debt for minigrids in sub-Saharan Africa, when available, **is typically above 15%** • Developers may **choose not to connect the poorest customers** because of pressure to maintain their high debt repayments • If a developer is unable to pay back their borrowed capital they become **less likely to keep up O&M** • Foreign exchange uncertainty and inflation drive up the cost of borrowing in local currency, but repaying loans in foreign currency is risky when revenue from customers is in local currency

Source: RMI analysis and field visits

4

Lack of strong and consistent minigrid regulations and policy slows market growth

Licenses, permits, and tariffs	• Depending on the market, developers spend time in discussions with government officials at all levels to **determine which licenses and permits are required** • Licenses and permits can cost **thousands of dollars per site** and take **several months** or more to process • Developers are **not able to recover their costs with grid parity tariffs** and tariff approval processes are unclear and difficult to navigate • New developers are **hesitant to enter the market** because of these uncertainties, stifling market growth
Taxes, duties, and lack of subsidy for poorest	• Minigrid developers often **pay high taxes and duties** on their imported equipment • When duty exemptions exist, minigrid developers often have a hard time taking advantage of them because of **processes that are long and bureaucratic** • Developers **incur storage and labor costs** as a result of import delays • **Example:** in Sierra Leone, GST/duty effectively adds 40% to cost of goods sold, a cost which is passed on to customers
Inter-connection and grid exit	• Developers **avoid some of the best sites** with existing economic activity and latent demand, often located near grid connected areas because of unclear policies around interconnection or buy-out if the grid arrives. Many of these sites are unlikely to be connected anytime soon and even if they were the service may be unreliable and customers would likely still use minigrid power • **Developers have difficulty raising capital** because investors are concerned about the future of their assets if the main grid arrives

Source: RMI analysis and field visits

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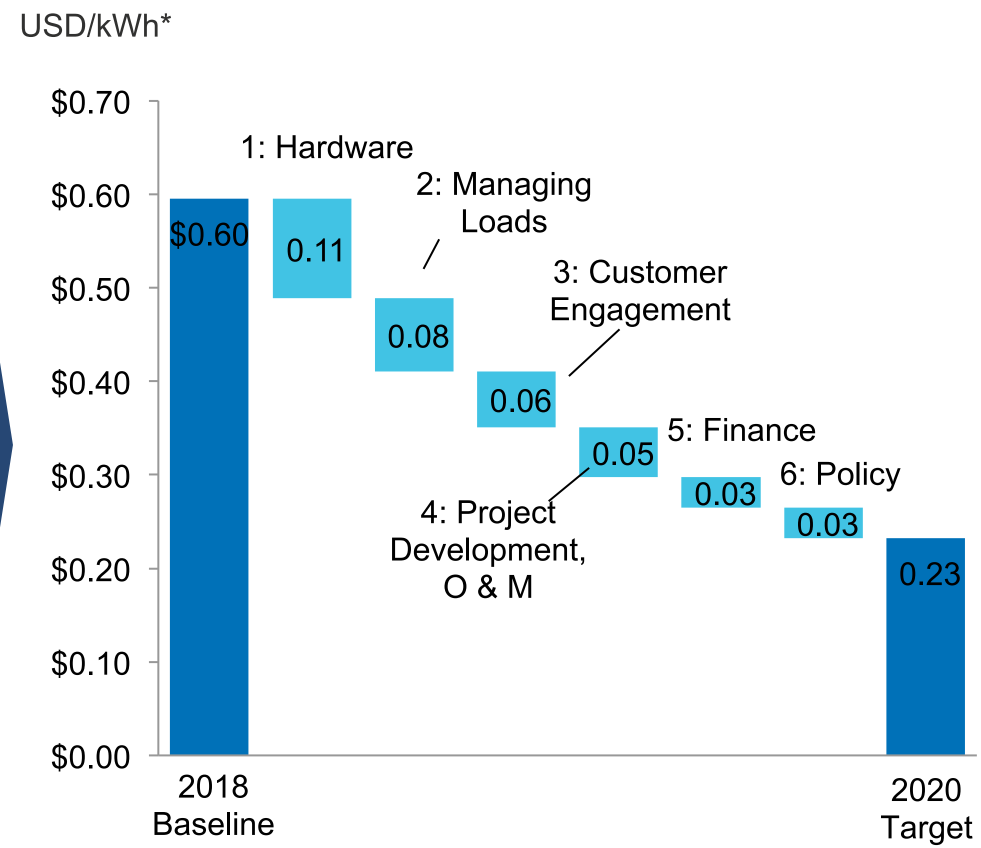
Possible solutions

Capturing opportunities in six categories can reduce cost to near $0.20/kWh (60% reduction) by 2020

An incoming hypothesis

- To stimulate conversation during the charrette, RMI has developed **a possible scenario** for reaching an LCOE of $0.23/kWh
- **The following slides briefly describe the approach** in each of these six cost reduction categories (more detailed assumptions are provided in the appendix)
- At the charrette we **will test and build off of these ideas, but many outstanding questions remain**
- RMI is not advocating for a specific solution set or market segment

Cost reduction opportunities in six categories



*LCOE for total cost of service including all costs shown previously in slide 20–22

A standardized modular hardware system applied at scale can save $0.11/kWh

Current situation:

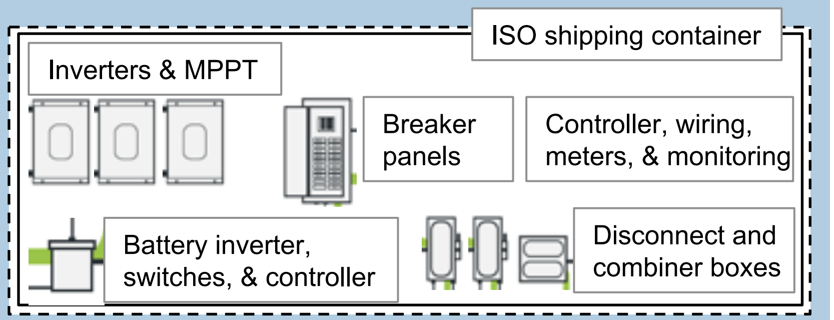
- High system cost at low volume
- Custom engineering and complex install in the field for small batch of projects
- Global cost reduction trends for many components, especially PV and some batteries

Proposed approach:

Standard, modular, and containerized minigrid solution can reduce cost of service by 20%

- Expecting hardware cost reduction of 18% due to global trends over the next 3 years
- Bulk purchasing and higher volume for logistics/ overhead into Africa saves additional 15%
- Standardized modular solution reduces engineering time by a third and install by 80%
- Standardized modular solution with integrated M&V also improves reliability and reduces O&M (discussed on slide 32)
- Further savings possible from simplified or local pre-assembly of PV and racking

Example standardized solution (50 or 100kW)



Outstanding questions:

- What sizes should be standardized around?
- Would batteries be included with standardized solution?
- Would racking and PV be standardized and pre-assembled as well?
- Should these units be designed for potential future grid integration?
- Bulk purchased lithium-ion cells have been reported as low as $90/kWh, what technical barriers still exist (e.g. weather, cycling, BOS)?

Component images from: https://solarcalculator.com.au/solar-power-systems/
Bloomberg New Energy Finance, “2017 Lithium-Ion Battery Price Survey.” December 5, 2017.

Actively managing load profiles can save $0.08/ kWh on hardware and operating cost

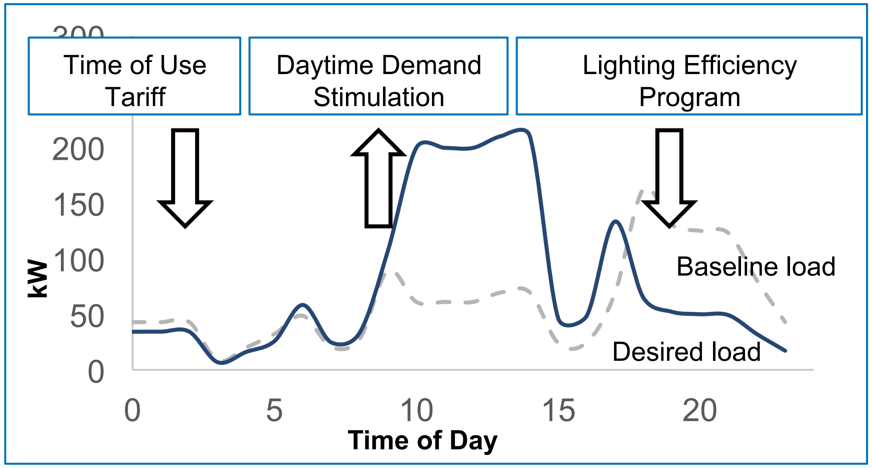
Current situation:

- Many off-grid sites lack productive use loads
- Agrarian and domestic loads exacerbate morning and evening peaks
- Latent public (e.g. water pumping) and private (e.g. productive use) demand for energy exists

Proposed approach:

Encourage daytime use through load management programs to reduce LCOE by 13%

- **Site selection:** Target sites with higher existing daytime load
- **Energy efficiency:** Reduce night-time lighting loads by 50% by using LED lighting
- **Demand stimulation:** Double daytime use by financing flexible, productive uses (e.g. water purification, pumping)
- **Tariffs:** Simple tariff structure to encourage daytime use can shift 20% of nighttime load (e.g. time of use)



Effects of targeted load management on baseline load

Outstanding questions:

- How do minigrid companies sustainably offer consumer financing for demand stimulation?
- Can load curves be optimally shaped through selective distribution, a kiosk model, or energy as a service?

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Customer engagement can save $0.06/kWh across the system despite being 3% of total cost

Current situation:

- Customer engagement is critical for demand stimulation and managing load profile (slide 30)
- Slow/uncertain customer acquisition leads to underutilized system capacity in early years
- Revenue lost from non-collection or poor customer retention issues. Payment is often inefficient because of a nascent mobile money framework.

Proposed approach:

- Focus first on productive-use and largest customers
- Partner with organizations like ag. coops and telcos that have existing customer relationships to:
  - Provide better understanding of willingness and ability to pay
  - Gain insight into productive use and demand stimulation needs
- Use mobile money and/or transparent and intuitive customer interface (e.g. USSD)
- Track metrics on customer acquisition and retention to improves sales and offerings

Case study: One Acre Fund's rapid growth was fueled by the integration of digital tools

Tool	Purpose	Farming Value Chain	Minigrid Value Chain Stage Equivalent
Mobile money to facilitate loan repayment	Mobile Transactions	Inputs	Transactions, collections
Mobile data collection to increase accuracy and efficiency	Data collection	Cross-cutting	Data collection, Metrics tracking (e.g. ability to pay)
Tablet enrollment to increase efficiency of registering new and returning clients	Data collection, information exchange, precision agriculture, transactions	Planning, inputs	Planning, customer acquisition, transactions
Crop health application for diagnosis of diseases and pests	Precision agriculture, information exchange	On-farm production	Remote M&E, demand stimulation

Outstanding questions:

- How can we achieve energy access goals while prioritizing the best customers?

Assumptions: 50% of capex cost reduction from load management attributed to customer engagement due to demand stimulation.

Sources: USAID "Finding the Best Fit: One Acre Fund's integration of digital tools in Kenya." July, 2017. https://oneacrefund.org/documents/285/Finding_The_Best_Fit_USAID_One_Acre_Fund.pdf

Increasing scale, localized expertise, and remote monitoring can save $0.05/kWh

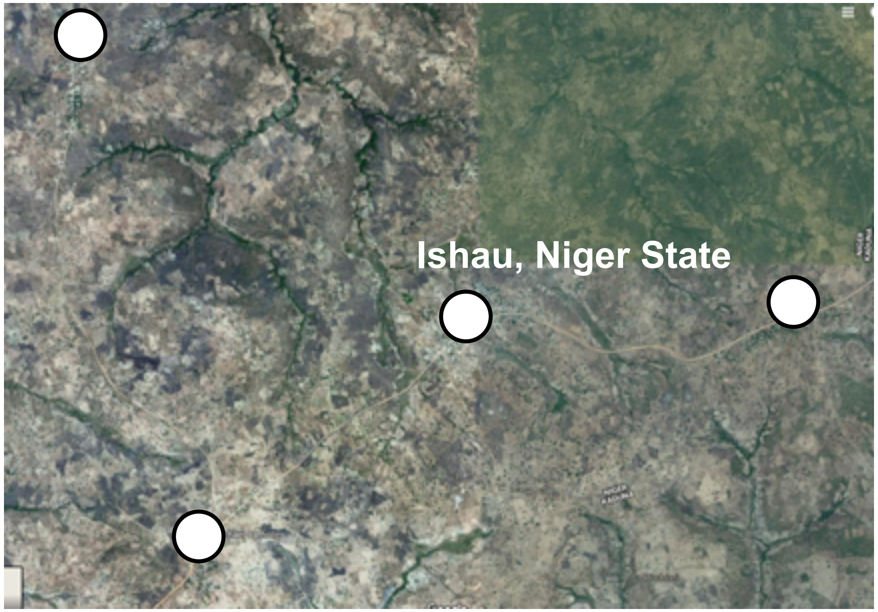
Current situation:

- Developers and operators serve sites far from major cities across multiple states and regions
- International companies have high labor costs
- Long project delays lead to idle labor

Proposed approach:

Increase scale to serve 100+ sites efficiently by targeting labor and logistics through clustering and partnership

- Select and serve clusters of sites within 2-3 hour travel from each other
- Form strategic partnerships along the value chain to take advantage of economies of scale, local labor and knowledge, and specialization
- Engage with communities to reduce land costs through donation while increasing site security
- Reduce overhead costs by 60% through rapid scaling-up number of sites served



Example: Four communities (~50-200kW) in a tight cluster 3 hours drive from Abuja

Outstanding questions:

- How can transaction costs stay low as the number of parties involved grows?

Assumptions: Clustering and remote monitoring decreases distance traveled 65%, site visit frequency by 50%, staffing by 80%. Local partnerships increase site selection efficiency by 150%. Planning foresight reduces idle labor 100%.

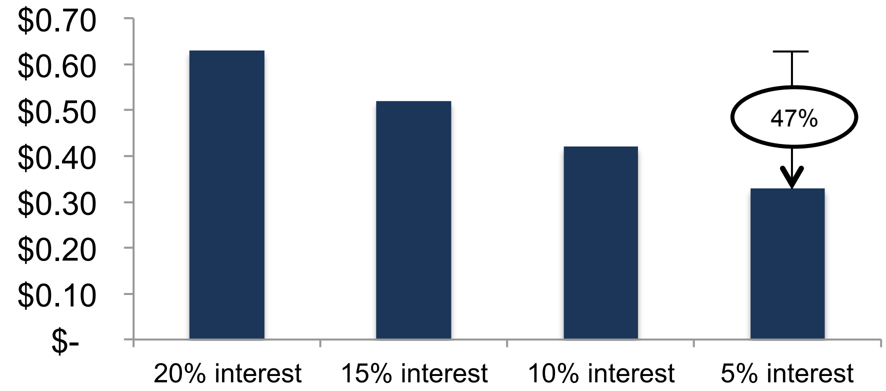
RURAL ELECTRIFICATION AGENCY

Reducing the cost of capital by 4% to enable more rapid scaling can save $0.03/kWh

Current situation:

- Most projects are funded by grant, equity, or with greatly subsidized interest rates
- Commercial loan rates in sub-Saharan Africa are typically between 15% and 20%
- USD or EU-denominated loans offer alternatives but also come with high cost (15-20%), FOREX risk and currency mismatch for local developers

Effect of debt cost on LCOE, typical solar-battery minigrid site*



Proposed approach:

- Use blended finance facilities to aggregate minigrid sites, manage risk, and apply equity, debt financing
- Use credit enhancement tools, such as FOREX risk hedging, customer payment backstops, and collateral guarantees to leverage other capital
- Invest in quality assurance frameworks and consistent robust data collection to give investors clarity and confidence

Outstanding questions:

- What should a successful blended finance facility look like? Who are the key actors to ensure success?
- Are there effective ways to aggregate dozens, hundreds of minigrids and assess risk?
- How can OPEX grants be applied, implemented and monitored to achieve desired results?

*Project also has backup diesel generator

Supportive regulation and policy can increase ease of doing business and save $0.03/kWh

Current situation:

- Fees can add almost 50% to hardware cost, including customs, VAT, and local taxes (e.g., 20%, 19%, and 9%, respectively)
- Delays at port and in licensing slow growth and tie-up working capital
- In many markets, minigrid regulations either not in place, or have not yet been demonstrated

Proposed approach:

- Waive customs/duties and VAT for all minigrid components (not just PV)
- Reduce port delays for minigrid components
- Clarify grid interconnection procedures, both technical and financial
- Publish grid extension plans
- Allow cost-reflective tariffs (at least for pilots and within some limits)
- Reduce licensing/permitting requirements where appropriate

Outstanding questions:

- How should tariffs be set?
- What happens, technically and financially, when the grid arrives?
- If necessary, how can subsidies be used in a way drives growth, connects customers, and does not distorting the market?

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Implementation

Participants will test cost reduction ideas by creating business models for three representative market segments

	Small off-grid site *Komsiga, Tanzania*	**Large off-grid site** *Onyen Okpon, Nigeria*	**Large under-grid site** *Obafemi, Nigeria*
Size and location	• 100 households • 50 km to closest town • 10 kW peak	• 500 households • 36 km to closest town • 200 kW peak	• 300 households • 25 km to closest town • 120 kW peak
Ability to pay	• Current average household energy expenditure: $1.00/wk	• Current average household energy expenditure: $3.75/wk	• Current average household energy expenditure: $5.00/wk
Economic activity	• Farming: cassava, maize, bananas	• Farming: dairy, cocoa, cassava • Agricultural processing	• Farming: cassava, cocoa, yam • Agricultural processing • Other commercial activity
Unique attributes	• Clustered sites • Mobile money widely available • Strong solar resource	• Community will provide land • Some homes already wired	• Clustered sites • Distribution in place • Cheap diesel
Policy	• Supportive policy for small minigrid development • Subsidy available	• Supportive policy for minigrid development • Permit required, >100 kW	• Minigrid regulations provide for under-grid development; need DisCo cooperation
Replicability	• 100s of similar sites across Tanzania	• 100s of similar sites across Nigeria	• 1000s of similar sites across Nigeria

Note: fact sheets describing each site more fully are available in the appendix

Some participants will also explore program designs to support the business models and accelerate cost reduction

Goal:
Design a program funded by development partners and investors to deliver cost reductions and support scaling minigrid business models

Illustrative program

	Phase 1	Phase 2	Private sector handoff
# of sites	-	-	-
Cost per site	-	-	-
Total cost	-	-	-
Funding type	Grant	Concessional	Blended
Outcomes	- - -	- - -	- - -

Proposed approach:

- Start with grant funding to prove and de-risk the basic business model while transitioning toward concessional and eventually blended finance
- Design a pipeline of pilot projects to answer key questions and provide some certainty to developers and hardware suppliers
- Use global best practice tender process to drive down cost and reward innovation

Outstanding questions:

- What lessons learned can we take from previous grant funded projects to accelerate progress?
- What size and type of funding is needed over time?
- What subsidies work best to align incentives for cost reduction and get the best bang for buck?

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Appendix: modeling and market segment assumptions

Assumptions: hardware cost

	US/EU $/W	SSA* $/W	2020 Target $/W	Notes
PV modules	0.42	0.58	0.30**	All solar component prices based on Shine*** cost modeling adjusted to expected SSA prices. Benchmarked against current SSA minigrid developer costs. All 2020 costs include BAU global market cost trends
Racking	0.11	0.15	0.09	Current: higher material cost 2020: reduction through new low cost ballasted systems or through preassemble or local manufacturing
PV BOS	0.05	0.08	0.064**	Includes BOS, AC Station, Comms/Monitoring system
Battery storage	145 $/kWh	175 $/kWh	158 $/kWh	Pb-acid; 5% year over year reduction. Li-ion is an interesting alternative, but not included here
Inverters	0.07	0.12	0.06**	Current: 50 to 100 kW units at $.07/W AC; includes $0.05/kWh for shipping 2020: includes 2/3 reduction through reduced clipping
Battery Inverter		0.18	0.13**	Based on SMA/Schneider off-grid solutions and local minigrids
Battery BOS	0.01	0.01	0.01**	Includes racking, rack management, and other BOS
Distribution	$20,000/km	$15,475/km	$15,475/km	Assuming LV distribution (1 and 3 phase), panelboards, and poles
1 ph. connect/meter	$140	$140	$56	Per connection 2020: assume a load limiter at 1/3 cost
Com connect/meter	$335	$335	$268	Per connection
Additional savings from standardization	NA	NA	20%	Hardware supplier spends less time on sales and engineering plus can accept lower margin for package sale at higher sales volume

*Not including duty, install, or transportation to site

** Assume 20% cost reduction through bulk purchasing while assembling standardized solution.

***Shine is RMI's community scale solar program using economies of scale, standardized system design, innovative BM, and other levers to lower

Assumptions: installation and construction cost

	SSA $/W	2020 Target* $/W	Notes
Diesel install	.008	.008	All install costs include local labor costs plus engineers allocated to project to design, install, and supervise 3 laborers, 20 days, $10 per day, to install a gen and housing 2020: Diesel Gen does not come included in standard solution
Solar install	.047	0.08	SSA costs based on Shine US cost calculations for a standardized system adjusted by ratio of Nigerian wage to US wage
Storage install	0.02	0.003	Current: Assumes construction of racking and housing using 3 engineers and 5 laborers, 30 days, $50/day, 300 kWh battery 2020: Assumes 5 laborers hook batteries to standard solution in 5 days
Distribution install	$1,500/km	$1,500/km	Current and 2020: Team to install poles every 50 meters, 60 min per pole, 5 laborers at $20 per day plus a truck at $500 per day
Connections & meters install	0.003	0.003	40 min per install, junior engineer at $25/day; no change with standardized system

*Lowered installation cost due to a containerized, standardized system

Assumptions: other cost

	Current	2020 Target	Notes
Transport equip to site	$4,000/ site	$300/site	Current: Assume 3 containers/truckloads per site with time spent aggregating between containers and purchasing in country 2020: 2 trucks delivering to a cluster of sites less distance from port; less time aggregating due to bundled containers
System engineering	$21,000/ site	$4500/site	Current: 6 engineers per site and 2 consultants working for 1.5 months (based on conversations with developers) and 15 days on site during construction 2020: 1 consultant and 1 engineer for 1.5 months
Project development	$170,000/ site	$13,000/site	Current: Includes cost of up to 60 days of port delays and duties and fees; 2020 requires less interaction with port authority, less trucks/trips, and less engineering troubleshooting, and no port delays
Community engagement	$850/site upfront $6250/site ongoing	$1600/site upfront $3000/site ongoing	Current: Includes the cost of identifying potential customers, productive use scoping, gather data on current use and current expenditures, site selection and 1 on-site staff for customer relations 2020: Costs are spread across more sites and customer and site ID is done more efficiently. 1 on-site staff is shared between 5 sites. A USSD system is implemented as a customer portal
O&M cost	$8,000/site	$1,000/site	Current: one person per site and engineers dispatched from main office on a regular basis 2020: One person covers 5 sites; increased number of sites
Overhead	$7000/site	$3000	Current: Small staff spread over 15 sites 2020: Large staff spread over 100 sites; Overhead includes data tracking and analysis

Assumptions: other cost (continued)

	Current	2020 Target	Notes
Fuel cost	$0.8/L	$0.75/L	Current: includes $0.10 for diesel logistics and theft 2020: 50% reduction in diesel logistics
Duty on PV equip	0%	0%	Exempt
Duty for all other equip	25%	0%	Current: 20% Import Duty (ID) and 5% Value Added Tax (VAT) for batteries; 5% ID for Meters; 10% ID for inverters 2020: All minigird components exempt from ID and VAT
Losses	$20,000/site	$5,000/site	Technical losses Current: Parasitic loads from 810W AC 2020: Replace AC with higher cost 214W AC Nontechnical Losses Current: Slow customer acquisition and customer turnover leads to 30% undersubscription in year one, shrinking to 10% in years 3 to 10 and 0% in years 11 to 20 2020: Better customer engagement leads to 30% undersubscription in year one, shrinking to 0% in years 4 to 20
Financing	WACC: 13%	WACC: 9%	Current: 9% debt cost, 75% debt share, 25% equity cost 2020: 4% debt cost, 75% debt share, 25% equity cost

Assumptions: sources

	Current
Hardware Costs	• Interviews with RMI Shine team and Shine modeling (https://www.rmi.org/our-work/electricity/shine-community-scale-solar/) • Interviews with local minigrid developers (including GVE, Nayo Tech, Rubitec, VPS) and leading international minigrid companies (including PowerGen, SPRD) • Data collected from site visits to local minigrid sites and minigrid sites in India • Data from sites and current operations in India (SPRD) • Due diligence and cost information from GIZ • Interviews with global equipment suppliers
Installation and Construction Costs	• Interviews with RMI Shine team and Shine modeling • Interviews with local minigrid developers (including GVE, Nayo Tech, Rubitec, VPS) and leading international minigrid companies (including PowerGen, SPRD) • Interviews with global equipment suppliers
Other Costs	• Interviews with local minigrid developers and leading international minigrid companies • Interviews with demand stimulation and subsidy experts • Conversations with emerging economy investors • https://www.customs.gov.ng/ • https://www.safaricom.co.ke/personal/get-more/information-services/ussd

Market segment fact sheet: Small off-grid site
Komsiga, Tanzania*

*Komsiga is listed by the Tanzanian REA as requiring off-grid development; however, the REA/RMI teams have not been to this site and cannot guarantee the accuracy of information provided here

Community overview

Location	Kilindi District, Tanga Region (NE Tanzania)
Distance to town	56 km to district headquarters 300 km to Dar es Salaam (major airport)
Nearest electrified town	Kilindi, 56 km away
Accessibility	Rough dirt road 6 hr drive from Dar es Salaam
Area	100 households within 1km of community center
Main sources of livelihood	Farming: cassava, maize, bananas, rice, sisal

Potential customer segmentation

No customers are currently using electricity:

- 100 households
  - 10 large
  - 90 small
- 1 manual grinder
- 1 water pump
- 2 petty traders
- 1 tailor
- 1 barber
- 1 salon
- 1 primary school

Potential new loads: There are very few existing loads in Komsiga due to the unavailability of electricity to run appliances, so potential customers using manual processes have been listed here. There is additional opportunity for water purification, refrigeration, irrigation, etc. Although Komsiga does not exhibit significant cattle herding, other similar communities might have dairy- or cattle-related energy needs.

Current energy alternatives and usage

A typical household spends the following on energy alternatives:

Kerosene: $0.75/week

<u>+ *Cell charging*: $0.25/week</u>

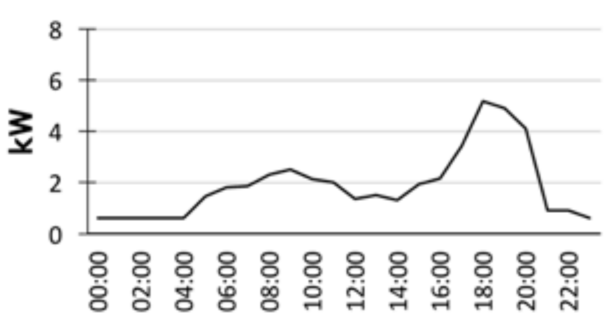
Average household energy expenditure: $1.00/week

Total current self-generation estimated at 1kW (commercial)

Grid infrastructure:

Currently there is no distribution infrastructure in Komsiga. Further, it has been identified by the Tanzanian Rural Energy Agency as a site for future off-grid electrification. While this does not guarantee the national utility, TANESCO, will not expand into the area, development will have the support of the REA and Tanzania Renewable Energy Association.

Estimated load curve**



**load curve is estimated by the use of energy alternatives, but may not be accurate

Komsiga currently has no distribution infrastructure and little capacity for electricity self-generation (above)

Market segment fact sheet: Small off-grid site
Komsiga, Tanzania

Resource availability
- Community will ask $120/year for the rental of land for minigrid distribution siting
- The community receives cell service from Airtel
- Mobile money is widely available
- Diesel costs $1.03/L or $3.90/gal locally, but is not always available
- Solar irradiation ranges from 4.38-6.19 kWh/m^2/dy (seasonally) and averages 1525 kWh/m^2/yr
- During the rainy season, expect up to one week of consecutive days without sunshine
- Commercial debt available at 15%; concessional financing available (see below)

Market scalability
There are 2 other off-grid communities within a 15 km radius of Komsiga, which are accessible from Komsiga.

There are hundreds of similar sites across Tanzania, but many of these are isolated due to their extreme remoteness.

Local businesses are eager for the opportunities available from electricity, such as selling refrigerated drinks (left)

Policy & Regulatory overview
According to Tanzanian national government regulation, isolated solar-hybrid minigrids up to 1MW must complete the following procedures to obtain a license:
- Obtain permission to conduct business by registering the company in Tanzania
- Obtain a Letter of Intent from the distribution network operator indicating they have no objection to the proposed minigrid system
- Conduct all EIA and other assessments as required
- Register the system with EWURA (Energy and Water Utility Regulatory Authority), but no permit required for systems < 1MW

<u>Tax and duty specifications</u>
- Solar cells and modules are import duty- and VAT-exempt in Tanzania
- Imported generators (<75 kVA) are import duty- and VAT-exempt
- Imported batteries are subject to 25% import duty but are VAT-exempt

Subsidy Availability
The Tanzanian REA offers *performance-based grants* to minigrid developers. The developer must submit technical, financial, and economic feasibility analyses as well as social and environmental impact analyses. Projects with higher IRR, and developers with a demonstrated ability to meet 20% of the cost with equity, will be prioritized.

For the purpose of this exercise, assume projects may choose to receive their disbursement through several available options, or through a combination:
- Concessional financing
- Capital grant for capital expenditures (to be paid out in installments)
- Per-kWh delivered or per-connection operational subsidy
- Grant funding or financing for aggressive demand stimulation programs

Help requested on subsidy design
With ongoing funding opportunities for minigrid development, the REA* would appreciate your input on which, or which combination of, the subsidy options would be most attractive to you as a developer.

*this is a fictional request, but subsidy design is an important issue for minigrids aimed at improving rural energy access

Market segment fact sheet: **Large off-grid site**

Onyen Okpon, Cross River State, Nigeria*

*Data collected during RMI/REA site visits, but developers would need to verify

Community overview

Location	Obubra LGA, Cross River State (SE Nigeria)
Distance to town	36 km to LGA headquarters 406 km to state capital (major airport)
Nearest electrified town	Esabang, 7km away
Accessibility	Well-maintained dirt road 4 hour drive from Calabar
Area	Town center covers about 1 km^2, but residential areas extend radially along several roads
Main sources of livelihood	Farming: dairy, cocoa, cassava, yam, rice, palm, plantain; Processing of cassava, yam, palm oil

Available load information

- 500 households
  - 200 large
  - 300 small
- 20 grinders
- 2 boreholes
- 1 furniture-maker
- 3 viewing centers
- 4 tailors
- 30 petty traders
- 2 Salons
- 2 Barber shops
- 2 churches
- 3 public schools
- 1 health center

Potential new loads: The community is known for its high agricultural productivity; community leaders note the possibility of palm oil processing, which is now done manually. Many households indicate the desire to purchase new appliances in the near future.

Current energy alternatives and usage

A typical household spends the following on energy alternatives:

Kerosene: $1.75/week
+ *Torch*: $1.00/week
+ *Cell charging*: $0.50/week
+ *Generator*: 10% of the population spends $5/week on fuel

Average household energy expenditure: $3.75/week

Total current self-generation estimated at 200kW (commercial) + 60 kW (residential)

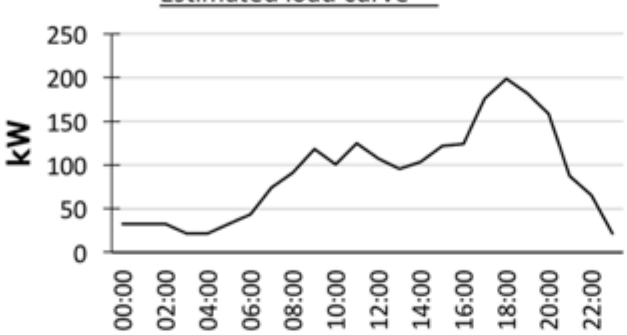
Grid infrastructure:

Currently there is no distribution infrastructure in Onyen Okpon, indicating that this site can be developed as an isolated minigrid according to NERC regulations.

In the nearest electrified town, grid reliability is poor—a few unpredictable hours of electricity per day.

The grid is not expected to expand to Onyen Okpon for at least the next few years due to the financial constraints of the distribution company.

Estimated load curve**



**load curve is based on current known energy usage, and does not include any projection for demand increase

Current self-generation of electricity depends on local availability of diesel (left)

Market segment fact sheet: **Large off-grid site**
Onyen Okpon, Cross River State, Nigeria

Resource availability
- Community willing to provide land for minigrid operations for free
- Homes of wealthier residents are already wired for eventual electricity provision
- MTN tower located within community; cell service is available from MTN, Glo, and Airtel
- Nearest bank is 7km away; mobile money available only through bank-led model
- Diesel costs N250/L ($0.69/L or $2.63/gal) locally, but is not always available
- Solar irradiation ranges from 3.73-5.64 kWh/m^2/dy (seasonally) and averages 1350 kWh/m^2/yr
- During the rainy season, expect maximum of 4 consecutive days without sunshine
- Commercial debt available at 18%

Market scalability
There is not significant clustering of off-grid communities near Onyen Okpon.

There are hundreds of similar sites across Nigeria, but currently these are largely unidentified.

(left) Local businesses currently rely on expensive self-generation of electricity for agricultural processing

Policy & Regulatory overview
According to the Nigerian Electricity Regulatory Commission (NERC) Mini-Grid Regulations of 2016:
- Off-grid minigrid may be developed in an unserved area where there is currently no existing distribution and the distribution company is not planning to expand in the near future
- Where the power to be distributed is less than 100kW:
  - The minigrid must be registered with NERC but is not bound by technical codes or standards for design, construction, commissioning, operation, or maintenance
  - If the grid extends to the area covered by the minigrid, the operator must de-commission and remove all assets within two months with no compensation from the DisCo
- Where the distributed power is greater than 100kW (but installed generation capacity is still less than 1MW):
  - A permit from NERC is required to construct/operate/maintain the minigrid
  - The minigrid cannot interfere with DisCo expansion plans into the area
  - The minigrid must meet the standards from the Metering Code
  - If the grid extends to the area covered by the minigrid, the permit-holder can become an interconnected minigrid operator, or may remove assets or transfer unwanted assets to the DisCo for a standard compensation (the depreciated value of the assets + 12 months' worth of revenue)

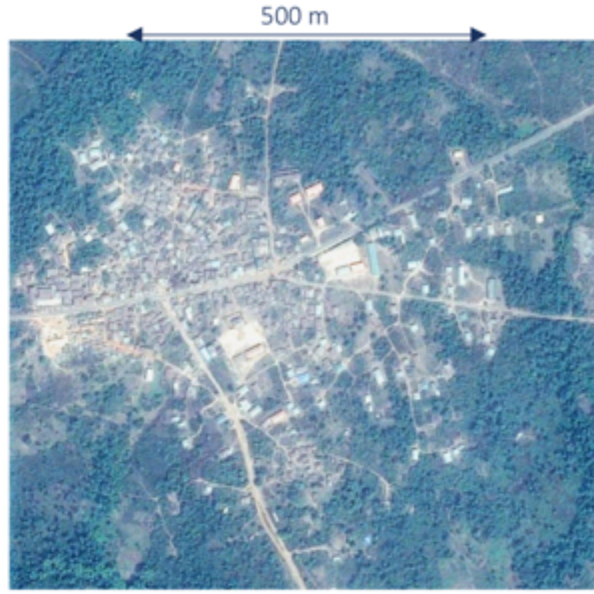
<u>Tax and duty specifications</u>
- Solar cells and modules are import duty and VAT-exempt in Nigeria
- Imported batteries are subject to 20% import duty + 5% VAT
- Imported electricity meters are subject to 10% import duty but are VAT-exempt

Market segment fact sheet: **Large Under-grid site**
Obafemi, Ogun State, Nigeria*

*Data collected during RMI/REA site visits, but developers would need to verify

Community overview

Location	Obafemi-Owode LGA, Ogun State (SW Nigeria)
Distance to town	75 km to LGA headquarters 25 km to state capital (major airport)
Nearest electrified town	Ajebo, 15 km away
Accessibility	Rough tar road 2 hr drive from Lagos
Area	Town center (right) covers 1km², but residential areas stretch for several km along main road
Main sources of livelihood	Farming: cassava, cocoa, yam, plantain; Processing of cassava, yam; Other commercial activity

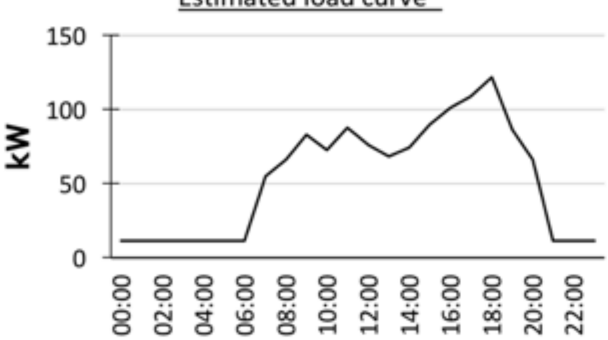


Available load information

- 300 households
  - 200 large
  - 100 small
- 8 grinders
- 4 welders
- 5 boreholes
- 3 viewing centers
- 4 tailors
- 25 petty traders
- 2 salons
- 2 barber shops
- 1 credit agency
- 1 court house
- 2 churches
- 3 public schools
- 1 police station
- 1 health center

Potential new loads: Significant commercial activity occurs in Obafemi, but it is limited by the high cost of diesel self-generation. Several artisans (e.g. welder) suggested they could grow their business with the availability of more affordable power. Many households indicate the desire to purchase new appliances in the near future.

Estimated load curve*



*load curve is based on current known energy usage, and does not include any projection for demand increase

Current energy alternatives and usage

A typical household spends the following on energy alternatives:

Kerosene: $0.47/week
+ *Torch*: $1.54/week
+ *Cell charging*: $0.50/week
+ *Generator*: 50% of the population spends $5/week on fuel

Average household energy expenditure: $5.01/week

Total current self-generation estimated at 80kW

Grid infrastructure:

Obafemi has not received power from the distribution company for over a decade due to equipment vandalism and lack of maintenance. The community was formerly served by a utility, and nearly all homes and businesses in the town are wired to receive electricity. This site may only be developed as an interconnected minigrid according to NERC regulations.

Distribution poles and wires are available throughout the community (above)

Market segment fact sheet: **Large Under-grid site**
Obafemi, Ogun State, Nigeria

Resource availability
- Community is asking $1000/year for the rental of land for minigrid distribution siting
- 90% of homes and businesses are already wired for power
- MTN tower located within community; strong network coverage
- Mobile money available only through telco-led model in Nigeria
- Diesel costs N200/L ($0.55/L or $2.10/gal) locally, and is nearly always available at local markets
- Solar irradiation ranges from 3.93-5.64 $kWh/m^2/dy$ (seasonally) and averages1300 $kWh/m^2/yr$
- During the rainy season, expect maximum of 2 days without sunshine
- Commercial debt available at 18%

Market scalability

There are a significant number of under-served communities in the vicinity of Obafemi-Owode LGA, as well as across Ogun State.

There are thousands of similar underserved communities across Nigeria.

Local processing of agricultural products currently relies on diesel gensets, since electricity is not available (left)

Policy & Regulatory overview

According to the Nigerian Electricity Regulatory Commission (NERC) Mini-Grid Regulations of 2016:
- Minigrids built in communities with existing distribution infrastructure are considered *interconnected*
  - Interconnected minigrids are permitted only in areas where customers are currently underserved by the local distribution company
  - Interconnected minigrids can be built to buy power from and feed into the grid, or in areas where power is currently not distributed, as isolated units sharing some of the grid infrastructure.
- Contractual agreement from the distribution company, community, and minigrid developer must be obtained before an interconnected minigrid may be constructed
- Developers of interconnected minigrids must receive a permit from NERC to construct, operate, and maintain the system. This permit requires:
  - Standardized connection agreement with every customer, including the tariff schedule
  - Meeting requirements of the Nigerian Metering Code
- Permit-holding minigrid operators are protected by the Mini-Grid Regulations against grid expansion

Distribution companies have the right to refuse minigrid developers from working within their territory, but they are also under considerable financial stress and obligated to serve the customers they have.

<u>Tax and duty specifications</u>
- Solar cells and modules are import duty and VAT-exempt in Nigeria
- Imported batteries are subject to 20% import duty + 5% VAT
- Imported electricity meters are subject to 10% import duty but are VAT-exempt