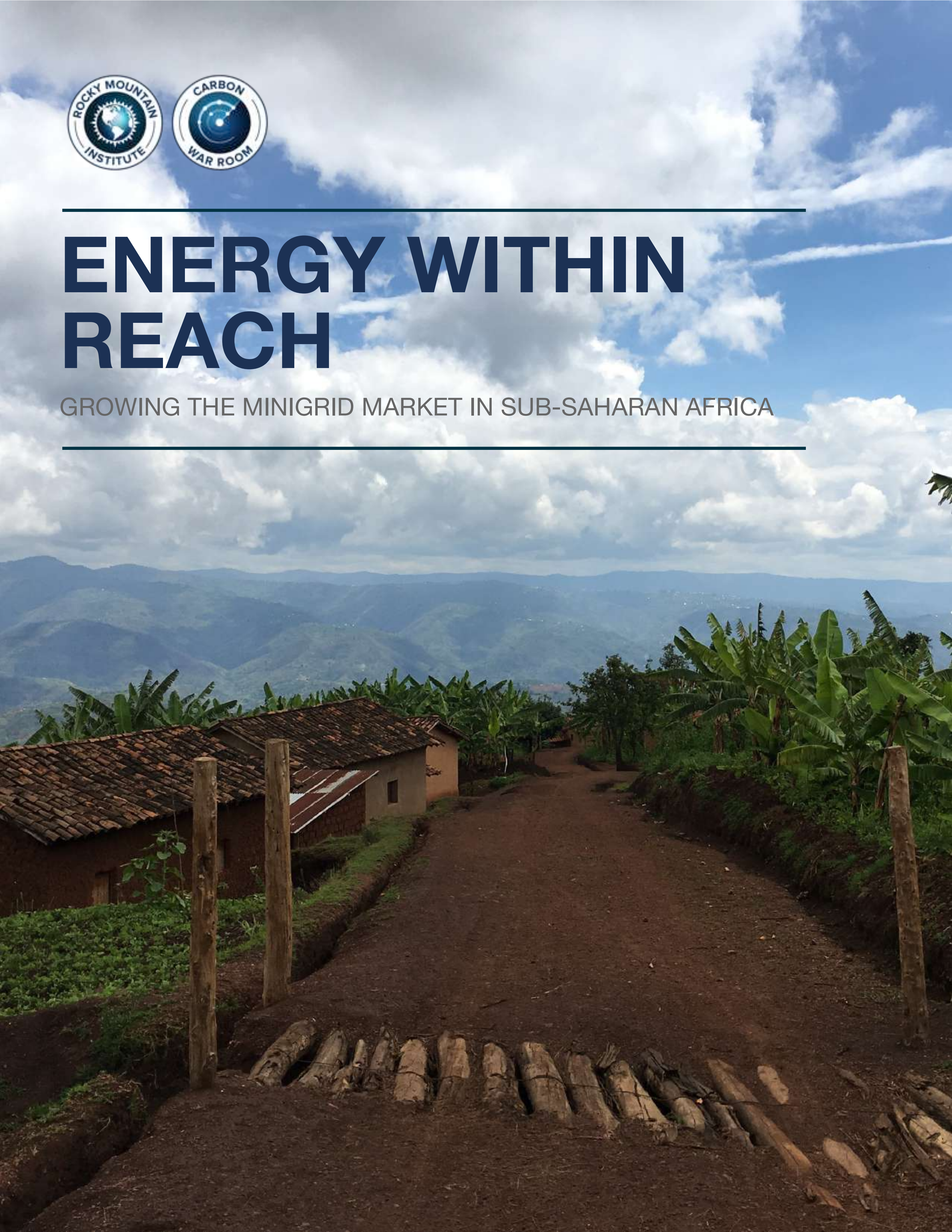
ROCKY MOUNTAIN INSTITUTE

CARBON WAR ROOM

ENERGY WITHIN REACH

GROWING THE MINIGRID MARKET IN SUB-SAHARAN AFRICA



AUTHORS & ACKNOWLEDGMENTS

AUTHORS
Josh Agenbroad, Kelly Carlin, Stephen Doig,
Claire Henly, Eric Wanless*

*Authors listed alphabetically. All authors are from Rocky Mountain Institute unless otherwise noted.

ADDITIONAL CONTRIBUTORS
Kaitlyn Bunker
Mark Dyson
Kendall Ernst
Selena Wang-Thomas

CONTACTS
Josh Agenbroad, jagenbroad@rmi.org
Kelly Carlin, kcarlin@rmi.org

SUGGESTED CITATION
Kelly Carlin, Josh Agenbroad, et al.
Energy Within Reach: Growing the minigrid market in sub-Saharan Africa.
(Rocky Mountain Institute, 2017).
www.rmi.org/energy_within_reach

ACKNOWLEDGMENTS
The views expressed in this report are solely those of Rocky Mountain Institute. The authors thank the following individuals/organizations for offering their insights and perspectives on this work.

Harrison Leaf, SteamaCo
Emily Moder, SteamaCo
Emily McAteer, FACTOR[e] Ventures
Richard Gomes, Shell Foundation
Emma Miller, Shell Foundation
Nicole Pointdexter, Energicity
Manoj Sinha, Husk Power Systems
Suman Sureshbabu, The Rockefeller Foundation
Clare Boland Ross, The Rockefeller Foundation

ABOUT ROCKY MOUNTAIN INSTITUTE
Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. In 2014, CWR merged with RMI and now operates as an RMI business unit. RMI has offices in Basalt and Boulder, Colorado; New York City; Washington, D.C.; and Beijing.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

One billion of the world's poorest people in emerging markets lack electricity access. The urgent need to provide them with energy access has generated excitement for potential solutions, from solar home systems to grid extension. One solution of increasing interest that could fill an important gap between these two ends of the spectrum is minigrids—small isolated distribution networks increasingly powered by clean energy. Development partners, investors, and development banks have been focused on the promise of minigrids for several years and have invested or earmarked millions to expand them, yet minigrid market growth remains slow and commercial viability elusive.

Rapid scaling and adoption of minigrids depends on their commercial viability. This paper provides an understanding of the economics behind minigrids and a comparison to competing alternatives like solar home systems and grid extension. Building on this foundation, we provide an estimate of the addressable off-grid market in four leading sub-Saharan African countries, of which minigrids will compete for a share, and then provide specific recommendations to accelerate minigrid adoption and innovation.

Site selection is critical. Distance to the grid and load size are the two most important factors. Grid extension costs increase rapidly with distance from existing transmission lines, improving the competitiveness of off-grid options like minigrids or solar home systems. Higher load sizes can justify grid extension costs to a point, but at distances over five kilometers grid extension is rarely the least-cost energy access option. Similarly, between the off-grid electrification options of solar home systems and minigrids, higher loads favor minigrids. When load size is sufficient, the distribution network and fixed costs of minigrids can be offset by better economies of scale and capacity utilization, and small solar home systems cannot economically supply the level or type of power required for larger appliances or productive loads (e.g., AC or three-phase power).

Beyond minigrid site selection, grid reliability and government policy are the two external factors that most affect minigrid commercial viability. In some cases the reliability of the existing or nearby grid connection is so low that customers may be willing to pay a premium for a minigrid with improved reliability. Supportive minigrid policy, which includes a solar VAT exemption, expedient import procedures, and most importantly an off-grid plan that acknowledges the role minigrids can play in electrification, is an essential early foundation for minigrid commercial viability.

Capturing the substantial cost reduction opportunities available to minigrid systems will greatly improve competitiveness and expand the market potential. There is a 50 percent gap between average and best-in-class system costs in sub-Saharan Africa, which could be closed through an increased emphasis on competitive procurement of hardware and managing soft costs through site selection and customer acquisition, even for grant-financed minigrid pilot projects. In addition, economies of scale and technology improvement over time can further reduce cost. Overall, the cost for an average system today can be reduced 50–75 percent by 2025. Aggregation across the value chain could streamline development, hardware, metering, operation, and finance. Additionally, standardized, modular hardware with only distribution and metering handled on site could reduce hard costs while providing better flexibility to match generation supply to demand. Soft costs make up nearly half of typical project costs, which could be reduced with improved, aggregated software and smart metering, along with streamlined, standardized installation processes.

Minigrid companies can also provide better service at a lower cost by focusing on end-use service rather than power consumption, a growing practice in major U.S. and European utilities. Metrics should focus on cost for a typical service package (e.g., cost/customer with three lights and cell phone charger or business with refrigerator). These metrics show the substantial difference that equipment choice and energy efficiency can provide, while also focusing attention on the customer's perspective, particularly his or her ability and willingness to pay.

The current total addressable off-grid market in four leading African countries alone is estimated to be $740 million in annual revenue.[i] This includes only those people without energy access who currently have an ability to pay for off-grid systems. If system cost can be reduced by 50 percent, as described in this report, this market would expand to $1.5 billion annually. Minigrids can compete for their share of this market against solar home systems by focusing first on higher load size sites. As system cost and electricity demand evolve over time so will the market segment where minigrids can provide the best cost and service.

Based on the economic analysis and market sizing described above, this paper recommends the following:

- **Coordinated trials** to test the commercial viability and scalability of minigrids are needed. For development partners and government, the bidding process for grant-funded minigrid projects or government concessions should be improved to focus on driving toward commercial viability. Trials should ensure reliable data is collected regarding cost, pricing structure, system specifications, and management of collection and theft. A two-phase bidding process can be used to gather information and test qualifications before final proposals on a series of projects are submitted. This structure allows governments and donors to fine-tune project specifications, push bidders to articulate a road map toward commercial viability, set cost-reduction targets, and identify key enablers from government and/or NGOs to accelerate market development.
- **The private sector** should focus on continued cost-reduction and service improvements. Opportunities include better site selection, integrated hardware and software packages, modular capacity, specialized local project development and management expertise, aggregated finance, and a focus on end-use service instead of power consumption. The private sector should start with the most attractive market segments (larger loads, far from existing grid, with ability to pay) while positioning itself relative to competing energy access options. Today's off-grid market is large with plenty of room for rapid growth. Solar home systems and lanterns could complement minigrid initiatives by introducing customers to solar and testing creditworthiness while addressing lower load segments that are not currently commercially viable for minigrids.
- **Development partners** should play a coordinating and financing role for the early stage minigrid market. By facilitating discussion between governments and the private sector, and providing carefully placed technical assistance and advocacy for a clear set of minigrid enabling policies, they can support governments with ambitious electrification targets that prioritize off-grid growth. Blended finance, coordinated by development partners, can begin to leverage outside investment while supporting efforts to better understand the due diligence and de-risking that will be required for full handoff to commercial financiers.
- **Governments** need to provide predictable enabling environments for minigrids if they are to achieve their ambitious energy access targets. Governments can reduce regulatory risk for companies and their investors with clear, comprehensive off-grid energy plans; streamlined import procedures; dependable incentives for renewables and energy efficient appliances; and education/awareness campaigns that communicate to their citizens the role of off-grid products, and minigrids in particular.

[i] All currency is in U.S. dollars unless otherwise noted.

1. THE MINIGRID OPPORTUNITY

Minigrids can be the least-cost option for electricity access for millions of people who lack access to reliable electricity, however market penetration remains low.

1.1 The promise of minigrids

Of the 1 billion people living in sub-Saharan Africa in 2015, approximately two-thirds do not have access to power.[1] An additional 400 million people in South Asia, primarily India, also lack access to reliable electricity.[2] For a significant portion of those over 1 billion people, minigrids may be the least-cost option for electricity access compared with the two main alternatives: grid extension and solar home systems.

Over the past decade, the investor and development community interest in minigrids has risen from a whisper to a roar. A 2011 International Energy Agency (IEA) report argued that 36 percent (over 400 TWh) of the additional global electricity needed to connect the 1 billion unelectrified will be met via minigrids.[3] In 2014, Sustainable Energy for All, the UN's Ban Ki-moon's leading energy access initiative, took up the call by dedicating a High-Impact Opportunity group, "Clean Energy Minigrids," to prescribe a path to reach the IEA target. The World Bank joined suit by setting up a Global Facility on Mini-Grids in April 2016. Several impact venture capital firms—including the Acumen Fund and Energy Access Ventures—have focused substantial equity investment in the space.

Established energy players like E.ON, First Solar, and others have made strategic investments in minigrids in the developing world. In the past five years, dozens of minigrid startups have appeared in Africa and India to take advantage of decreasing PV and storage costs. Manufacturers producing smart meters, software, and payment technology have made similarly dramatic progress in the past five years. In the world of concessional finance, minigrids are now seen as a key part of the energy access solution. For instance, the African Development Bank's $60 million Sustainable Energy Fund for Africa (SEFA) is primarily focused on the promotion of minigrids; the Scaling-Up Renewable Energy Program (SREP) has dedicated tens of millions of dollars to minigrids in Africa; The Rockefeller Foundation has dedicated $75 million to its Smart Power for Rural Development program in India; and the UK's Department for International Development (DFID) has allocated £75 million to its Green Mini-Grids Africa program.

1.2 Key barriers to minigrid growth

While the promise of minigrids is high, current market penetration, even in the most promising markets, is below 1 percent.[ii, 4, 5] Venture capital investments excluding impact investments are still rare because investors see the minigrid market as too risky.[6] Market rate debt is prohibitively expensive and access to project financing is limited, such that companies must own and operate projects they develop—rather than monetizing them and using the proceeds to grow their development pipelines. Even in the most successful systems, electricity prices are high, typically above $1.00/kWh, which hampers economic development, the ultimate goal of electrification.

What barriers underlie this perceived and real risk? The value proposition of minigrids relative to competing energy access alternatives such as solar home systems and grid extension has been unclear. Average costs for minigrids are high and even best-in-class minigrid costs struggle to compete with alternatives in some locations. Regulatory risk in the form of unpredictable policies and utility plans is high in most markets, discouraging companies and investors. As of yet, there is no clear road map forward for proving commercial viability and driving rapid growth.

[ii] Market penetration is defined as the percentage of the population in a given country that is using minigrids.

1.3 Making minigrids a viable part of economic development

The purpose of this report is to explore the reasons for the slow growth of the minigrid market, what can be done to speed it up, and the roles of different participants to accelerate market growth. This report includes a competitive analysis of minigrids as an option for providing power for basic services and economic development in Africa while drawing on lessons from India where systems are more mature. To be successful, minigrids must compete with solar home systems and grid extension on cost and reliability. This report uses factors such as distance from the grid, load size/density, future cost-reduction potential, and regulatory issues affecting the business case to target the best markets for minigrids in Africa. Using current energy access rates and ability-to-pay data, we estimate the total addressable market for off-grid energy access in four leading African markets, of which minigrids will compete for a share. Finally, we provide an actionable road map with a set of recommendations for private sector, government, and nonprofit actors to reduce costs and accelerate market growth.

DEFINING MINIGRIDS IN THE EMERGING MARKETS CONTEXT

Minigrids—sometimes referred to as microgrids, nanogrids, and picogrids—are defined in this report as isolated generation assets with any component of distribution. Although minigrids are in use around the world, this report is focused on minigrids in Africa.

It is important to note that minigrids in emerging markets are distinct from those in other markets. In North America, the European Union, and Asia, minigrids are primarily used in extremely remote communities or islands, or to provide resiliency during emergencies. Systems can be as large as 250 MW. In the emerging markets of sub-Saharan Africa and India, minigrids are much smaller, typically ranging from 500 W to 2 MW. In this context, minigrids provide primary energy access rather than resilience, and are predominantly solar-diesel and solar-diesel-battery generation systems with distribution networks isolated from the main grid. Unless otherwise noted, the figures and analysis provided in this report refer to solar-diesel generation minigrids.

2. THE ECONOMICS OF MINIGRIDS

Current minigrid costs need to be understood in a context of competing alternatives and the key drivers that determine competitiveness.

2.1 Minigrid cost comparison and key drivers

The competitiveness of a minigrid depends on its cost relative to the cost of alternatives, namely grid extension and solar home systems. Table 1 summarizes the relative advantages and disadvantages of competing solutions.

TABLE 1. THE COMPETITIVENESS OF ELECTRIFICATION OPTIONS

	Advantage	Disadvantage
Grid Connection	• Low generation cost due to large economies of scale	• Grid extension very expensive as distance increases • Often low reliability
Minigrid	• Compared with solar home systems, generation cost reduced due to economies of scale and improved utilization (for non-coincident loads) • High reliability	• Compared with solar home systems, higher capex
Solar Home System	• No interconnection lines • High reliability	• Only least-cost for lower loads • Cannot currently support productive loads

An advantage to the grid is its lower generation costs (~$0.05-$0.35/kWh in Africa), but one must pay for expensive transmission lines when villages are widely spaced and use little power.[7] Solar home systems have high generation costs (typically several dollars per kWh) but avoid the cost of distribution lines, metering, and theft. Between these two energy access options are minigrids, the competitiveness of which depends on a wide array of interrelated parameters. In contrast to the costs associated with grid extension and solar home systems, minigrid costs have an additional degree of complexity.

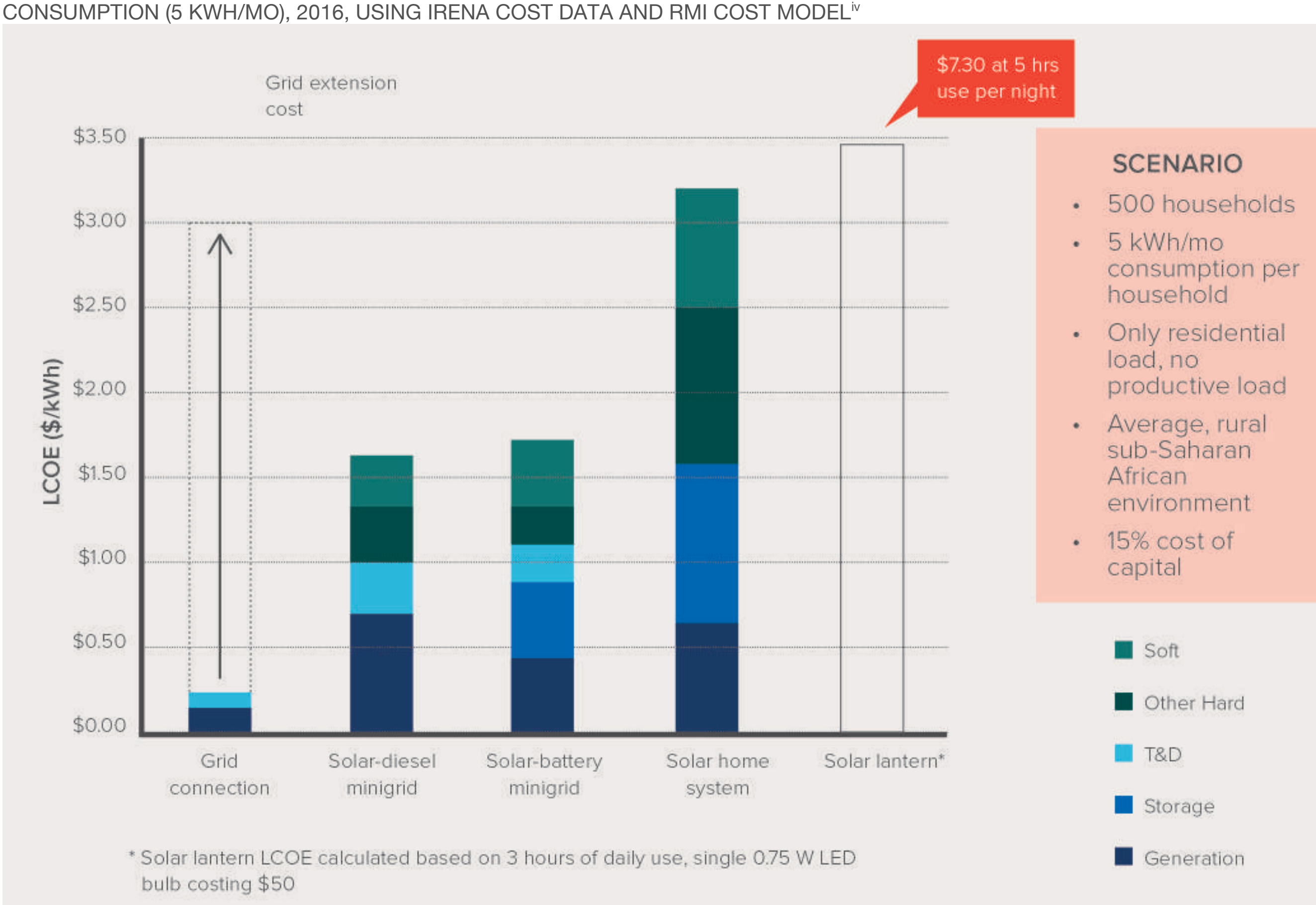
2.2 The cost structure of minigrids

Among a set of recent minigrids examined by the International Renewable Energy Agency (IRENA), installed costs ranged from $1.40/W to over $12.00/W.[8] This wide range may be attributed to four factors: (1) poor or inconsistent reporting of costs; (2) tests and pilots that were focused on factors other than costs (e.g., access, adoption rates); (3) subscale and customized solutions; and (4) widely varying conditions including regulatory risk, labor rates, or maintenance regimes.

Figure 1 compares the levelized cost of electricity (LCOE)[iii] for grid, stand-alone solar home systems, and minigrids in a typical rural scenario, with the important caveat that typical scenarios vary widely across sites and countries in sub-Saharan Africa. The range of costs for these key components and other costs is described in Table 2.

[iii] The levelized cost of electricity is the sum of all costs divided by the sum of electricity produced over the lifetime of an electrification option.

FIGURE 1. BEST-IN-CLASS COST STRUCTURE OF COMPONENTS OF COMPETING ALTERNATIVES AT A FIXED LEVEL OF CONSUMPTION (5 KWH/MO), 2016, USING IRENA COST DATA AND RMI COST MODEL[iv]



SOURCE: IRENA AND OTHER COST DATA WITH RMI COST MODELING

Generation is typically a large portion of the total, comprising 26 to 44 percent of average.[9] Solar-diesel systems may also include a small battery to better manage and offset some diesel generation, particularly when running at lower loads when diesel generator efficiency is low. For solar-diesel hybrids, generation costs may be as low as $0.30/kWh.[v]

Despite the enthusiasm donors and impact investors may have for supporting minigrids without a diesel component, sizing purely solar-battery minigrids for peak load while planning for high reliability is currently significantly more expensive than sizing minigrids that use a diesel generation component. In many sub-Saharan countries, rainy seasons present a generation sizing challenge that can either be addressed at high cost with excess storage capacity or at lower cost with idle diesel capacity. With the aim of providing reliable energy access and keeping economic development in mind, we have only considered highly reliable systems.

Storage and fuel costs also vary in response to high reliability requirement loads (e.g., telecom towers) such that minigrid operators may need to run diesel while having the batteries act as the uninterruptable power source. In less stringent settings batteries can act as the nighttime supply and curtailments can occur to keep storage costs down. Today's systems most often rely on lead-acid batteries, but the declining cost of lithium-ion

---

[iv] Based on RMI interviews and IRENA average component costs from *Solar PV in Africa: Costs and Markets* (Sept. 2016); Assuming for solar home system a 15 W solar PV panel, 17 aH SLA battery, four 1 W LED bulbs, cell phone charging, and 50% nightly discharge.

[v] The cost of the distribution network, the load profile, the cost of capital, and the cost of fuel all complicate the above figures. In some scenarios where the cost of capital is significantly below market rate and the load profile leads to high asset utilization, solar-diesel-battery generation minigrids are the least-cost option.

batteries is making lithium-ion a more common form of storage and will soon improve the competitiveness of solar-diesel-battery and solar-battery minigrids against solar-diesel systems.

TABLE 2. RANGE OF COSTS FOR KEY MINIGRID COMPONENTS

Component	Input assumption	Comment	Source
Generation – solar	$1.30–$3.00/W	Best-in-class costs are quite low, but logistics and the challenges/risks of installation can drive prices up. Further reductions expected.	IRENA,[10] BNEF[11]
Generation – diesel generator	$1.00/W	The cost of diesel generation is fairly constant.	NREL[12]
Storage – battery	$0.15–$0.35/Wh	Battery costs depend on battery type, but overall are coming down.	BNEF[13]
Distribution network[vi]	$2.00–$5.00/m	Distribution network costs depend on local labor and material costs, as well as design, and are relatively fixed.	NRECA[14]
Medium-voltage network[vii]	$25.00/m	Medium-voltage network distribution costs are relatively uniform and fixed, but contractors can demand a premium. Distance to the grid increases costs.	NRECA[15]
Diesel fuel	$1.00–$1.30/liter	Volatile commodity that can drive swings in recurring cost.	GlobalPP[16]
Soft costs	$0.40–$5.50/W	Soft costs, which include site selection and acquisition, surveying, permitting, and initial customer acquisition, can be as much as 50% of total costs.	RMI[17]
Recurring costs	$0.02–$0.15/kWh plus per annum site costs	Includes fixed and variable costs associated with operations and maintenance, revenue collection, and metering, as well as customer relationship management. Fuel not included.	RMI

Not including finance costs, soft costs include:

- Site selection and surveying
- System design
- Permitting process and costs, including import duties and registration fees
- Customer acquisition costs

[vi] Distribution is at low voltage, less than 240 V.

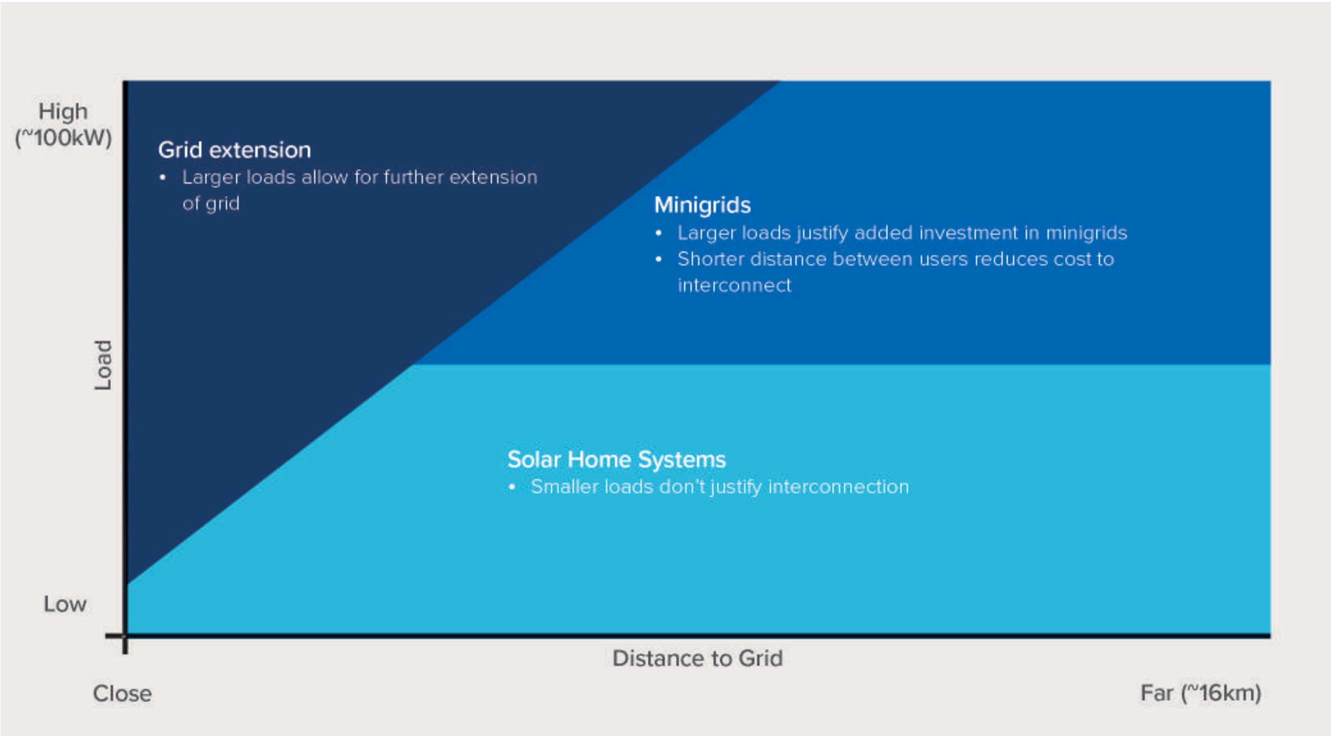
[vii] Medium voltage lines are defined as approximately 10 kV to 30 kV.

Soft costs range between 10 percent and 50 percent of total installed costs. Efficient site selection, customer acquisition and assessment of potential customers, design, monitoring, and customer service all drive these costs down. Proven tools that combine these functions, whether through software or a step-by-step process, can help provide this efficiency. However, if these soft costs are managed, monitored, and addressed separately and inefficiently, costs may be near the high end.

2.3 Site selection

The characteristics of the site where the minigrid will be located determine minigrid cost and the cost of competing alternatives. The two most important characteristics contributing to minigrid competitiveness are distance to the existing grid and load size of a prospective minigrid coverage area. The interplay of these factors supports a general relationship between grid extension, minigrids, and solar home systems, shown in Figure 2.

FIGURE 2. THE LEAST-COST OPTION FOR ENERGY ACCESS DEPENDING ON LOAD SIZE AND DISTANCE FROM THE EXISTING GRID[viii]

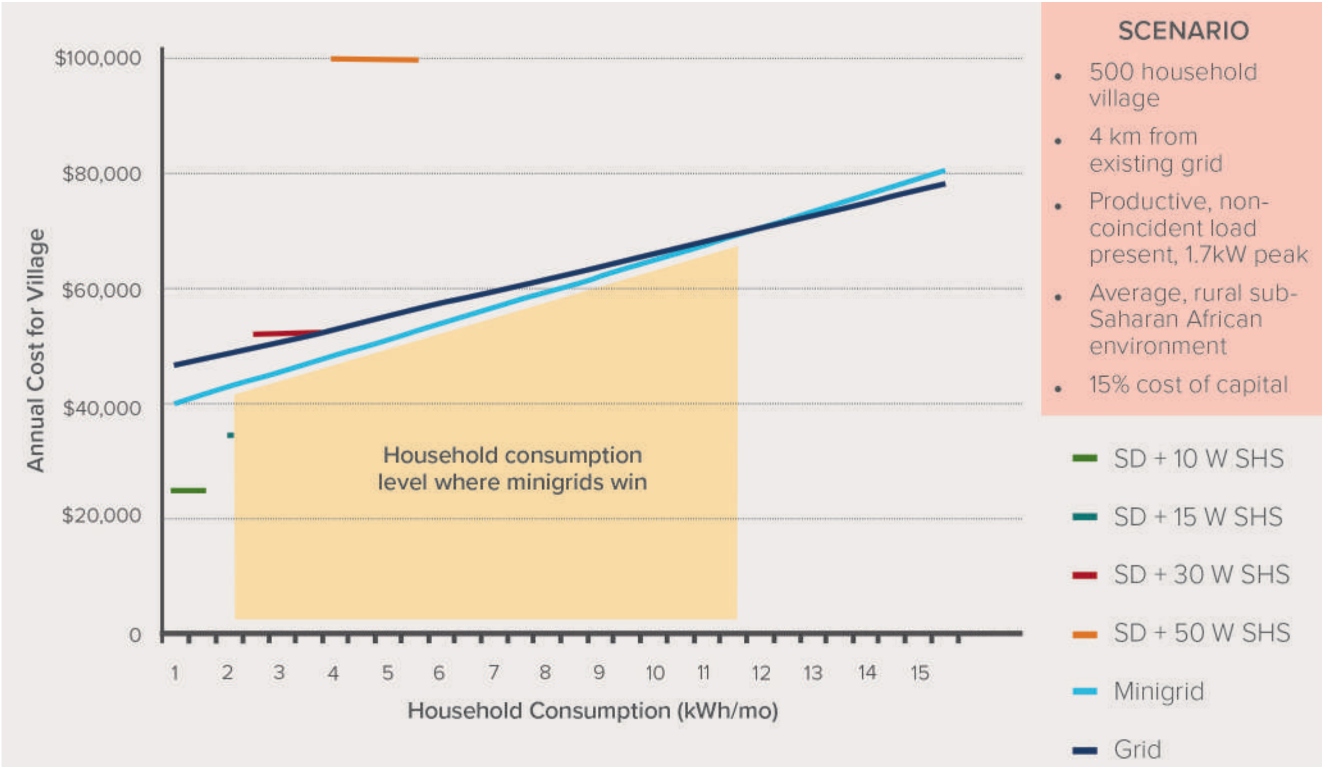


Load size

If the cumulative load is too small, the fixed costs of wires, metering, and fixed soft costs push minigrids above the cost of stand-alone solar home systems. If the load size is sufficient, then the minigrid is able to take advantage of economies of scale not available to solar home systems. Once the load gets large enough it will pay to pull in a medium voltage line. Figure 3 illustrates the effect of load size in a typical sub-Saharan African village. At a very low load level, stand-alone solar home systems are the least-cost option. At a very high load level, the lower cost of grid generation makes it the least-cost option. In the case of this village, minigrids are the least-cost option for household consumption between 2 kWh/month and 12 kWh/month.

[viii] The chart illustrates the general relationship between energy access alternatives, though specific break points are determined by local conditions.

FIGURE 3. LOAD SIZE DETERMINES MINIGRID COMPETITIVENESS

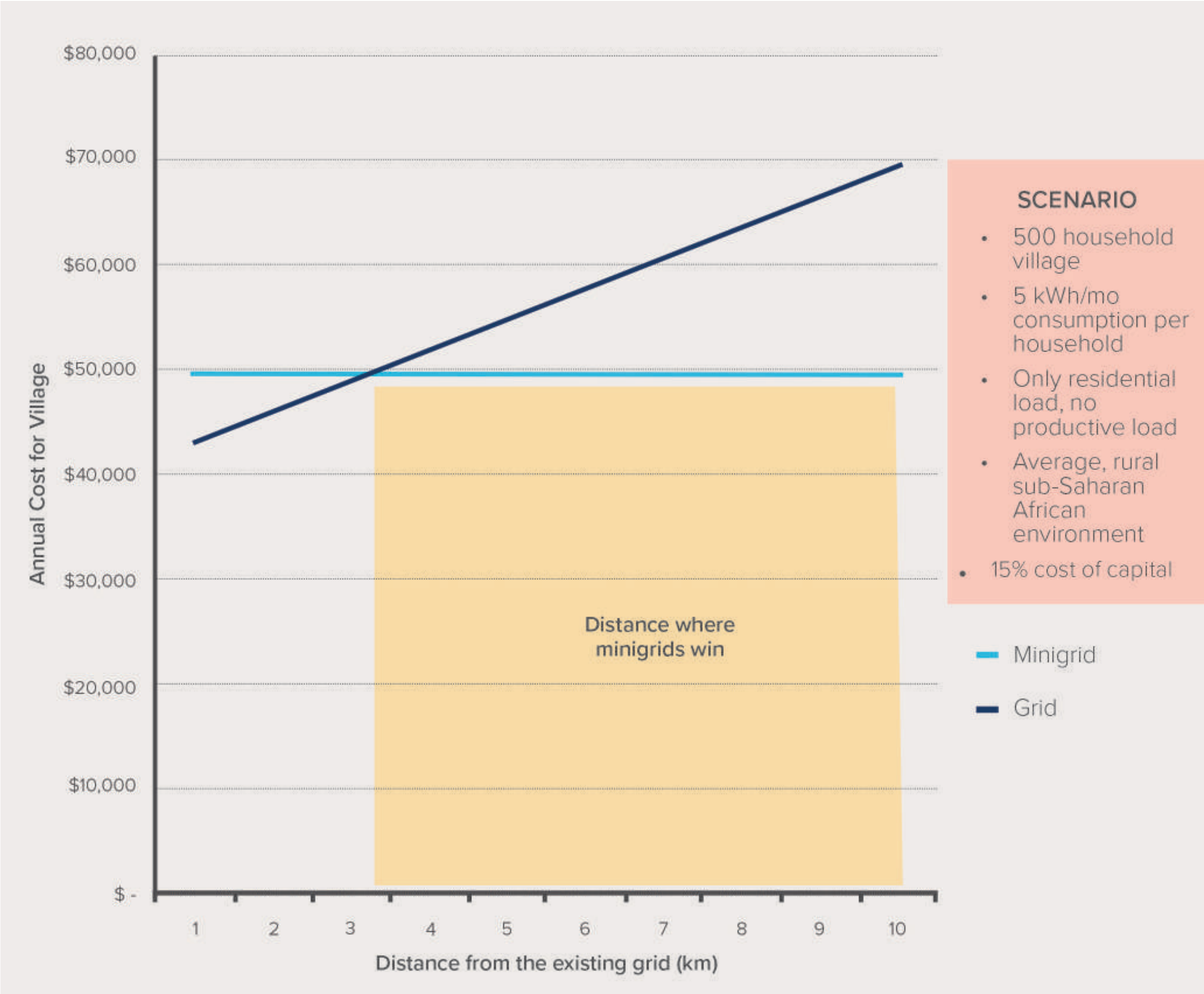


* SD=STAND-ALONE SOLAR-DIESEL HYBRID GENERATION FOR LOADS TOO LARGE FOR SHS; SHS=STAND-ALONE SOLAR HOME SYSTEMS OF INCREASING SOLAR PV MODULE SIZES (30 W, 50 W, 100 W)

Distance from the grid

Grid connection cost increases with distance from the existing grid infrastructure. Figure 4 compares the annualized cost of energy access for a typical village for the grid and with a minigrid. Because minigrid prices are not impacted by distance from the grid, their costs remain constant regardless of distance. The cost of grid extension, in contrast, climbs as the distance increases, and in this example becomes more expensive at a distance of approximately 4 km.

FIGURE 4. DISTANCE FROM THE GRID DETERMINES MINIGRID COMPETITIVENESS



Additional site-selection factors

Load density: Load density is the distribution of the minigrid load across a village (kW/km^2). Dense village structures require less low-voltage line materials and labor to install, thus reducing distribution costs so they favor minigrid economics over solar home systems. The cost savings from high densities diminish at above approximately 400 people per square kilometer. As a result of cultural differences and land-planning policy, dense village clusters tend to be more common in South Asia and West Africa. More dispersed village structures are more common in East Africa and make minigrid viability tougher with all other factors being equal.

Grid generation cost: From large hydropower at the low end to on-grid diesel and heavy fuel oil at the high end, generation costs in sub-Saharan Africa range from $0.05/kWh to more than $0.35/kWh.[ix, 18] Higher grid generation costs improve the competitiveness of off-grid options like minigrids. The low generation costs that often come with hydropower reduce off-grid competitiveness.

[ix] These costs are independent of African electricity tariffs, which are often not cost-reflective and are heavily subsidized.

Grid extension cost: Based on the cost of construction and materials, grid extension costs can vary based on terrain and by country, as widely as $7,000/km to $25,000/km.[19, 20] The connection fee charged to customers is also, in some cases, much higher than the actual cost. In most countries, a flat connection fee is assessed, whether or not the fee reflects true connection cost. High grid extension costs improve off-grid economics.

Finance costs

The vast majority of minigrids currently in operation in Africa and India do not, and likely cannot, access debt financing, relying instead completely on equity or grant financing. This reduces or eliminates finance costs, but ultimately limits company and market growth.

According to the Energy Access Practitioner Network, “[F]inancing remains the top consideration and limiting factor in the mini-micro-grids sector” in Africa and South Asia.[21] Challenges for debt financing are understandable; market-rate debt available for off-grid energy development typically starts between 16 and 20 percent in sub-Saharan Africa and between 11 and 14 percent in India.[22] The impact of high-cost debt on overall costs is significant, but even more problematically the lack of access to debt stunts market growth by tying up developer capital in minigrid assets while waiting for a gradual return on investment.

Steep debt finance costs for minigrids reduce their competitiveness against grid extension and solar home systems as energy access options. Bringing the debt finance costs of minigrids in line with concessional finance rates would open up the possibility of project finance and improve competitiveness.

2.4 Economically productive loads

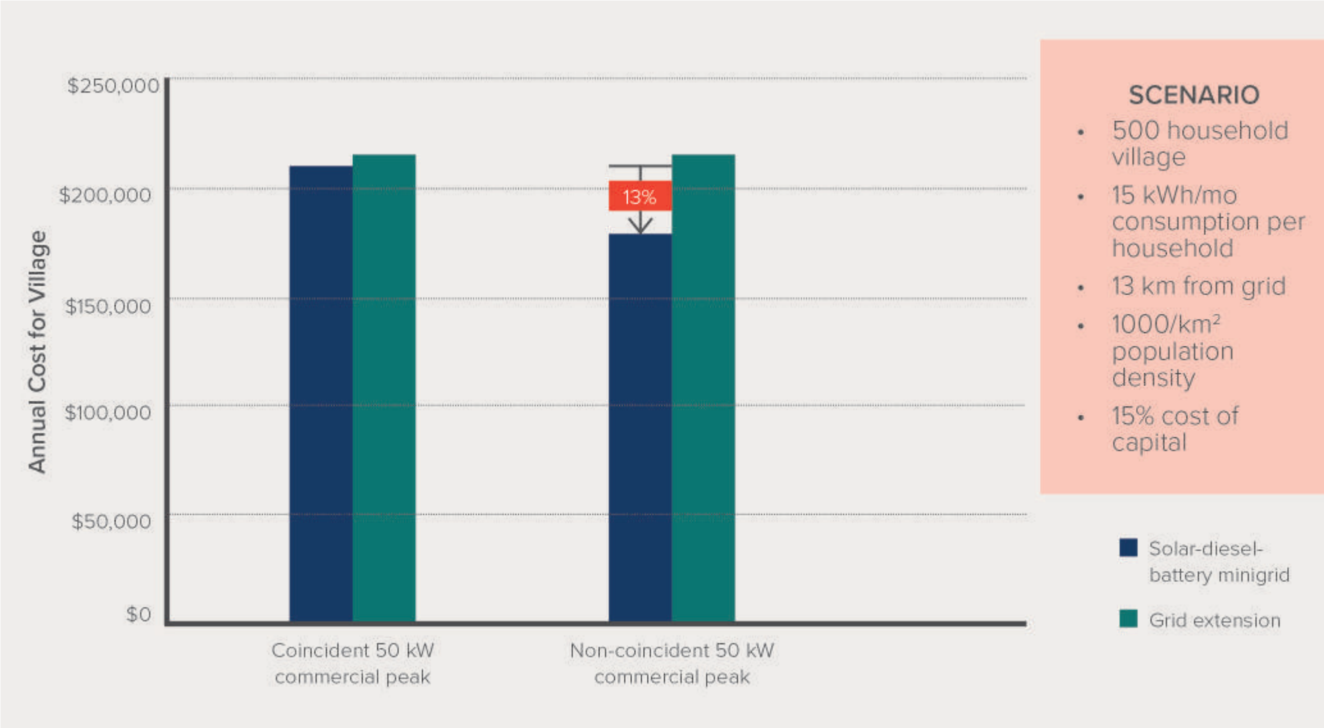
Higher power is a necessary ingredient for significant economic growth. The largest widely available solar home systems in Africa today have 200 W solar panels and batteries. While the power they provide is enough for very small commercial businesses like barbers, restaurants, bars, and small shops, 200 W and the storage to run five lights, a radio, and a small television through the night is not nearly enough to power a grain mill, coffee-washing station, irrigation pump, or value-add agricultural facility. Currently, for genuine commercial and industrial loads, either large-scale stand-alone generators—diesel, solar-diesel, solar-battery, or hydropower—or minigrids are necessary.

Productive loads improve minigrid economics

Minigrids include distribution costs, putting them at a disadvantage against large-scale stand-alone generation unless distribution can also improve generation asset utilization. Crucially for minigrids, a daytime productive load can complement an evening residential load peak and in doing so, improve asset utilization. Across rural sub-Saharan Africa, loads tend to peak in the evening due to residential customers. Lighting represents most of this peak load.[23] A daytime productive load that improves generation asset utilization could be a lumber mill, a tea plantation, or a coffee-washing station. The base load of a telecom tower—which requires steady, constant power 24 hours a day—also improves asset utilization, but to a lesser degree than a commercial or industrial customer who is active during the day but quiet during peak residential hours.

The positive effect of productive loads on minigrid economics increases as system size increases and offsets other fixed non-generation costs. For small productive loads—less than 20 kW—the effect is minimal. As shown in Figure 5, the cost savings for a productive load of 50 kW in a typical scenario is 13 percent.

FIGURE 5. NON-COINCIDENT COMMERCIAL AND INDUSTRIAL LOADS IMPROVE ASSET UTILIZATION AND MINIGRID ECONOMICS



3. REDUCING MINIGRID COSTS

Continuing to reduce minigrid costs depends on applying demand-side management, putting pressure on key cost drivers, and controlling finance costs.

3.1 Managing demand with energy efficiency and energy services

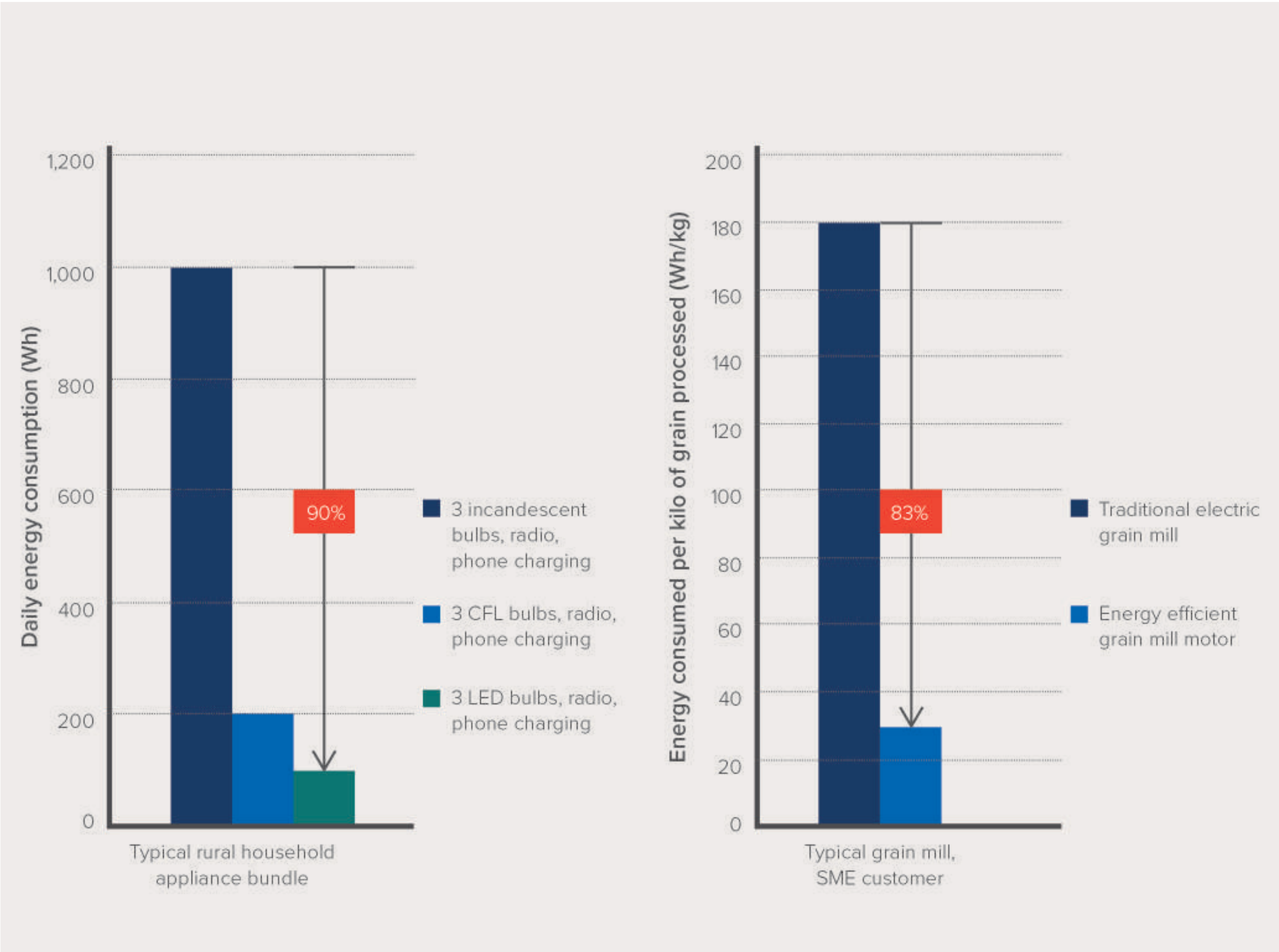
A comparison between minigrids, grid extension, and solar home systems based only on LCOE ignores efficiency opportunities on the demand side and the benefits of optimizing the system to provide services. Simply put, power producers typically want to sell more energy (kWh) and capacity (kW) because that is traditionally what they have been paid for. Similarly, sellers of appliances and commercial/industrial equipment have had little incentive to provide the most efficient devices because it is the customer who pays for the electricity. In sub-Saharan Africa, these misaligned incentives have led to overinvestment in power systems to meet rarely needed peaking needs and to ignore the efficiency opportunities that cost much less (typically $0.01–$0.08/kWh) than additional generation. Customers ultimately care about the service provided by power—high-quality lighting, phone charging, radios, and televisions—not necessarily the power itself. If the same service can be provided at less cost with more efficient appliances, that value should be communicated to the customer. It is possible to preserve customer choice by offering a range of energy efficient products or offering financial incentives for the selection of energy efficient products.

By being involved in demand-side resources, minigrid developers and operators can position themselves as *energy service providers* and in doing so, improve their cost competitiveness by significantly increasing the utilization of their assets' fixed costs and by creating a different value proposition than other energy options. Major grid utilities in the U.S. and the European Union, such as E.ON, that face similar pressures are trying to move in this direction.[24]

Like solar lantern and solar home system companies, some minigrid companies currently provide customers with energy efficient lightbulbs, and in some cases, radios and televisions. Selling higher-power energy efficient residential, commercial, and industrial appliances and machines would further improve the value of minigrids at the same cost. Providing energy efficient appliances as part of a service package to customers not only reduces their energy use, but also decreases the cost of the fixed plant (generation, wires), which means for every kWh consumed the total cost is lower (see Figure 6).

Smart meters—meters that allow bidirectional communication between minigrid operators and customers—which are increasingly affordable and used by minigrid developers, can also provide the option of time-based rates and are another tool for demand-side management. For example, customers could be encouraged through lower prices to use excess solar power during the day.

FIGURE 6. THE USE OF ENERGY EFFICIENT APPLIANCES DECREASES POWER CONSUMPTION SUBSTANTIALLY[25]



If minigrid operators see themselves as energy service providers involved not only in supplying electricity but also in managing demand, their cost for service provided decreases with energy efficiency gains.

It is true that the same opportunity to manage demand for residential as well as commercial and industrial customers is available to the grid and solar home systems, but for utilities in Africa it is a difficult opportunity to realize. Solar home system companies are wisely acting on the opportunity to manage demand, but because of their small size, there are few commercial and industrial applications for solar home systems. Minigrids can act on the opportunity to manage both residential as well as commercial and industrial demand.

3.2 Reduce hard and soft costs

It's currently possible to reduce average minigrid costs by more than 50 percent to achieve best-in-class costs.[26] Beyond that cost savings, the global cost trajectory of key minigrid components will continue to decline, and significant opportunities exist to further reduce hard, soft, and finance costs. Over the next nine years, there's an opportunity to reduce best-in-class costs an additional 50 percent.

Hard cost global trajectories

The dropping costs of solar and storage will likely make solar-diesel systems, or even solar-battery systems, very competitive options. Both installed PV module costs in Africa and Li-ion battery storage costs are predicted to halve between 2016 and 2025.[27, 28] Other hardware costs can also be reduced through improved technology and the strategies described below. This would reduce the per kWh price of a best-in-class minigrid by an additional 25 percent of today's cost, as shown in Figure 7.[x]

Opportunities to further reduce hard costs

Hard-cost-reduction opportunities include:

- Bundled purchases, better bargaining power, improved supply chain practices
- Relying on companies that specialize in software, generation and storage components, and metering, rather than individual minigrid-developer custom-designed systems
- Smoothing of demand through residential, commercial, and industrial energy efficiency and demand response to reduce required hardware capacity and more efficient demand so less hardware is needed for the same service
- Increased modularity of systems to improve system sizing and reduce overspending on capital. This could include containerized minigrids, which are manufactured on a large scale with standardized hardware. Since accuracy of demand projections is poor—undersupply is a major risk to reliability and customer retention, while overcapacity leads to unnecessary operating expenditure—modularity of generation and storage can give flexibility to scale up quickly as needed

Opportunities to reduce soft costs

Soft-cost-reduction opportunities include:

- Streamlining surveying, permitting, sizing, monitoring, and financing. Delays in permitting, incorrect sizing, and costly finance can increase the cost of project development, capital expenditures, and operating expenditures. Correctly sizing generation assets before a minigrid is developed, based on software modeling and historical data, can reduce operational expenditures for years to come.
- Automation through software. Many minigrid companies currently handle design and development in-house, and use several software products to handle system sizing, mapping, monitoring, and metering.[29] Many of these functions can be automated and improved using software.
- Use of smart meters. The benefits of smart meters include reduced theft, tracking of revenue data, and improved payment functionality. The alternative of using local collection agents is generally problematic, costly, and reduces the ability of minigrid operators to experiment and understand customer behavior.
- Clustering minigrids. Ongoing operational soft costs per site reduce as companies grow and are able to service a number of clustered minigrid sites rather than a handful of isolated sites.
- Coordination with government grid extension and off-grid plans. Although some bilateral efforts have been made, the minigrid industry should communicate common needs to governments and development partners poised to provide technical assistance and advocate for enabling environment policies.

Academic and development finance experts are working to identify the requirements for successfully siting minigrids, efficiently surveying customers, sizing systems, and quickly deploying minigrids.[xi] This work will help determine and publicize minigrid best practices.

Opportunities to reduce finance cost

Finance costs will fall as robust minigrid models are demonstrated and investor confidence increases. Figure 7 shows the effect of reducing rates from 15 percent to 10 percent. Further reductions in the cost of capital can be

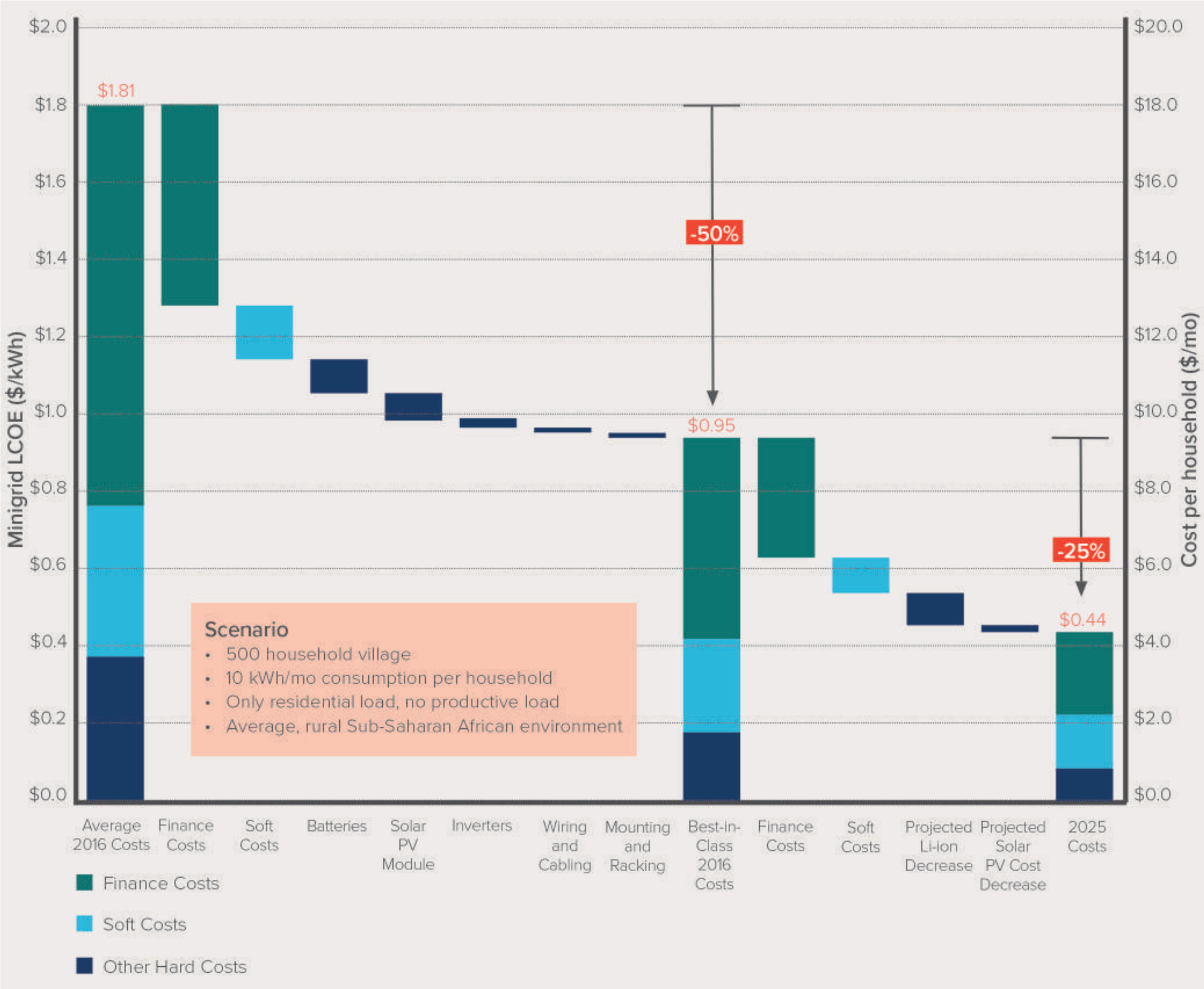
---

[x] Based on RMI industry interviews and modeling, an approximate soft cost reduction of 25% from today's best-in-class costs is possible in the next 9 years.

[xi] These include MIT and the World Bank's ESMAP program.

realized as the industry fully matures. Note that many of today's minigrids benefit from grant financing and bear little finance cost.

FIGURE 7. AVERAGE INSTALLED SOLAR-DIESEL-BATTERY MINIGRID COSTS CAN BE REDUCED BY 75 PERCENT[30, 31]



SOURCE: IRENA, RMI INDUSTRY INTERVIEWS AND MODELING

3.3 Increase access to finance

Minigrid finance costs are high and can be reduced, but increasing access to venture debt, patient capital, and collateral guarantees is of even greater importance. Beyond the allocation of development finance institution (DFI) money, it's necessary to increase financier confidence in the market through standardized due diligence, a better understanding of best practices, and improved project cost reporting.

Increase availability of appropriate grant, patient equity, and venture debt capital

Based on the early seed stage of the minigrid market, grant financing will continue to be necessary, especially until commercial viability is proven. Patient equity from development finance institutions with below-market-rate returns is also needed, and in contrast to pure grant financing, patient equity can be invested in a way that corresponds with minigrid timelines and returns, while supporting progress toward commercial viability. Venture debt from foundations and development finance institutions can also serve a similar purpose.

Address barriers to accessing finance

The early stage and high risk of minigrid markets in Africa require not only capital to be made available for growth, but also that barriers to accessing that capital be addressed:

- *Company barriers:* collateral and customer payment guarantees
- *Investor barriers:* a need for standard minigrid due diligence, a better understanding of the minigrid business model, and ways to address the small ticket size of minigrid projects

Minigrid companies' attempts to access financing are often stymied by collateral requirements, risk of customer default, and the small ticket size of individual minigrid projects.[32] Collateral requirements in Africa are frequently limited to cash and property, neither of which is readily available for seed stage companies. Minigrid assets are also relatively illiquid, posing a collateral challenge. Unproven customer track records increase perceived risk for investors. The high project-by-project due diligence costs of small, one-off investments deter investors. The lack of investment means that companies are unable to both convert operating profits into working capital with which to manage inventory and simultaneously pursue a pipeline of projects to improve the economics of individual projects.

Investors are reluctant to commit resources to a market without a proven, viable business model. Better due diligence tools and data transparency for projects will also increase financier confidence in the nascent minigrid market and ability to evaluate project returns and risk. Both commercial and concessionary financiers are wary of the risk of grid extension and electricity theft, which could be addressed through stakeholder engagement, tactical project siting, and improved payment collection processes.

Software may help bring down financing costs if developers are better able to show with data the expected cash flow of their projects to investors, or investors can aggregate projects to lend to a portfolio. A concerted blended finance approach, and creative instruments to securitize against future cash flows, could help to address these issues.

4. POTENTIAL MARKET FOR AFRICA

The addressable off-grid market in four leading African countries, of which minigrids will compete for a share, is currently $750 million in annual revenue. Reducing costs by 50 percent doubles the addressable market size to $1.5 billion.

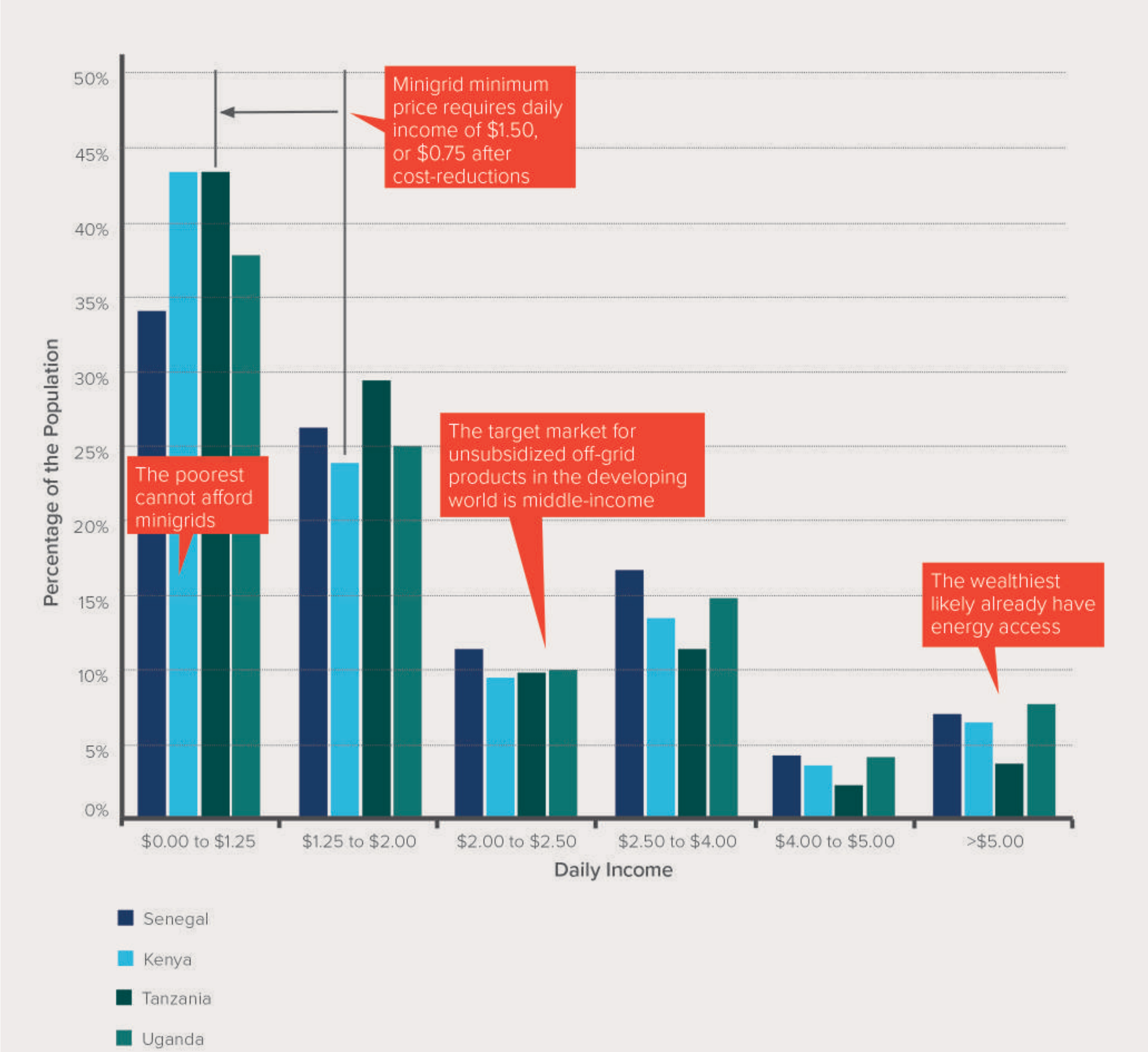
4.1 Determining market size

Rather than estimate the entire market, we're going to focus on four leading African countries with significant minigrid markets and minigrid-friendly regulatory environments—Senegal, Kenya, Tanzania, and Uganda. The potential off-grid market for these countries is $750 million in annual revenue. It can be a $1.5 billion market if today's minigrid costs are reduced by 50 percent. A basic estimate of the total addressable market for minigrids in these four countries can be made considering two factors: (1) the size of the market without current access to electricity, and (2) the portion of that market with the minimum ability to pay for minigrid energy access. [xii, 33]

Detailed country-specific mapping, as the United Nations Department of Economic and Social Affairs (UN DESA) has begun to do with its Universal Electrification Access program, will provide a more fine-grained picture of the market.

[xii] The initial total addressable market can be calculated by taking income histograms of leading off-grid markets, assuming the wealthiest people in the market are the ones with access to grid electricity, and setting a minimum minigrid pricing floor of $0.15/day. Up to 10 percent of income can be dedicated to non-cooking energy expenditures, so the potential minigrid customers need to have an income of at least $1.50/day.

FIGURE 8. THE TOTAL ADDRESSABLE MARKET FOR MINIGRIDS IS CONSTRAINED BY CUSTOMER ABILITY TO PAY IN FOUR LEADING AFRICAN MARKETS



SOURCE: WORLD BANK, POVERTY AND EQUITY DATA, 2013

If costs are reduced by 75 percent as shown in Figure 7, the load size that can be served is smaller, greatly growing the market as shown in Figure 8. Figure 9 shows relative total addressable market sizes before and after cost reductions in Senegal, Kenya, Tanzania, and Uganda.

This market sizing ignores the effect of additional demand-side management through energy efficiency, particularly for commercial and industrial customers, which would increase the size of the addressable market. Additionally, this report considers only residential customers, though commercial and industrial customers would increase the size of the market as well.

FIGURE 9. CURRENT ADDRESSABLE MARKET AND POTENTIAL ADDRESSABLE MARKETS WITH OUTLINED COST REDUCTIONS IN FOUR LEADING AFRICAN COUNTRIES

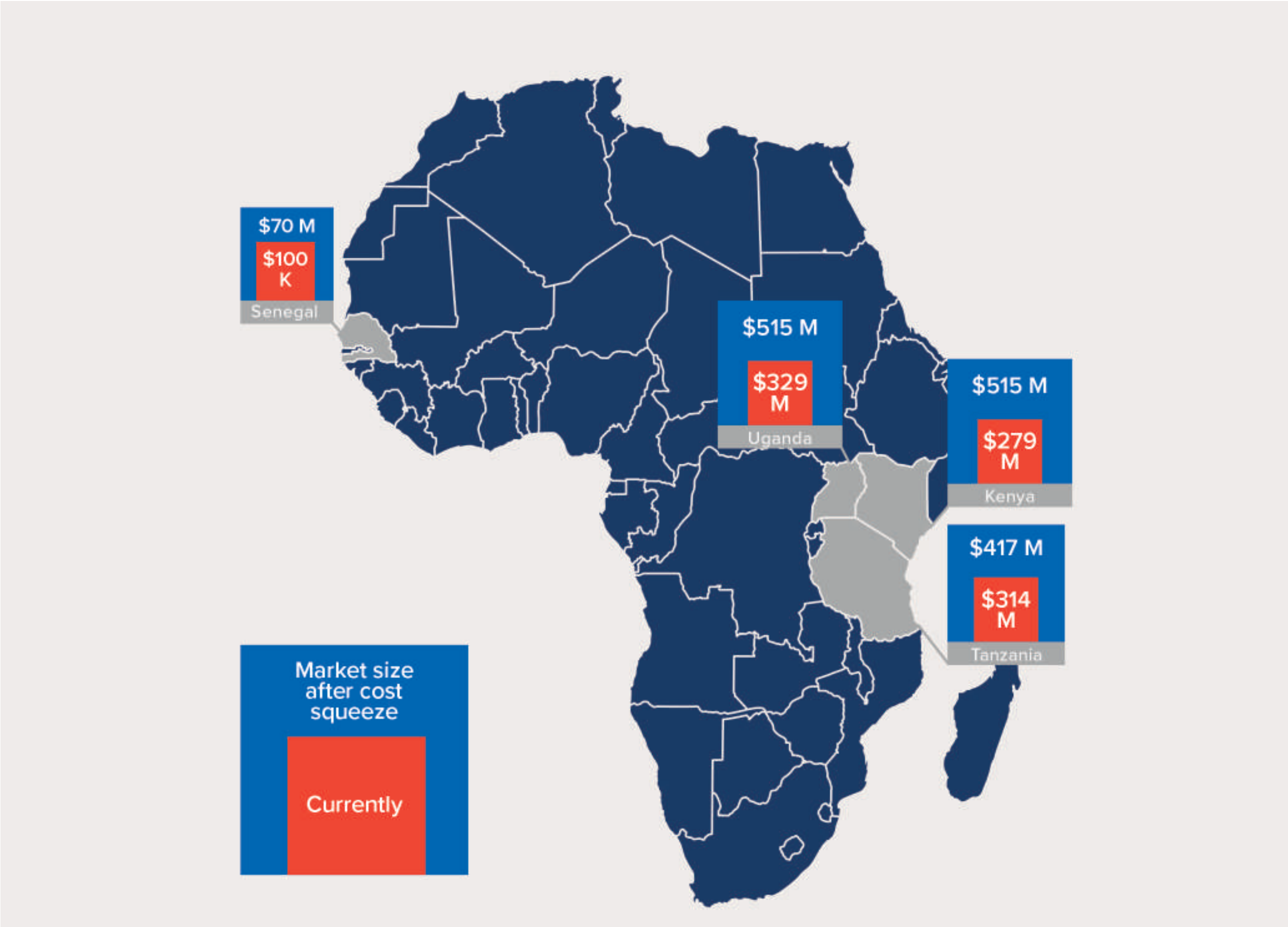


TABLE 3. MARKET SIZES IN FOUR LEADING AFRICAN MARKETS

	Total population (M)	Population w/o energy access that can afford minigrids (K)	Annual revenue potential ($M)	Revenue potential after cost-reduction ($M)
Kenya	44	11,600	$279	$515
Tanzania	49	5,600	$134	$417
Uganda	38	13,700	$329	$515
Senegal	14	100	$3	$70
Total	145	31,000	$745	$1517

4.2 External factors

When considering the market size, it is important to note that outside of the business model, there are two significant factors that can sway minigrid economics and risk, and hence, market size: grid reliability and the presence or lack of a national off-grid energy plan. In practice, one or more of these factors has an extreme effect on minigrids in nearly every market.

Grid reliability

The reliability of the grid can have a real impact on economic development because investment in capital that can only be utilized based on the vagaries of the electrical system often leads to poor economics for the investments. The grid is so unreliable in parts of Africa and India, and reliable power is so important for businesses, that customers are willing to pay a premium for reliable off-grid energy access, even when they have grid connections or grid extension is imminent.

As an illustration, the four leading minigrid markets referred to here have between 6 and 10 outages per month, with an average outage duration of 8.3 hours.[34] The lack of reliability of the grid across sub-Saharan Africa helps to explain the reliance on oil-fired back-up generation.[35]

National off-grid energy planning

Energy planning policy has a tremendous impact on the commercial viability of minigrids because it can provide clarity on revenue time horizons, what can be charged to consumers, and what happens should the grid arrive at a later date. While most sub-Saharan African governments and utilities are aware of the potential role of minigrids and off-grid technology generally, only a small number of governments and utilities have deliberately incorporated off-grid planning into their national energy strategy. Strong national off-grid energy planning includes the following:

- Off-grid electrification targets, with granularity on solar home systems vs. minigrids
- Clarity and certainty of grid extension: Provide transparent plans to the public regarding where the grid will likely be extended in the next 10 years (i.e., off-grid zones)
- Tariff flexibility/concessions for minigrid operators: Minigrid tariffs, which serve remote areas and must remain cost-reflective, are generally higher than grid tariffs
- Buy-out clauses, feed-in tariffs, or other forms of cost-recovery for minigrid owners when the grid arrives

Greater involvement of government and utilities in private minigrid development could better align incentives between utilities and the private sector. Utilities can use minigrids as outposts for future grid extension, stimulating demand within prebuilt distribution networks. The minigrid operator could have the benefit of integrating into the grid when it arrives, and protecting against the risk of stranded generation assets.

TANZANIA: A MODEL FOR MINIGRID REGULATION

Under the Standardized Power Purchase 2 (SPP2) rules issued by the Energy and Water Utilities Regulatory Authority (EWURA), projects in Tanzania under 1 MW do not require a license but need to register with the regulator, whereas projects under 100 kW are not only exempt from licensing but also from tariff approval.

In other markets, licensing and tariff approval can be an onerous, multimonth process, and if not granted, jeopardizes the minigrid business model. Freedom to set minigrid tariffs reassures companies that they will be able to recoup costs.

The SPP2 rules also consider options to avoid stranded assets if and when the grid arrives at a minigrid site—a significant source of risk for minigrids and their investors. Either (1) the utility, TANESCO, pays for the distribution network and the minigrid owner can sell off the generating assets; (2) the minigrid operator buys electricity from TANESCO and continues to use its own distribution network; or (3) the minigrid operator continues to generate and distribute its own electricity and in addition sells excess electricity to TANESCO.[36]

Additional factors

The external factors considered here are not incorporated into the market sizing calculation, but they complicate assessment of market size. In some cases these external factors grow the market, in others they constrain the market. An overview of their likely effects is surveyed in Table 4.

TABLE 4. EXTERNAL FACTORS AFFECTING MINIGRID COMMERCIAL VIABILITY

Factor	Effect on minigrids	Example
Solar VAT exemption	Renewable energy products in many emerging markets are exempt from VAT on import. VAT taxes in Africa are usually around 15%.	Some East African Community countries previously proposed to eliminate VAT exemption for off-grid solar products.
Subsidized Capex/Opex	Subsidized Capex and Opex, or access to concessionary finance for one form of energy access over another, distort the playing field.	Subsidized solar home systems proposed as part of Kenya's SkyPower program would have distorted the market against minigrids. Subsidized grid power is the norm throughout the developing world, distorting cost comparisons.
Relative speed of deployment	The possibility of deploying faster than the grid gives minigrids an advantage, but in some scenarios favors solar home systems.	The speed necessary to reach Rwanda's 2018 electrification targets may trump other economic factors that would otherwise favor the grid or minigrids.
Foreign land ownership laws	Restrictions on foreign land ownership can stifle minigrid development. Land-use laws can prioritize minigrid networks over stand-alone alternatives.	India favors land ownership for solar as part of a minigrid over stand-alone systems. Tanzania's restrictions on foreign land ownership have slowed minigrid development.

INDIA MINIGRIDS: INSIGHTS FOR AFRICA

An ocean away from Africa on the Indian subcontinent is the Silicon Valley of minigrids. Here a bevy of foundations, entrepreneurs, private sector players, impact investors, and more traditional sources of debt are creating a living laboratory, testing and refining minigrid business models to reach economic viability and spur local economic development. The minigrid market in India, particularly in the states of Uttar Pradesh and Bihar, is more mature than the sub-Saharan African market, with just over 8 MW of cumulative capacity developed in India through 2014.[37]

Since 2010, foundations such as The Rockefeller Foundation and Shell Foundation have helped spur the establishment of more than 100 minigrids in India using solar PV, battery storage, and backup generation. They are priming demand, creating access for the most needy, and finding the right balance across customer segments.

To be sure, many locations in India and Africa differ in some important respects. In India, minigrids often function in parallel with the electric grid. Distribution lines and poles run side by side and many customers connect to both systems and switch back and forth opportunistically. Those customers choose cheap subsidized grid power when available, and switch to more reliable power from minigrids when grid power is not available. The economy in many areas is also more developed than many parts of Africa with a higher density of potential commercial and residential customers who already have some appliances or established businesses. Even so, there are lessons that are relevant to African markets that can reduce minigrid growing pains in that region:

- **Minigrids provide tangible social benefits:** Minigrids in India have demonstrated social benefits beyond electricity access. In Uttar Pradesh and Bihar, The Rockefeller Foundation found that minigrids led to 23 percent of customers eliminating harmful kerosene use, an increase in appliance purchases among middle- and higher-income customers, a significant improvement in study conditions for children, and an improvement in operations of public facilities such as markets and schools.[38]
- **Minigrids benefit small businesses:** Minigrids in India have had a positive impact on commercial customer revenues. One study by The Rockefeller Foundation found a 13% increase in revenues in a sample set of 300 shops and micro-enterprises accessing energy through minigrids.[39] In a recent visit we found woodworkers increasing productivity tenfold for certain tasks like wood planing, which allowed them to concentrate on higher value work.
- **Correct system sizing and maintenance are critical:** Site selection, customer acquisition, and system design are major drivers of operational expenditures and capacity utilization and deserve more attention. All of the system operators we recently interviewed in Uttar Pradesh and Bihar are very focused on how to get more revenue out of their current capacity. We also found a real need for better maintenance procedures to ensure proper operation and maintenance of system components, especially battery banks.
- **Up-time is important:** Customers become frustrated and often leave the minigrid for alternatives if system reliability does not exceed 95 percent. Anything less than reliable energy access for commercial and industrial customers hinders the goal of real economic growth.[40] Our observation and discussions with small shop owners found that they gladly pay more for reliable minigrid power over the intermittent available grid energy.
- **Higher-load customers can provide a foundation for commercial viability:** Larger commercial and/or industrial customers provide a base load of power demand that has relatively less acquisition and customer support costs and that increases capacity utilization. If these businesses are open primarily during the day, they also provide a good match with low-cost solar power. Once established, they can also provide the backbone of the distribution grid that makes it economical to connect lower-demand customers such as small shops and homes. There are alternative models that focus primarily on very small-load customers and save costs by providing direct current systems, but our

observations in the field suggest that they may find significant challengers in stand-alone solar home system providers.[41]

- **It is important to stimulate efficient demand:** While the efforts are nascent, The Rockefeller Foundation and others are priming demand by selling items as varied as clean water and cold storage centers for market stalls, laborsaving power tools, and “white goods” such as fans and television sets. Since peak demand drives capital expenditures and capacity utilization in minigrids (as it does in traditional grids), the adoption of efficient devices will be critical to long-term economic viability. Just as traditional utilities work together with large industrial customers to manage startup and balance loads, minigrid companies must work with productive-use customers. Using soft-start motors and more efficient appliances, as well as negotiating time of use, can help maintain reliability and save money for both the customer and the utility. Thus, minigrid operators should consider selling services instead of power, thereby aligning customer and operator incentives.
- **Uttar Pradesh is an emerging role model for minigrid policy:** Uttar Pradesh has the longest-running minigrid regulatory framework and most refined minigrid policy in the world. It has successfully regulated varied and flexible tariffs and is proactively addressing minigrid asset options if and when the grid is extended. Elements of these policies have been emulated in Kenya, Tanzania, and Nigeria.[42]

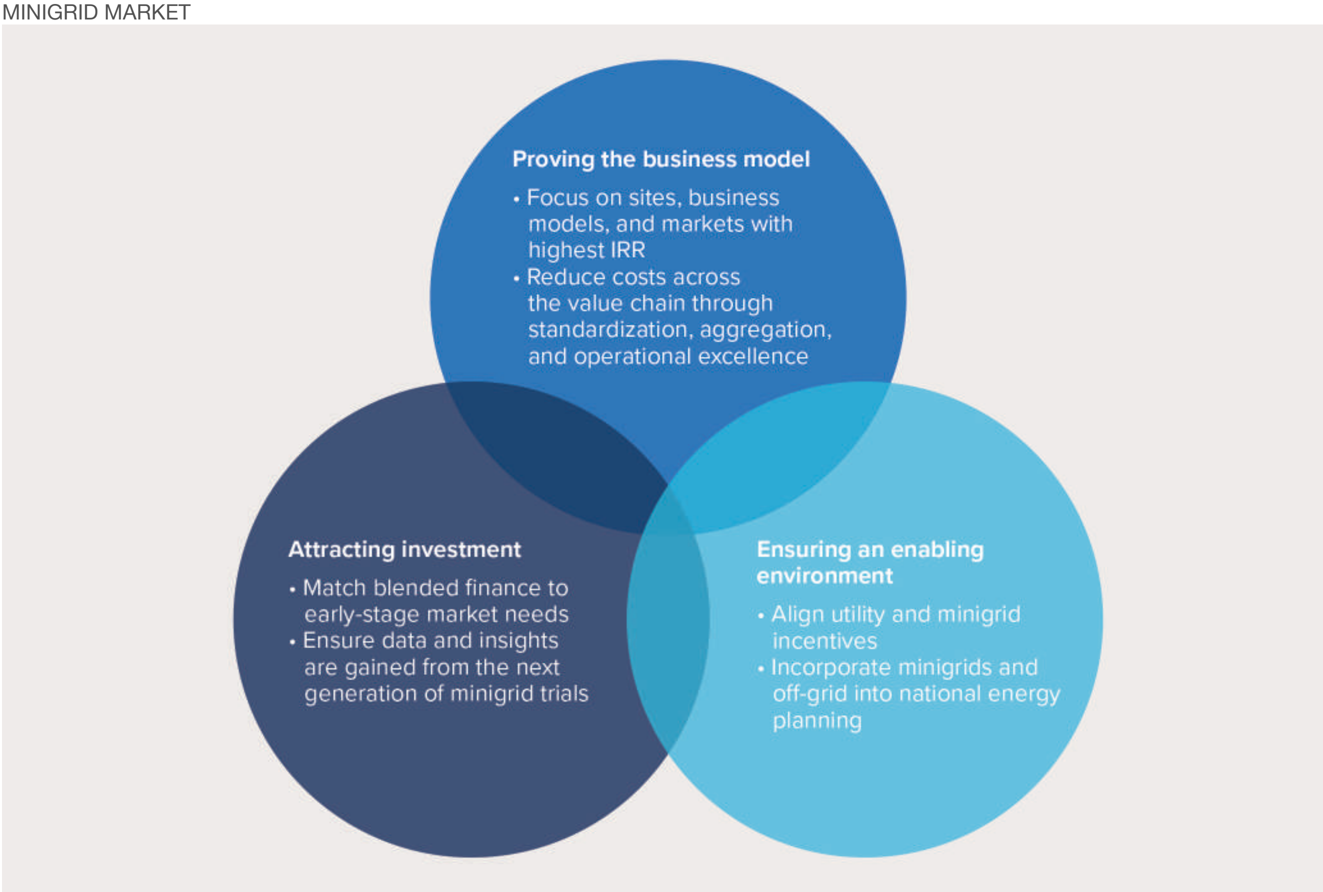
These specific insights and lessons are echoed in the more generic lessons outlined in this report: 1) getting cost and capacity right are critical; 2) site selection, especially load size, is critical, as is understanding competitive or complementary positioning relative to the grid and stand-alone systems; 3) the regulatory environment can accelerate progress or stifle innovation and drive out investors; and 4) minigrid companies should consider more than just selling units of energy by thinking about appliance efficiency and the services they provide.

5. GROWTH STRATEGY

A concerted effort by private, public, and development sectors can unlock the potential of minigrids.

Accelerating the growth of the minigrid industry requires: (1) proving the business model, (2) attracting investment, and (3) ensuring an enabling environment. Proving the business model is critical because entrepreneurs, donors, and investors need to see proof that minigrids can find market niches where they can operate profitably. Although that demonstration falls on the shoulders of the companies, it also needs to be supported by those who invest in those companies and the governments considering a role for minigrids in their country's power system. Attracting the right blend of investments and maturing that blend over time can be led by a consortium of development partners, private investors, and foundations that can create a blended finance facility that can bring the right type of investment dollars now and as the market matures. Ensuring an enabling environment needs to be led by governments and supported by their utilities. Crucially, incentives must be aligned so that minigrids are a viable contributor to economic development and can be integrated into the grid when appropriate, and that operators are given an incentive to improve the cost of service in what would otherwise be local monopolies. Figure 10 summarizes the three overlapping needs and key efforts to attain them.

FIGURE 10. PRIVATE SECTOR, DEVELOPMENT PARTNER, AND GOVERNMENT ACTIONS CAN WORK TOGETHER TO SUPPORT THE MINIGRID MARKET



While those goals might be achieved through the natural and organic expansion of minigrid markets, a more coordinated effort is needed. First and foremost it is essential that the next generation of minigrid trials yields shareable concrete data and insights that will induce faster customer adoption, identify and pull cost-reduction levers, build the case for economic viability, attract additional as well as more conventional financing, and prove the case that minigrids can play a role in economic development. Doing so will require carefully but rapidly deployed tests with target metrics and outcomes identified in advance and clear roles for lead and supporting stakeholders.

5.1 Role of coordinated trials

Create trials for proof of concept and scaling insights and data

Data and experience with minigrids, let alone minigrids designed to be commercially viable, are rare. Grant-funded minigrid pilot projects have not always been designed to yield valuable data, test commercial viability, or drive toward cost reduction and better policy. Comparisons of minigrid economics, customer needs, and economic development effects are difficult at best. The hypotheses outlined in this paper should be tested on the ground as soon as possible to build government, development partner, and investor confidence through a body of knowledge and shared information that will help mature the market quickly and answer key questions that are keeping many governments and investors on the sidelines.

Pilot projects can be better designed to test specific hypotheses and provide rigorous experiments and facts. A phased bidding approach with an expanded set of selection criteria can deliver real results while also driving toward rapid learning, reducing cost and improving value, and identifying key enablers that require government and development partner attention. Phase one is a request for input and qualifications to identify qualified bidders, refine project specifications, and understand cost-reduction strategies. Phase two is a request for quotes and solicitation of final proposals from qualified bidders, with a potential recurring bid on additional concessions. This bidding approach should be combined with an expanded set of selection criteria listed below.[xiii]

For the best initial **cost, service, and management,** solicit information regarding:

- End-use pricing
- Technical specifications
- Cost and pricing structure
- Management of collection and theft

To also drive toward **long-term viability and scaling,** solicit information regarding:

- Road map for cost reduction
- Service offering enhancements
- Site and company growth plans
- Market enablers
- Data-gathering approach

Roles: Development banks and foundations are best positioned to fund focused, cost- and growth-oriented pilot projects. Governments can also follow a similar process in the awarding of concessions.

Output: Pilot projects are valuable only insofar as they provide opportunities for improvement. Soft-cost- and hard-cost-reduction tests and innovative finance mechanisms are both valuable potential outcomes of pilot projects. Ideally, grant financing is combined with venture debt and patient equity so minigrid developers are growth oriented.

Incentives: Cost-transparent pilot projects geared toward proving commercial viability and bankability of minigrids are the foundation for private sector minigrid growth.

[xiii] Based on recent RMI experience in managing similar bidding processes in island nations and community-scale solar.

5.2 Role of the private sector

To grow the minigrid market, the private sector must drive down costs while increasing energy efficiency and capacity utilization.

The private sector—including minigrid developers, hardware and software companies, operators, and financiers—can focus on driving down cost in several ways:

- Aggregate hardware and software development so that a handful of companies are competing to provide meters, charge controllers, generation, siting and design software, etc.
- Use demand-side management, particularly energy efficiency for commercial and industrial customers, to improve asset utilization, providing the same value at decreased cost.
- Focus on site-selection factors that heavily impact cost.
- Organize a coordinated industry voice for minigrid companies to communicate with government in order to align electrification plans and targets while designing fair regulation that can accelerate industry growth.
- Work together with providers of solar home system to familiarize potential minigrid customers, test creditworthiness, and build demand.

Roles: Private sector companies should lead these initiatives, but foundations, nonprofits, and development finance institutions can spur them on by focusing attention on cost-reporting, innovations in cost reduction, and efforts to manage commercial and industrial demand on minigrids. Most important, the minigrid trials suggested above can create an open environment in which to test cost-reduction ideas.

Outputs: Successful private sector efforts to reduce costs will increase market size and adoption, attract more investment, and provide a better value proposition to potential customers. Foundations, nonprofits, and development banks can publicize cost information and cost-reduction efforts, as described above.

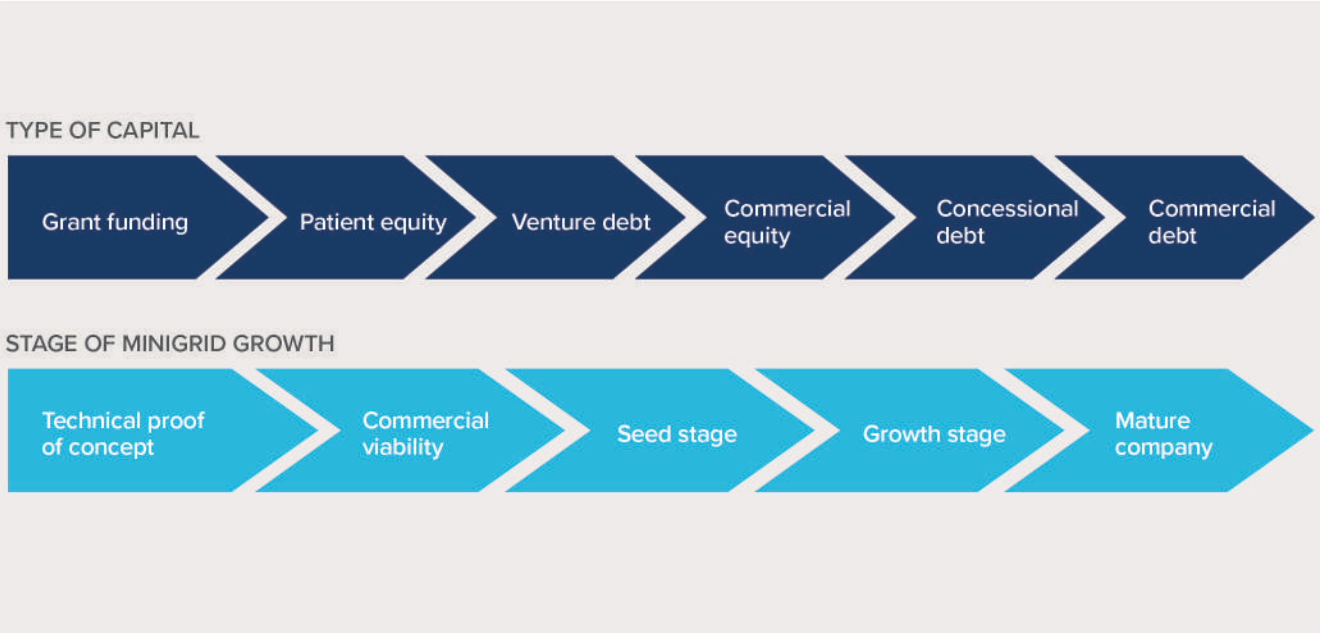
Incentive: Improving profitability and proving the minigrid business model can be commercially viable.

5.3 Role for development partners and NGOs

To grow the minigrid market, development partners and NGOs should set up a blended finance facility to improve access to finance and improve the due diligence process. Development partners can also grow the market by supporting minigrid-enabling environments with tools and capacity building, and provide targeted minigrid grants for proof of concept and scaling.

Improving access to finance for minigrids requires a twofold effort: (1) ensuring the appropriate types and amounts of capital are allocated, and (2) addressing a set of barriers to accessing that capital, including collateral requirements, the risk of customer payment default, and a lack of standard due diligence for minigrid finance. A blended finance facility, either operating regionally or globally, can help with both of these efforts by coordinating the different types of needed capital, and matching them to appropriate and qualified companies, while facilitating credit enhancements and improved due diligence to attract more financiers. Insights gained from a series of well-controlled and analyzed minigrid trials could help inform the blend of investments needed and their possible evolution over time.

FIGURE 11. COORDINATED BLENDED FINANCE FACILITY COULD USHER MINIGRID COMPANIES THROUGH STAGES OF GROWTH



As shown in Figure 11, at different stages of minigrid company growth, a blended finance facility could provide specific investments and credit enhancements:

- Grants: To support efforts to prove commercial viability, focused on the viability of the business model and cost reporting.
- Patient equity and venture debt: Terms and lower-return expectations that match the growth stage of the minigrid market, an under $2 million ticket size, eventually to draw in commercial equity and debt.
- Convertible debt, soft loans, and credit enhancement: Low or no collateral requirements with flexible terms, under $2 million collateral, customer payment and buyback guarantees, currency risk hedging instruments. (Banks in sub-Saharan Africa often have high cash or property-only collateral requirements that inhibit debt issuance. Customer payment and asset buyback pose similar challenges to the easier flow of investment.)

Roles: Bilateral and development banks, which are increasingly dedicating funds to minigrids, must structure minigrid finance carefully in a way that supports accountability and growth. Foundations and nonprofits could help design and operate blended finance facilities.

Output: Design, fund, and operationalize a minigrid blended finance facility or facilities with national or regional focus.

Incentives: Careful, concerted finance for minigrids can leverage precious donor resources and leverage commercial finance quickly to achieve the electrification and economic development goals of development partners.

5.4 Role for government

To grow the minigrid market, governments in Africa can provide an enabling environment that supports both minigrids and national energy access goals.

Governments need to provide predictable enabling environments for minigrids if they are to achieve their ambitious energy access targets. Governments can reduce regulatory risk for companies and their investors with clear, comprehensive off-grid energy plans; streamlined import procedures; dependable incentives for renewables and energy efficient appliances; and education/awareness campaigns that communicate to their citizens how off-grid products, and minigrids in particular, work and their benefits. Aligning utility and minigrid incentives through collaboration would help bring certainty on several levels and de-risk the role of minigrids for government, utility, the private sector, and financiers. Governments can also support well-run pilot projects focused on proving commercial viability, testing plans for minigrid growth, and integrating minigrids into the existing grid.

Key topics to address in parallel with and as part of the proposed minigrid trials include:

- A realistic map of grid-extension plans in line with least-cost objectives that also identifies high-potential minigrid zones
- Aligned incentives across utility and off-grid policies
- Coordination with the off-grid private sector
- Consistent policies around tariffs and subsidies. Minigrids require higher tariffs than the grid because they serve costly, unelectrified locations; communicate cost expectations to customers
- A clear plan if and when the grid arrives

Roles: Governments and utilities set plans, regulations, concessions, and requests for proposals regarding minigrids. Development partners and NGOs can provide support to government with expertise and training. Achieving energy access and economic growth targets are often goals shared by government and development partners. NGOs can play the role of unbiased facilitators between government and the private sector to help align incentives to achieve targets. Both development partners and NGOs can provide targeted technical assistance and capacity-building efforts to support the integration of minigrid and off-grid planning into national energy plans.

Outputs: Clear off-grid strategies, including minigrid-enabling environments, off-grid targets, and pilot projects to prove minigrid commercial viability.

Incentives: Sub-Saharan African governments increasingly have set aggressive electrification and economic growth targets. Efficient and rapid rural electrification is essential to their success, and the success of their people. Working in cooperation with private sector minigrid companies to achieve those targets requires, first and foremost, providing an enabling environment for their operation and investment.

6. CONCLUSION

In the urgent effort to provide electricity access across Africa, minigrids fill a sweet spot between small, nimble solar home systems and traditional grid extension. From a least-cost planning perspective, a single solution to the energy access challenge does not exist. However, with careful planning, a tremendous number of customers could be served best with minigrids. Determining where this sweet spot exists requires consideration of village load sizes and distance of the load from the grid, and operating in markets that welcome minigrids and other off-grid technologies. Minigrids could and do operate in grid-connected areas, and in countries that do not yet provide robust enabling environments. But minigrids will not attract commercial finance or achieve rapid growth unless they focus on markets where the prize is largest, the return on investment is most significant, and the enabling environment is assured.

Realizing the potential of minigrids in sub-Saharan Africa will require a concerted effort and plan by the private sector, development partners, and African governments. It is essential that a coordinated effort focus on carrying out the next generation of minigrid trials that will yield a robust trove of data and insights to improve economics, increase the customer value proposition, attract commercial investment, and meet the needs of government energy access and economic development goals.

Success will depend on focusing on high-potential countries and regions within them; clear roles for stakeholder groups; a willingness by them to collaborate; and clear metrics, milestones, and outcomes that have been determined in advance. We believe that doing so will provide answers in 12–24 months to key questions that are hampering acceleration of minigrid solutions.

7. ENDNOTES

[1] International Energy Agency, *Africa Energy Outlook* (2014). http://www.worldenergyoutlook.org/resources/energydevelopment/africafocus/

[2] Gowen, Annie. "India's huge need for electricity is a problem for the planet." *The Washington Post.* November 6, 2015.

[3] *Energy For All: Financing access for the poor*. International Energy Agency. 2011.

[4] *Rural Electrification with Renewable Energies in East Africa. Africa-EU Partnership, Renewable Energy Co-operation Programme.* Accessed January 9, 2017. www.afd.fr/webdav/site/afd/shared/…/RECP-synthese-electrification-Afrique-Est.pdf.

[5] *Kenya Market Assessment for Off-Grid Electrification.* Carbon Africa Limited, TramaTecnoAmbiental S.L.,Research Solutions Africa Limited, Energy Research Centre of the Netherlands. October 2015.

[6] Manetsgruber, D. et al. *Risk Management for Mini-grids: A New Approach to Guide Mini-grid Deployment*. Alliance for Rural Electrification. 2015.

[7] *Power Up: Delivering Renewable Energy in Africa*. The Economist Intelligence Unit. 2016; and RMI industry interviews

[8] IRENA. *Solar PV in Africa: Costs and Markets*. September 2016.

[9] Ibid.

[10] Ibid.

[11] Stopforth, Kieron. "How Rwanda could leapfrog to a future with 100% access to clean electricity." Bloomberg New Energy Finance. November 11, 2013.

[12] Kurtz, J., G. Saur, S. Sprik, and C. Ainscough. *Backup Power Cost of Ownership Analysis and Incumbent Technology Comparison.* NREL. September 2014. http://www.nrel.gov/docs/fy14osti/60732.pdf

[13] "Electric vehicles to be 35% of global new car sales by 2040." Bloomberg New Energy Finance. February 25, 2016. https://about.bnef.com/blog/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040/

[14] *Guides for Electric Cooperative Development and Rural Electrification.* NRECA. https://www.nreca.coop/wp-content/uploads/2013/07/Module7DistributionLineDesignandCostEstimationforRuralElectrificationProjects.pdf

[15] Ibid.

[16] "Diesel prices, liter." Accessed October 9, 2016. http://www.globalpetrolprices.com/diesel_prices/

[17] Based on industry interviews.

[18] *Power Up: Delivering Renewable Energy in Africa*. The Economist Intelligence Unit. 2016.

[19] ESMAP/World Bank/UNDP. "Reducing the Cost of Grid Extension for Rural Electrification" (2000);

[20] Alliance for Rural Electrification. "Hybrid Minigrids for Rural Electrification: Lessons Learned." 2011; Industry interviews.

[21] UNF/SE4ALL/EAPN. "Investing for Energy Access: 2015 Directory of Investment and Funding Opportunities."

[22] RMI industry interviews.

[23] Enlighten/United Nations Environmental Programme. *Regional Report on Energy Efficient Lighting in Sub-Saharan African Countries*. 2012.

[24] "E.ON launches US energy service business with eye on renewables." *PV Magazine*. 9 April 2015. http://www.pv-magazine.com/news/details/beitrag/eon-launches-us-energy-service-business-with-eye-on-renewables_100018983/#axzz4OnRvHFwK

[25] Smith, Amy. "New Mill Design Grinds More Grain for Less Money." African Technology Forum. 1998.

[26] IRENA. *Solar PV in Africa: Costs and Markets*. September 2016.

[27] Ibid.

[28] Lacey, Stephen. "Stem CTO: Lithium-Ion Battery Prices Fell 70% in the Last 19 Months." *Greentech Media Research*. June 28, 2016.

[29] Based on industry interviews.

[30] IRENA, *Solar PV in Africa: Costs and Markets*, September 2016; Industry and expert interviews.

[31] RMI minigrid costing analysis.

[32] RMI industry interviews.

[33] Bacon, Robert, S. Bhattacharya, and M. Kojima. *Expenditure of Low-Income Households on Energy*. The World Bank. June 2010.

[34] World Bank. (2015). Power outages in firms in a typical month (number). *World Bank Data.* http://data.worldbank.org/indicator/IC.ELC.OUTG. Accessed 12 December 2016.

[35] Platts. (2015). UDI World Electric Power Plants Database, 2015. Platts-McGraw Hill Financial.

[36] *Mini-grid Policy Toolkit: Case-study Tanzania*, EU Energy Initiative Partnership Dialogue. http://www.euei-pdf.en/recp/mini-grid-policy-toolkit. Accessed 12 December 2016.

[37] Schnitzer, D. et al. (2014), *Micro-grids for electrification: A critical review of best practices based on seven case studies*, UN Foundation, Washington, D.C., http://energyaccess.org/images/content/files/MicrogridsReportFINAL_low.pdf

[38] Interview with Smart Power for Rural Development. March 9, 2017

[39] Ibid.

[40] RMI industry interviews

[41] Ibid.

[42] Ibid.

22830 Two Rivers Road
Basalt, CO 81621 USA
www.rmi.org