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THE STATE OF THE OFF-GRID APPLIANCE MARKET

OCTOBER 2019

EFFICIENCY FOR ACCESS COALITION

This report analyzes major trends in the off-grid appliance sector, establishes its position as a fast-growing and attractive market, and seeks to mobilize investment and policy support to accelerate the sector's growth.

The report builds on the 2016 *State of the Off-grid Appliance Market* report, published by Global LEAP, which represented the first comprehensive accounting of the state of the household appliance sector. It provided the first-ever snapshot of the global off-grid appliance market via data-driven analysis of the scale, market trends, and barriers for three important and promising appliance categories: televisions, refrigerators, and fans. This report refreshes the 2016 analysis and builds upon its earlier findings, adding further data from recent Efficiency for Access Coalition research, GOGLA survey data on appliance sales, a review of the broader scholarly literature, updated interviews with key off-grid appliance enterprises, and country deep-dive profiles for Côte d'Ivoire, Ethiopia, India, Kenya, Myanmar, Nigeria, Sierra Leone, and Uganda to illustrate the diversity of sector challenges and opportunities.

This report was developed by Dalberg Advisors in close collaboration with CLASP as part of the Low Energy Inclusive Appliances program, a flagship program of the Efficiency for Access Coalition. Efficiency for Access is a global coalition promoting energy efficiency as a potent catalyst in clean energy access efforts. Currently Efficiency for Access Coalition members lead 12 programs and initiatives spanning three continents, 44 countries, and 22 key technologies.

The Efficiency for Access Coalition is jointly coordinated by CLASP, an international appliance energy efficiency and market development specialist non-for-profit organization, and the UK's Energy Saving Trust, which specializes in energy efficiency product verification, data and insight, advice, and research.

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ACRONYMS

A2EI	Access to Energy Institute
AC	Alternating Current
AMDA	Africa Mini-grid Developer's Association
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditures
DC	Direct Current
DESCO	Distributed Energy Service Companies
DFI	Development Finance Institution
DFID	The United Kingdom's Department for International Development
DHS	Demographic and Health Surveys
EEI	Energy Efficiency Index
EforA	Efficiency for Access Coalition
EnDev	Energising Development Programme
EPC	Electric Pressure Cooker
ESMAP	World Bank Energy Sector Management Assistance Program
FSP	Financial Service Provider
GIZ	German Corporation for International Development
GOGLA	Global Off-Grid Lighting Association
GSMA	Global System for Mobile Communications Association
GST	Goods and Services Tax
IAP	Indoor Air Pollution
ICT	Information and Communications Technologies
IFC	International Finance Corporation
IoT	Internet of Things
IRENA	The International Renewable Energy Agency
KOSAP	Kenya Off-Grid Solar Access Project
LCD	Liquid Crystal Display
LEIA	Low-Energy Inclusive Appliances Programme
MECS	Modern Energy Cooking Services
MEPS	Minimum Energy Performance Standards
MFI	Microfinance Institution
MSME	Micro, Small, and Medium Enterprises
OEM	Original Equipment Manufacturer
PAYGO	Pay As You Go
PRONER	National Program for Rural Electrification
PV	Photovoltaic
RBF	Results Based Financing
REAN	Renewable Energy Associate of Nigeria
R&D	Research & Development
SDG	Sustainable Development Goal
SHS	Solar Home System
SOGE	USAID Scaling Off-Grid Energy
SSA	Sub-Saharan Africa
SWP	Solar Water Pump

ABBREVIATIONS

TEA	UK aid Transforming Energy Access Programme
TIC	Testing Inspection and Certification
UNCDF	The United Nations Capital Development Fund
UNEP	The United Nations Environment Programme
UPI	Unified Payments Interface
USAID	The United States Agency for International Development
VAT	Value-Added Tax
WBG	World Bank Group
WEEE	Waste Electrical and Electronic Equipment Center
WHO	World Health Organization

EXECUTIVE SUMMARY

In the past few years, efficient off-grid appliances[1] have moved from the fringes of the energy access dialogue to its very center. The growth of off-grid and mini-grid electrification to address the basic energy needs of more than two billion off-grid and weak-grid[2] households and small businesses worldwide is a critical first step up the energy access ladder. Capturing the full socio-economic benefits of access to energy, however, requires the provision of higher levels of energy services. The private sector, funders, and governments are increasingly recognizing the essential role that efficient off-grid appliances can play to meet household needs at scale, generate new income and entrepreneurship opportunities, and, simultaneously advance energy enterprise profitability and sustainability through increased energy demand.

The off-grid appliance sector, while still nascent, is on the cusp of transformational growth in 2020 and beyond. Appliance sales are growing rapidly. The efficiency, performance, and range of available household and productive use appliances is increasing almost daily. While still prohibitive for many, prices continue to decline, boosting sales and growing the size of the obtainable market. The overall ecosystem for off-grid appliances has also evolved dramatically in the past few years, with many new private sector enterprises, dedicated initiatives, and intermediary organizations; rising interest from donors, implementers, and industry associations; and growing activity by commercial investors. Nevertheless, many challenges persist and there are ample opportunities to further accelerate sector progress while ensuring that quality appliances are developed and distributed in ways that maximize household-level impact while also protecting consumer safety and financial sustainability.

This report by the EforA Coalition tracks the evolution of the fast-moving off-grid appliance market. The report builds on the Global LEAP Awards' seminal *The State of the Off-grid Appliance Market* report, published in 2016,[3] and offers:

- Updated information about the off-grid household appliance space including new evidence on the impacts of off-grid appliances
- Recent intelligence on underlying technology and market trends
- Deeper insights into consumer needs and demand
- Fully updated and revised estimates of the off-grid appliance market size and growth trajectory
- Off-grid appliance market profiles for eight countries in Asia and Africa.

The report focuses exclusively on household off-grid appliances and, in particular, on three of the most in-demand product categories: televisions, fans, and refrigerators.[4] There are also exciting dynamics in the very early stage off-grid productive appliance market, so this report is launched alongside a supplement report on small-scale solar water pumps (SWPs),[5] currently the most commercially mature category of off-grid productive use appliances. This report also complements the World Bank Lighting Global program's 2019 report on Productive Use Leveraging Solar Energy (PULSE), which focuses on a broader range of off-grid appliances for smallholder agriculture.[6]

The infographic on the next page provides an overview of key household off-grid appliance sector statistics. The pages that follow offer an overview of key report findings and recommendations.

1. Efficient off-grid appliances are defined as electrical appliances appropriate for use in both off-grid and unreliable or 'weak' grid contexts where standalone solar energy systems are insufficient to power conventional appliances. Because they run on lower-load energy systems, off-grid appliances are typically compatible with DC systems, but also include AC appliances combined with inverters.
2. The 'weak-grid' market, also sometimes labelled as 'under-electrified', refers to households and businesses which have sporadic, low-quality grid connectivity, typically only a few hours daily with a high degree of intermittency (i.e., frequent and unpredictable power outages). For brevity and simplicity, where not otherwise noted, all references in this report to off-grid markets refer to both off-grid and weak-grid households, the latter specifically defined as those that have access to grid electricity for less than 50% of the day.
3. The earlier report was published by CLASP in partnership with the Global Lighting and Energy Access Partnership (Global LEAP) Awards, a Clean Energy Ministerial initiative led by the U.S. Department of Energy. See https://efficiencyforaccess.org/publications/the-state-of-the-global-off-grid-appliance-market-2017
4. See top appliances categorized by perceived demand in CLASP, *Off-Grid Appliance Market Survey: Perceived Demand and Impact Potential of Household, Productive Use and Healthcare Technologies,* Efficiency for Access Coalition, 2018, https://efficiencyforaccess.org/publications/off-grid-appliance-market-survey.
5. Solar Water Pump Outlook 2019: Global Trends and Market Opportunities. Efficiency for Access Coalition. 2019, https://efficiencyforaccess.org/publications/solar-water-pump-outlook-2019-global-trends-and-market-opportunities
6. World Bank & Dalberg Advisors, *Productive Use Leveraging Solar Energy (PULSE),* World Bank Lighting Global Program. 2019. https://www.lightingglobal.org/resource/pulse-market-opportunity/

OFF-GRID APPLIANCE MARKET SNAPSHOT

Energy Consumption

Household energy consumption in the United States and Europe

5-10x
greater than in India

10-20x
greater than in Nigeria

20-200x
greater than in most of rural Africa

Appliance Ownership

Number of appliances per household

15-40
developed countries

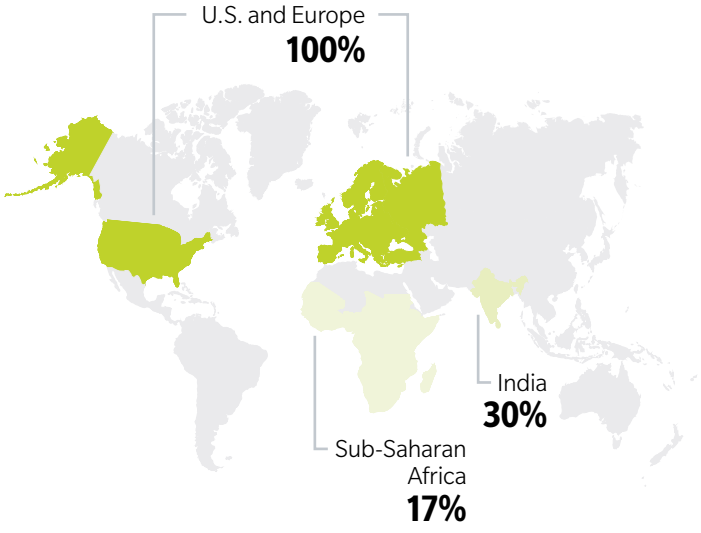
3-10
middle-income countries (e.g. India)

2-5
rural Africa

Appliance Penetration

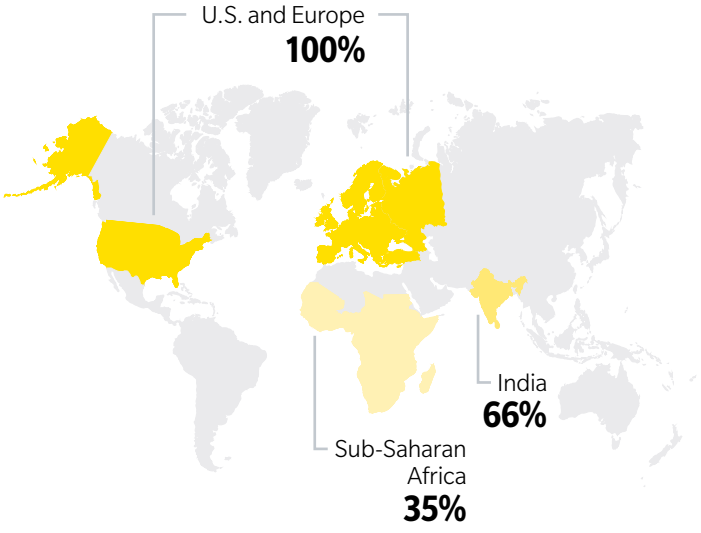
Penetration of household appliances is low in many parts of the world. In rural areas, the penetration is even lower—4% for refrigerators and 18% for televisions in rural Africa.

Refrigerators



0-100% PENETRATION

Televisions



0-100% PENETRATION

OVERVIEW OF KEY REPORT FINDINGS

TECHNOLOGY AND SUPPLY DYNAMICS

Sales for off-grid appliances have grown 50-80% annually. The total number of off-grid TVs, refrigerators and fans distributed is estimated between 1.4 and 5 million.

Off-Grid Appliance Sales Are Growing

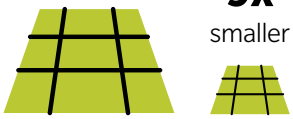
30-80% of solar home system kits now include an off-grid appliance. In the second half of 2018 GOGLA affiliates reported sales of:

175,000 fans

147,000 televisions

6,000 refrigerators

Off-Grid Appliance Energy Efficiency is Improving



9x smaller

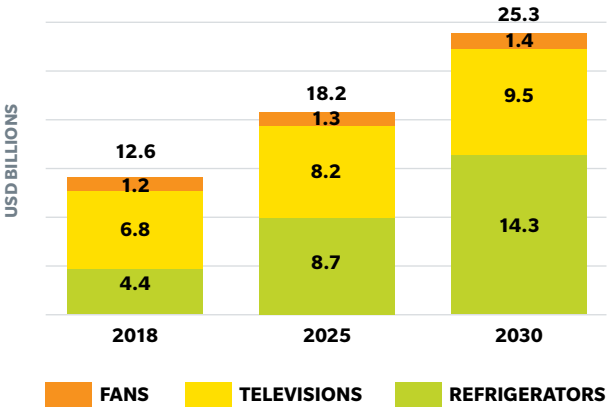
The size of the solar panel required to power a best-in-class off-grid refrigerator is nine times smaller than what is required to power a conventional refrigerator.

Between 2014 and 2017, the energy efficiency of televisions improved by **45%**

DEMAND AND MARKET POTENTIAL

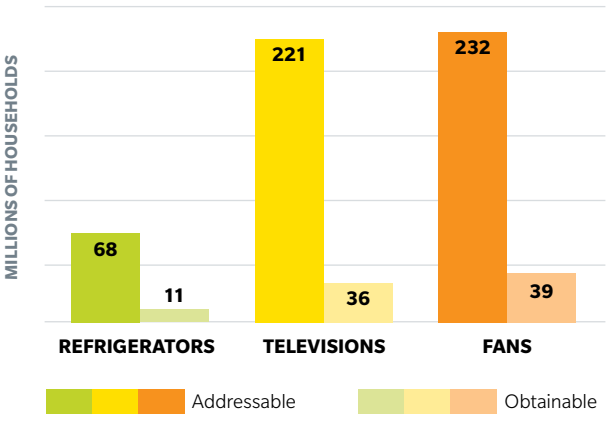
Cumulative Market Potential

The cumulative market opportunity across televisions, refrigerators and fans is estimated at USD 12.6 billion globally at the end of 2018. The market is predicted to grow to 25.3 billion by 2030.



Addressable vs Obtainable Market

The total obtainable market for off-grid appliances is significantly smaller than the addressable market largely due to limited access to finance and consumer accessibility.



Impact of Off-Grid Appliances

Refrigerators

help address food losses of 30% in sub-Saharan Africa (USD 4 billion)

Fans

reduce mortality during heat waves and increase overall health and wellbeing in households

Televisions

lead to improved educational outcomes and positive behavior change

Why are off-grid household appliances important?

Efficient appliances that are appropriate for off-grid and weak-grid markets are critical for increasing access to energy-dependent services. There are 475 million households globally with no grid access or unreliable access to electricity, 90% of which are in sub-Saharan Africa (149 million) and South Asia (275 million).[7] Renewable energy technologies, especially solar, are helping to bridge this gap. As of 2018, off-grid solar systems were already providing more than 73 million households, or 360 million people, with access to energy globally, and their reach was growing quickly.[8] While the solar and hybrid mini-grid market is more nascent than that for off-grid solar, mini-grids reached an estimated 10 million households in 2019, a number that is likewise projected to grow rapidly in the next few years due to major inflows of funding, falling component costs, and continued mini-grid business model innovation.[9]

Most off-grid solutions sold today provide only basic, low-power energy services, such as lighting and mobile phone charging. Off-grid populations are unable to access enough energy to power additional household services, such as home cooling, refrigeration, entertainment, and cooking. The new generation of increasingly affordable and efficient off-grid and weak-grid appliances—appliances that are substantially more efficient than conventional appliances and can accommodate energy-constrained environments and intermittent power supplies—can address many of these unmet household needs.

Off-grid appliances create foundational demand for energy services and help to make off-grid business models viable. The most far-reaching impact of off-grid appliances—and the reason that such appliances are becoming the primary focus for many energy access sector leaders—is the role they play in driving demand for off-grid energy and thus toward universal energy access by 2030. The uptake of appliances establishes a base level of demand to justify future investment into energy generation and distribution by both private sector actors and governments. It also provides a means for distributed energy service providers to generate and monetize greater value per customer, thus supporting more sustainable energy businesses that can support the high overheads of building out rural sales and service channels.

Off-grid household appliances have wide-ranging positive impacts on economic livelihoods, health, and education. Off-grid and mini-grid consumers are not seeking electrification for its own sake, but as a pathway to goods and services that can improve their lives in tangible ways. Appliances such as televisions, fans, refrigerators, connectivity devices (e.g. Wi-Fi routers), and electric cookstoves have broad positive impacts across multiple Sustainable Development Goals (SDGs), in addition to their role in advancing energy access (SDG 7). Off-grid appliance impacts are most notable for SDG 1 (poverty reduction), SDG 2 (food security), SDG 3 (health and well-being), SDG 4 (education), SDG 5 (gender equality), and SDG 8 (jobs and entrepreneurship). In most cases the impact evidence is anecdotal, but where it can be quantified the numbers are very substantial. In the case of economic impacts, for instance, data from a recent survey in Uganda showed that micro, small, and medium enterprises (MSMEs) who had purchased off-grid refrigerators, on average, increased their daily incomes 2.5-fold.[10]

Off-grid appliances are also becoming a critical element of the global push towards greater energy efficiency and greenhouse gas emissions reduction. Satisfying the appetite for energy access and modern life-changing appliances with efficient off-grid and weak-grid appliances represents a major opportunity to ensure that the next billion households to be electrified will start from the outset with high quality energy-efficient devices that minimize costs to the consumer and net impacts to the environment. The efficiency improvements should in time also influence the conventional appliance segment as the industry converges.

7. Dalberg estimate based on extrapolation from International Energy Agency (IEA) and country grid quality survey data.
8. World Bank & Dalberg Advisors, Off-grid Solar Market Trends Report, World Bank Lighting Global Program, 2018, https://www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report/.
9. For off-grid solar estimate of 73 million households and 360 million people, see ibid. For the mini-grid estimate of 47 million people covered by mini-grids (around 10 million households, assuming 4.5 people per household), primarily in Asia, see World Bank, Mini-Grids for Half a Billion People: Market Outlook and Handbook for Decisionmakers, 2019, https://openknowledge.worldbank.org/bitstream/handle/10986/31926/Mini-Grids-for-Half-a-Billion-People-Market-Outlook-and-Handbook-for-Decision-Makers-Executive-Summary.pdf?sequence=1&isAllowed=y.
10. Global LEAP and Energy 4 Impact Refrigerator Field Testing. Report Forthcoming.

What is the off-grid appliance demand today and what will the market size be in 2030?

Levels of overall energy utilization and household appliance use are very low in Sub-Saharan Africa (SSA) and South Asia, the two primary geographies of focus for this report. Annual household energy consumption in the United States and Western Europe is 5-10 times greater than that for an average household in India, 10-20 times greater than for an average household in a country like Nigeria, and 20-200 times greater than for households in most of rural Africa.[11]

Statistics on appliance access are equally stark:

- High income countries have 15-40 appliances, in contrast to 3-10 appliances for the average household in India, and 2-5 electric appliances (including mobile phones) for households in most of rural Africa.[12]
- In contrast to essentially universal TV and refrigerator access in middle and high income countries, in Sub-Saharan Africa, we estimate that only 17% of households have refrigerators and 35% have TVs, translating into a total of at least 33 million fans, 35 million refrigerators, and a mid-range estimate of 80 million TV sets.[13] This means that the entire region has 25% fewer refrigerators and TVs than Japan, which has only a tenth of Africa's population.[14]
- Appliance ownership by off-grid households is substantially lower. Excluding the middle-income outlier of South Africa, approximately 4% of rural African households have refrigerators and 18% have TVs.[15] Even in middle income India, for comparison, only 16% of rural households have refrigerators and roughly half have TVs.[16]

Potential demand for appropriately designed and efficient off-grid appliances is high. The gap in household appliance access and use in urban and rural Africa and South Asia is a strong indicator of the immense latent market demand for off-grid appliances.

We know from the purchase behavior of electrified households in the same income segment that demand for off-grid appliances like televisions, fans, and refrigerators, as well as others such as radios, irons, hot plates, and internet connectivity devices is very high. Furthermore, self-reported purchasing preferences suggest very high levels of latent demand. A large-scale survey of off-grid households across 10 countries in Sub-Saharan Africa revealed that 28% of households (18-35% range) intended to purchase a television and 14% (6-24% range) had an interest in purchasing a refrigerator upon gaining access to electricity.[17]

Demand for off-grid appliances is particularly high for households that have already experienced some of the benefits of energy access via basic solar home systems. For instance, a 2016 survey of solar home system households in Kenya showed that 37% of such households had a strong interest in buying a television and demand was likewise higher for appliances such as radios (28%), irons (26%), refrigerators (24%), and cookstoves (23%).[18]

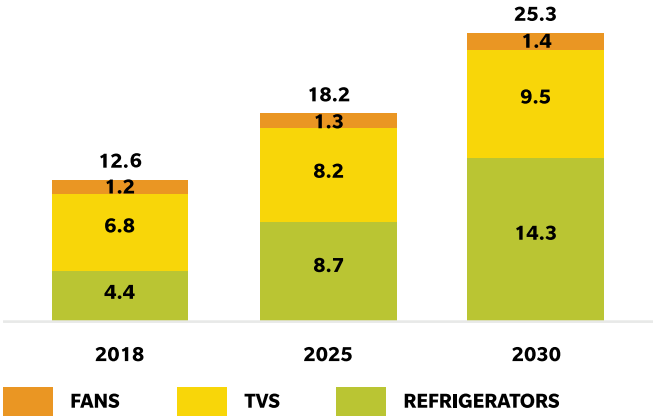
There is a significant potential market for off-grid appliances, which we estimate at USD 12.6 billion as of the end of 2018.[19] The addressable market, defined as the number of households which could acquire an off-grid appliance if financing was available, is linked to the current price of any given appliance and consumers' disposable incomes.[20] Using fans, televisions, and refrigerators as a market proxy, we estimate that the addressable market for off-grid appliances is up to half of the total global off-grid and weak-grid population. Using the latest available market data, as of the end of 2018, the addressable market ranged from 68 million households for expensive products like off-grid refrigerators (i.e. 15% of total off-grid and weak-grid households) to 221 to 232 million households for televisions and fans (approximately 50% of off-grid and weak-grid households).

11. Average annual household energy consumption is approximately 11,000 kWh in the US (of which 35-40% is linked to household appliance use), in the 3,500-6,500 kWh range for Western Europe, 900-1200 kWh in India, 500-1000 kWh in Nigeria, and only 50-500 kWh for most rural Africa, in line with the IEA rural energy poverty line of 50 kWh per capita, or roughly 250 kWh per household annually (based on World Energy Council, GOGLA, and IEA data).
12. Dalberg review of national energy survey and utility data; the developed world average is based on the average household appliance figures for the United States, UK, Spain, Korea, Singapore, and Japan.
13. The Dalberg estimate for TV and refrigerator penetration in Sub-Saharan Africa is based on 2012-2018 Development Health Survey (DHS) data across the 20 largest Sub-Saharan African countries which account for 83% of the region's total population; penetration for the others is based on the regional average (excluding outlier of South Africa); assumes up to 1.2 televisions per household based on Nigeria energy survey data.
14. Japan estimate extrapolated from Matsumoto, S., "Household Income Structure and Electrical Appliance Ownership: Evidence from Japanese National Household Survey", IJEEP, 2016, https://www.econjournals.com/index.php/ijeep/article/view/1483/929.
15. Dalberg analysis of the most recent regional DHS datasets (2012-2018) and using 2018 population and urban/rural share data.
16. Ibid.
17. Leo, B., et al, *What Can We Learn About Energy Access and Demand from Mobile-Phone Surveys? Nine Findings from Twelve African Countries*, CGDEV, 2018, https://www.cgdev.org/sites/default/files/what-can-we-learn-about-energy-access-and-demand-mobile-phone-surveys.pdf.
18. Lee, K., et al, "Appliance Ownership and Aspirations among Electric Grid and Home Solar Households in Rural Kenya", *American Economic Review: Papers and Proceedings*, 2016, http://emiguel.econ.berkeley.edu/assets/miguel_research/75/Lee_Miguel_Wolfram_2016a.pdf
19. Dalberg analysis, 2019. Market data based on fans, televisions, and refrigerators.
20. We estimate the total addressable market size by overlaying affordability on off-grid and weak grid household numbers. The obtainable market is further constrained by the availability of consumer finance and accessibility of the household to off-grid appliance distributors. Market sizing was developed for eight deep-dive countries and then extrapolated globally. Further details on the methodology and data sources are provided in the body of the report.

We estimate that the total obtainable market, while still substantial, is significantly smaller than the addressable market because access to finance is limited across many markets in sub-Saharan Africa and South Asia. Customer accessibility is a further constraint—distributors must be able to physically reach households to sell, service, and, if necessary, reclaim appliances. Factoring in these access to financing and physical accessibility barriers reduces the number of obtainable households to around 39 million for fans, 36 million for TVs and 11 million for refrigerators.[21]

The cumulative market opportunity across televisions, fans, and refrigerators is estimated at USD 12.6 billion globally. The market has the potential to double to USD 25.3 billion by 2030, driven primarily by refrigerator and television demand.

Figure 1: Cumulative market potential (USD billions)



Source: Dalberg market sizing

How has the off-grid appliance sector evolved in recent years?

In the three years since the first State of the Off-Grid Appliance Market Report[22] was published, the market has continued to grow rapidly. While comprehensive data on off-grid appliance sales is not currently available, self-reported data from individual manufacturers and distributors and other market proxies like solar home system sales suggest that, in aggregate, sales for off-grid appliances such as televisions, fans, and refrigerators have grown 50-80% annually. As a result of a few years of fast-growing sales, we estimate the total number of off-grid TVs, refrigerators, and fans in use in people's homes and small businesses today to be in the low millions.[23]

The members of GOGLA and companies that have participated in the Global LEAP Awards or engaged with the Low Energy Inclusive Appliances Program (LEIA) (collectively referred to as 'affiliates'), which most likely account for a minority of all off-grid television sales in many markets, reported selling 147,000 off-grid televisions, largely in Sub-Saharan Africa, in the second half of 2018 alone.[24] Fan sales from the second half of 2018 across all affiliates totaled 175,000, and were mostly concentrated in South Asia. As with TVs, fan sales are only partly reflected in GOGLA data.[25] For instance, in 2018, a Bangladesh based results-based financing program supported by Energising Development (EnDev) led to the sale of over 120,000 off-grid fans, all meeting high performance requirements, but these sales were not all reflected in the GOGLA data. Off-grid refrigerator sales, due to the high prices of refrigerators and resulting affordability constraints, are an order of magnitude lower; approximately 6,000 were sold by affiliates in the second half of 2018.

There are several reasons for the rapid sales growth of the off-grid appliance market. One cross-cutting driver of this sales growth has been the rapid growth of the off-grid solar sector. Based on interviews with solar home system distributors and select appliance manufacturers, depending on the specific geography, 25-85% of solar home system kit sales, of which there are well in excess of a million annually across the developing world, now include an off-grid appliance.[26] Other drivers of sales growth include ongoing improvements in off-grid appliance performance and quality, growing investment into off-grid appliance manufacturers and distributors which allows them to build out their distribution networks, and—importantly—growing appliance affordability for some

21. Dalberg market sizing estimate, 2019.
22. CLASP & Dalberg Advisors, The State of the Off-grid Appliance Sector Report, 2017, https://efficiencyforaccess.org/publications/the-state-of-the-global-off-grid-appliance-market-2017
23. Assuming a 50-80% growth rate in sales and 20-50% share of GOGLA affiliate sales to the overall off-grid appliance market results in aggregate sales of 1.4 million to over 5 million TVs, refrigerators, and fans million since 2014. Adding in countries like Bangladesh and India, which are poorly reflected in GOGLA data, the aggregate number of off-grid fans, refrigerators, and televisions in use across the developing world is likely to be in the 5-10 million unit range. Of these, we estimate that the highly efficient branded off-grid appliances are still a minor (10-30%) share of the total market. More precise figures will become available in future publications as industry reporting and thus GOGLA and LEIA data improve.
24. GOGLA sales data based on an early 2019 GOGLA affiliate survey.
25. CLASP data, 2019.
26. Dalberg stakeholder interviews, 2019.

categories of products. For example, the average retail price of off-grid televisions tracked by CLASP fell by 23% (from USD 150 to USD 115) between 2015 and 2018.

Televisions have become a critical driver of off-grid solar uptake in many markets, representing the most in-demand appliance for off-grid households and the primary add-on for solar home system kits sales. Fans sales are gaining momentum in hot and humid markets – most notably in South Asia, South East Asia, and in specific markets in West Africa (e.g., Nigeria, Senegal, Côte d'Ivoire, Ghana)—and are seen as important "add-ons" to solar home system kits. While refrigerators and other large appliances continue to generate a lot of interest, products are not yet sufficiently affordable to enable distribution at scale, at least not for household use. Other household appliances like electric off-grid cookers, with an immediate focus on electric pressure cookers, are at an even earlier stage of product development and market maturity.

Alongside sales, other clear indicators of market growth include the number of manufacturers, distributors, and products in the market for off-grid appliances. Just five years ago, branded manufacturers of off-grid televisions, fans, and refrigerators which specialized in products designed for developing world off-grid and weak-grid consumers numbered just 2-5 enterprises per product category, with only a handful of products visible in Africa and South Asia during market visits.[27] By 2017, as part of the Global LEAP Awards program, CLASP was already tracking dozens of high-quality, off-grid appropriate appliance manufacturers – 11 refrigerator manufacturers with 20 products, 8 television manufacturers with 15 products, and 7 off-grid fan manufacturers with 17 products.[28] These numbers have continued to grow. As part of the 2019 Global LEAP Awards round for off-grid refrigerators, CLASP received 39 submissions from 21 manufacturers across 15 countries and Hong Kong—67% of manufacturers were first time participants. The resulting growth in manufacturer numbers and product variety is already visible on the ground. For example, in 2018, during a survey of off-grid appliances available for sale in 10 rural markets in Tanzania, CLASP identified 16 unique brands across 12 TVs, 11 fans, and 2 refrigerators.[29]

Business models around off-grid appliance manufacturing and distribution are rapidly becoming more specialized as more players enter the space and the sector matures and becomes more competitive. Off-grid solar companies, the fastest growing segment of the off-grid appliance market, primarily focus on establishing long-term relationships with customers and upselling them appliances since selling durable, high-quality appliances is a great way to ensure sustained demand for solar system sales. Outside of this off-grid solar specialist segment, large, branded original equipment manufacturers (OEMs) are increasingly important as direct sellers to small retail outlets and as overall drivers of off-grid appliance market growth. Manufacturers of generic appliances (both AC and DC) are also growing, though due to a lack of publicly available data their pace of growth is difficult to quantify relative to other company segments. Their products are typically less energy efficient but more affordable than branded off-grid appliances, and are widely distributed in markets where there are few established off-grid solar home system players.

Beyond the off-grid solar sector, there is also increased interest from mini-grid developers in facilitating sales of appliances on-site to drive energy demand and generate value for their customers.[30, 31] Many mini-grid developers are focused on selling conventional rather than efficient appliances because their primary objective is to maximize energy consumption and thus tariff revenues. An increasing number of mini-grid actors, however, particularly those in Africa which are focused on household energy access, are starting to focus on the efficient appliance opportunity as a lever for extending the impact and viability of their business models. Several have now entered into or are exploring partnerships with efficient off-grid and weak-grid appliance manufacturers, a trend that will accelerate substantially in coming years.

The drive toward improved efficiency has been the central focus of off-grid appliance innovation. Among off-grid appliances tested by CLASP, the range in efficiency between average and best-in-class devices is high – the most efficient devices are 1.5x more efficient than the average for fans, 2x for TVs, and nearly 3x for refrigerators.[32] This means that even with relatively higher costs for super-efficient off-grid appliances, the total system costs for the customer can be significantly reduced by investments in system efficiency, thereby improving overall affordability and customer uptake.

27. Dalberg proprietary research, 2019.
28. See Global LEAP Awards Global Buying Guides, 2016-2017. See, e.g., https://clasp.ngo/publications/global-leap-awards-2017-buyers-guide-for-off-grid-fans-televisions.
29. CLASP, Appliance Data Trends, Efficiency for Access Coalition, 2018, https://efficiencyforaccess.org/publications/appliance-data-trends.
30. McCall, M. & Santana, S., Closing the Circuit: Stimulating End-Use Demand For Rural Electrification, Rocky Mountain Institute (RMI), 2019, https://rmi.org/insight/closing-the-circuit/.
31. CrossBoundary and Energy 4 Impact. Innovation Insight: Appliance Financing. 2019. https://www.crossboundary.com/wp-content/uploads/2019/08/CrossBoundary-Innovation-Lab-Innovation-Insight-Appliance-Financing-Final-07-Aug-2019-1.pdf
32. CLASP testing data from the Global LEAP awards.

It is therefore not surprising that off-grid appliance manufactures have been very focused on efficiency improvement. Success in this direction is most evident for televisions, where Global LEAP Awards data shows a 45% improvement in average off-grid TV efficiency from the 2013-2014 to the 2016-2017 Award rounds.[33] Efficiency gains for fans have been more modest, in the order of 10% from 2015 to 2017, but meaningful further improvement is possible with brushless DC motor and blade design innovation. In the case of refrigerators, much more significant efficiency improvement is required to improve affordability for households and small businesses. Promising innovations in brushless DC motors, variable speed compressors, and insulation materials and designs (e.g., phase-changing materials) suggest that efficiency improvements of 50% are achievable within the next few years and should help significantly grow the off-grid refrigerator market once achieved.[34]

Beyond efficiency and affordability, innovation has also increasingly focused on quality and consumer-adapted performance. As the off-grid appliance industry grows, it is developing a better understanding of customer behavior, preferences and ability to pay for particular appliances. In particular, companies are focusing more on product performance and customer-ready features. Prominent examples of such off-grid appliance features includes resistance to dust and humidity that characterize rural off-grid settings or, for instance, the integration of internet connectivity into the off-grid television set-top box for greater customer convenience. Our interviews show that while product price continues to be the primary driver of purchasing behavior, off-grid and weak-grid customers also care deeply about product quality, convenience of use, and aspirational features such as modern, aesthetically-pleasing form factors.

Consumer financing models, which are critical to sales growth, have also evolved over the past three years, driven by a deepening financial inclusion effort across off-grid markets. In this period, there has been tremendous growth in mobile money use (e.g. a 20 – 50% uptick in mobile money penetration in East Africa depending on country), and a 50% average increase in bank account ownership in markets where mobile money penetration is low,[35] along with a broad trend of increasing availability of mobile money across many regions. As off-grid appliances become larger and more sophisticated, a corresponding growth in financing options is critical to making these products affordable and commercially viable. In India, microfinance institutions (MFIs) have been the driving force in access to off-grid appliances—many now provide asset financing for a variety of appliances, ranging from conventional on-grid appliances to off-grid appropriate appliances. In sub-Saharan African markets with high mobile money penetration, such as Kenya, Rwanda, and Uganda, pay as you go (PAYGO) financing provides low-income consumers an affordable entry point for appliance access. For large developing markets with limited mobile money penetration such as Ethiopia and Nigeria, the lack of financing for off-grid appliances has constrained the growth of the market. Within the industry, there is a deeper understanding of these financing mechanisms in the past few years, along with a shared concern around default rates, especially with larger off-grid systems, and a growing recognition of the risks of over-burdening low income off-grid households with debt.

The broader ecosystem for energy access—including policymakers, regulators, investors, development actors—is gradually placing more emphasis on off-grid appliances. The off-grid appliance sector has been supported proactively in recent years by development partners such as UK aid, the World Bank, the German Society for International Corporation (GIZ), US Agency for International Development, Shell Foundation, and IKEA Foundation via bilateral initiatives such as the LEIA program as well as multi-donor programs. The Efficiency for Access (EforA) Coalition, a partnership of 15 public funders, philanthropies, and international agencies whose programs include LEIA and Global LEAP, among many others, was launched in 2018 to accelerate global energy access through energy efficient appliances. After rapid growth, EforA now has programs and initiatives spanning 44 different countries and 22 off-grid and weak-grid appropriate technologies.

In the meantime, impact investors looking to harness off-grid solar and mini-grid penetration are channelling growing volumes of patient equity capital and concessional debt to drive off-grid appliance sector growth. Civil society organizations such as CLASP and industry associations like GOGLA that play a role in market governance are furthering quality assurance and standards in an attempt to create a more transparent, competitive environment—and ultimately better choices for consumers. Growing grant funding is also supporting R&D for advancements in off-grid appliances, as exemplified by the EforA R&D fund, and the 2019 launch of a new specialized intermediary focused on global off-grid appliance innovation, the Access to Energy Institute (A2EI).

The growth of off-grid appliance ecosystem funders and intermediaries is expected to accelerate in the coming years as technologies improve, financing and distribution models are refined, and new appliance categories are introduced to the off-grid market.

33. Reflects an improvement in the TV efficiency index from approximately 38 to 55 inches per watt based on CLASP research.
34. Efficiency for Access Coalition. Off-grid Refrigeration Technology Roadmap. 2019. https://storage.googleapis.com/e4a-website-assets/Refrigeration-Roadmap_FINAL.pdf
35. World Bank, Global Findex Database, 2019.

What are the main barriers to growth?

Consumer affordability is the most significant constraint for the growth of the off-grid appliance market; access to capital for product innovators and distributors is also important. For example, in Kenya, which is one of the leading hubs of off-grid appliance innovation and uptake globally, nearly half of consumers are still unable to afford an average priced off-grid television and solar home system bundle even with standard consumer financing terms.[36] On the supply side, manufacturers struggle to lower the retail price of off-grid appliances given the high costs of distributing to off-grid and often last-mile regions. Given the nascency of most off-grid appliance technology, and still emerging demand in most markets, many manufacturers are unable to offer competitive pricing due to small order volumes. Furthermore, at this early stage of market development, even as underlying appliance component costs decline and provide opportunities to manufacturers to improve their margins, market actors are investing their profits into continued product innovation and scale-up of sales operations rather than by lowering prices for consumers to build market demand. These market dynamics constrain sector growth. This is especially true for larger, more expensive products such as off-grid refrigerators, which retail at around USD 900 in various African markets and have not had notable reductions in absolute price levels even while the performance to cost ratio has improved dramatically in recent years. This will likely change, however, as off-grid appliance manufacturers and distributors reach larger scale thereby driving down costs, and as the entry of new manufacturers and distributors puts competitive pressure on appliance prices in the most mature markets.

Governments are working to change or create policies in favor of off-grid solar expansion; however, off-grid appliances are not explicitly included in many of those efforts. Most countries have established ambitious electrification plans that are at various stages of implementation. In Nigeria, Kenya, and India, for example, there are dedicated national programs to increase off-grid electricity access. These plans, however, do not explicitly include off-grid household appliances. The lack of quality assurance policies exposes off-grid appliance customers to the real risks of poor-quality products. Few countries have subsidy programs or results-based financing (RBF) facilities targeting appliances, though several do for solar home systems. Most markets do not have tax incentives for off-grid appliances, and those that do have inconsistent application, making products more expensive for customers than they should be.

What needs to happen to accelerate growth?

The off-grid appliance market has the opportunity to drive substantial gains in—and greater impact of—electrification efforts by unlocking latent demand for energy-enabled services. We expect the market to evolve significantly over the next 5-10 years based on increased affordability due to higher incomes, declining appliance prices in line with historical trends (e.g. 30% decline in TV prices), and better access to consumer financing as well as growing access to off-grid and mini-grid electricity. Factoring in these trends, we estimate that the potential market could double to a USD 25 billion market opportunity by 2030. Likewise, the potential reach of off-grid appliances should grow substantially, from an obtainable market of 39 million households in 2018 to almost 60 million households in 2030, a roughly 50% growth in the number of households who should have the opportunity to benefit from off-grid appliance access and resulting quality of life improvements and economic benefits.

The market fundamentals for off-grid appliances are strong, they just require the right encouragement and support. The key to reaching this market potential are greater affordability which can be achieved through improved access to low-cost consumer financing tailored for off-grid appliances, better economies of scale in production and distribution, and ongoing technology innovation focused on boosting product efficiency and lowering costs. Other important drivers for faster off-grid appliance sales growth include deeper manufacturer and distributor insights into consumer needs to inform appropriate product development and distribution strategies, investment into customer awareness of off-grid appliances and their benefits, and donor and government support for enabling regulations and initiatives including: tax/tariff abatement for off-grid appliances, policy support for DC mini-grid development, public good investment into appliance R&D, support for market intelligence activities, and critical support for off-grid appliance quality standards which protect consumers.

36. Dalberg analysis, 2019, based on World Bank income data.

In line with these drivers for sector growth, several recommendations feature prominently in the report:

Government policies should further recognize the importance of driving energy demand through off-grid and weak-grid appliances within their electrification initiatives, and act accordingly.

National energy policies should explicitly support off-grid appliance technologies. Today, many policy actors and some donors consider off-grid appliances such as televisions, fans, and refrigerators to be luxury items. Likewise, some developing countries provide tax incentives for agricultural or fisheries equipment, without including productive use appliances like solar powered refrigerators or solar water pumps under such tax and duty exemptions. This narrative should be challenged and reframed to ensure that decision makers understand the transformative impact that efficient appliances—including both household and productive use appliances— can have on off-grid households and small businesses.

The argument for privileged regulatory and trade treatment of efficient off-grid appliances is particularly compelling for productive use equipment, but even in the case of household appliances covered in this report there is a strong case for governments to treat efficient appliances designed for off-grid settings, which contribute to energy access and drive demand, differently from on-grid appliances. Understanding this narrative and the role of appliances in reaching many of the SDGs can help governments move forward in developing sector support programs that incentivize efficient appliance uptake and adoption at scale.

Beyond taxes and tariffs, policy support for off-grid appliances requires governments to embrace well-designed off-grid appliance quality and efficiency standards. Furthermore, as mini-grid markets develop with the massive upcoming investments into the mini-grid sector that are projected over the next decade, support will be needed to create tariff structures and delivery models that incentivize the deployment of high quality, energy efficient appliances. Mini-grid developers do not have the same incentives to encourage the use of energy efficient appliances as solar home system providers because, in many cases, their business models depend on increasing energy consumption. However, as a number of mini-grid sector leaders are starting to acknowledge, it is more sustainable in the long term and in the best interest of customers to deploy high quality and energy efficient appliances on mini grids as it will improve the amount of energy services that customers receive for each watt paid for. Moreover, many of the technical innovations that have been made in the solar home system (SHS) sector to improve appliance durability and efficiency, while also considering affordability constraints and user preferences, will also be applicable to the mini grid sector.[37]

The financing of off-grid and weak-grid appropriate appliances should continue to be supported by donors and impact investors.

Even with business model innovation and falling appliance costs, the widespread scale-up of off-grid appliances will require many USD billions of consumer financing. Developing the consumer financing market for appliances will require substantial amounts of concessionary debt and risk capital from donors and impact investors.

As the off-grid appliance industry matures, not all of the consumer financing should be channeled via vertically integrated appliance distribution businesses as is currently the norm. Instead, donors and sector intermediaries should encourage banks, micro-finance organizations, and new specialist financiers which have relevant financial risk assessment and risk management competencies (and access to capital) to engage on the off-grid appliance financing opportunity. Such a shift would allow for more needed financial innovation—for example, adjustment of repayment periods to match harvest seasons in rural areas—and more streamlined and asset light business models for appliance distributors in line with a general move to greater business model specialization apparent in the off-grid solar sector.

The wealth of data produced by off-grid appliances should also enable development finance institutions (DFIs), philanthropic donors, and impact investors to develop new types of financial instruments, most notably, results-based financing schemes for consumers or value chain intermediaries (i.e., incentive payments tied to appliance uptake and use) that should address affordability constraints and thus help drive much broader consumer demand.

37. For a discussion of the linkages between mini-grid development policies and the off-grid appliance market see: Kopec, G., et al., The future of direct current electrical systems for the off-grid environment, Smart Villages, 2017, https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/TR8-The-future-of-direct-current-electrical-systems-for-the-off-grid-environment-web.pdf.

Consumer protection should become a more prominent feature of donor and sector intermediary off-grid appliance promotion initiatives.

One of the more pressing consumer protection issues for off-grid appliances is the development and dissemination of well-defined product quality standards, support for product testing and certification programs to help consumers differentiate between low and high quality products, and related consumer protection measures like the broader adoption of consumer warranties to limit consumers' financial risk and promote uptake. At the same time, appliance quality standards should not be overly restrictive during this early stage of market development to avoid impeding experimentation and innovation.[38]

The off-grid appliance industry should also ensure that consumer lending is done responsibly and does not over-burden off-grid households with debt, particularly because the average transaction size for off-grid appliance purchases (e.g. refrigerators) is substantially higher than for basic off-grid energy access kits. Repeated experience in other sectors such as micro-finance shows that self-regulation is challenging without significantly improved transparency on customer transactions, common financing standards, and appropriate intermediary bodies.

In addition, the off-grid appliance industry must provide regulations for data collection, security, and privacy since many off-grid household appliances feature Internet of Things (IoT) functionality (e.g. to monitor and remotely optimize appliance performance) and are thus starting to capture significant amounts of data on customer behavior, often with minimal disclosure and a lack of systematic thinking about customers' data privacy and security concerns.

Donors and other off-grid sector intermediaries should build multinational company and investor awareness around the large financial opportunity in appliances and provide targeted market entry support.

The potential of multi-national actors to bring incremental R&D resources and manufacturing scale could be transformative for the industry. This includes long-established global branded appliance and electronics players as well as large scale generic appliance manufacturers in Asia, most notably China. The entrance of such multi-national corporations into the market could precipitate a step change in technology and significantly lower prices in the off-grid market, increasing the competitiveness of the industry. Furthermore, the energy efficiency advancements made in off-grid appropriate appliances could also be retrofitted to on-grid appliances already being distributed by large corporates at scale throughout the developing world, helping support a move to reduced fossil fuel emissions globally.

While some multi-national companies and commercial investors are beginning to see the potential—in particular, the USD 10 billion television opportunity—donors and governments could play a decisive role to encourage this by providing more support for private sector actors to enter the off-grid appliance market. Potential levers of support relevant for large corporations and commercial investors include: developing market intelligence and business cases to highlight the economic opportunity, which can help regional executives and product development staff win internal arguments about resource allocation and customer prioritization; targeted advocacy and recognition (e.g. off-grid impact awards) for those private sector actors that are interested in garnering recognition for their SDG contributions; and—critically—improvements in the enabling environment, including streamlined certification and importation procedures and beneficial tax and tariff regimes (e.g. tax holidays, tariff/VAT reduction) for high priority appliances that advance government priorities.

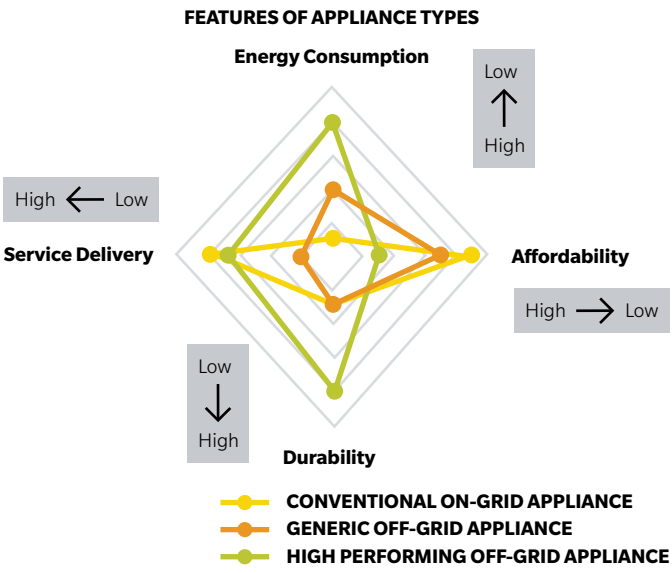
38. Efficiency for Access. Promoting High Performing Off-grid Appliances. 2019. https://storage.googleapis.com/e4a-website-assets/Promoting_High-Performing_Off-Grid_Appliances.pdf

What are off-grid appliances?

There is a growing need for appropriately designed, efficient, and cost-effective off-grid appliances capable of delivering modern energy services to underserved communities. The distribution of standalone solar energy systems and the installation of mini-grids in regions previously without reliable grid access, largely in South Asia, Southeast Asia, and Sub-Saharan Africa are improving energy access for households with limited resources. Still, for these households, energy supply remains low, and energy efficiency therefore remains a top priority for both the consumers and the energy service providers that serve them. There is a growing market for appliances that are designed specifically to operate in off-grid environments and that offer affordable upfront pricing and modest ongoing energy costs.

Off-grid appliances are appropriate for use in both off-grid and weak-grid contexts where standalone solar energy systems have insufficient capacity to power conventional electric appliances. Because they run on lower-load energy systems, off-grid appliances are typically compatible with DC systems, but also include AC appliances combined with inverters. Off-grid appliances include both ***generic off-grid appliances*** (typically designed to optimize price over performance) and what this report refers to as ***off-grid appropriate appliances*** (designed to optimize energy performance, service delivery, and quality).

Figure 2: Categorization of appliance types



CONVENTIONAL ON-GRID APPLIANCE	Domestic appliance that is powered by mains electricity (AC power supply) and are used in on-grid households, typically with stable and constant electricity supply.
GENERIC WEAK- AND OFF-GRID APPLIANCE	Generic, unbranded solar appliances are sold in grey market and are substandard in terms of performance and quality.
HIGH PERFORMING WEAK- AND OFF-GRID APPLIANCE	High-quality and efficient off-grid appliances that are intentionally-designed for end users living in energy-constrained environment and advertised for use with a PV module or a solar home system.

Source: CLASP

The report focuses on household off-grid appliances and in particular on three of the most in-demand product categories: televisions, fans, and refrigerators.[39] When we refer to ***off-grid appliances*** in this report, we mean both ***generic*** and ***high-quality, off-grid appropriate*** versions, unless otherwise specified.

Beyond the household, there are also exciting dynamics in the very early stage off-grid productive appliance market, and this report is being launched alongside a supplement on small scale Solar Water Pumps (SWPs),[40] which are currently the most commercially mature category of off-grid productive use appliances. This report also complements the World Bank Lighting Global program's 2019 report on Productive Use Leveraging Solar Energy (PULSE), which focuses on a broader range of off-grid appliances for smallholder agriculture.[41]

Why is the market for off-grid appliances important?

Efficient appliances that are appropriate for off-grid and weak-grid markets are critical for increasing access to energy-dependent services. Most off-grid solutions sold today to service the needs of hundreds of millions households that have no or weak grid access provide only basic, low-power energy services, such as lighting and mobile phone charging. Off-grid and mini-grid consumers are not seeking electrification for its own sake, however, but rather as a pathway to goods and services that can improve their lives in tangible ways.

39. See top appliances categorized by perceived demand in CLASP, Off-Grid Appliance Market Survey: *Perceived Demand and Impact Potential of Household, Productive Use and Healthcare Technologies,* Efficiency for Access Coalition, 2018, https://efficiencyforaccess.org/publications/off-grid-appliance-market-survey.
40. Efficiency for Access Coalition, *Solar Water Pump Outlook 2019: Global Trends and Market Opportunities,* 2019. https://efficiencyforaccess.org/publications/solar-water-pump-outlook-2019-global-trends-and-market-opportunities
41. World Bank & Dalberg Advisors, *Productive Use Leveraging Solar Energy (PULSE),* World Bank Lighting Global Program, 2019 https://www.lightingglobal.org/resource/pulse-market-opportunity/

Off-grid populations are unable to access enough energy to power additional essential household services, such as home cooling, refrigeration, entertainment, and cooking. The new generation of increasingly affordable and off-grid and weak-grid appliances—appliances that are substantially more efficient than conventional appliances and can accommodate energy-constrained environments and intermittent power supplies—can address many of these unmet household needs.

Off-grid appliances create foundational demand for energy services and help to make off-grid business models viable. The most far-reaching impact of off-grid appliances—and the reason that such appliances are becoming the primary focus for many energy access stakeholders—is the role they can play in driving demand for off-grid energy and thus toward the achievement of Sustainable Development Goal (SDG) 7, universal energy access, by 2030.

The uptake of appliances in off-grid regions establishes a base level of demand to justify future investment into energy generation and distribution by both private sector actors and governments. It also provides a means for distributed energy service providers to generate and monetize greater value per customer, thus supporting more sustainable energy businesses that can support the high overheads of building out rural sales and service channels.

Generating energy demand in this way has strong historical precedents from developed markets. When the United States was implementing its electrification program in the early 20th century, which boosted rural electrification from 10% in the 1930s to 96% by 1956, it did so by encouraging electric appliance use by providing financing and other market development support for household appliances such as refrigerators, washing machines, water heaters, and agricultural chilling equipment.[42] Similarly, in the UK, the Electricity Development Association, set up and financed by the electricity supply industry in 1919, played a crucial role in supporting urban and rural household electrification in the ensuing decades by promoting domestic demand for electrical appliances, most notably refrigerators, electric stoves, irons, and vacuum cleaners.[43]

Off-grid household appliances have wide-ranging positive impacts on poverty alleviation, livelihoods, health, and education. In addition to their role in advancing **energy access (SDG 7),** as outlined in Figure 3, emerging evidence suggests that household off-grid appliances also have broad positive impacts across multiple other SDGs, most notably SDG 1 (poverty reduction), SDG 2 (food security), SDG 3 (good health and wellbeing), SDG 4 (quality education), SDG 5 (gender equality), and SDG 8 (jobs and entrepreneurship). Productive use appliances strengthen the connection to SDGs including advancing agricultural transformation to contribute to SDG2 and SDG8 and increasing access to clean water (SDG6) with solar water pumps. We provide an overview of the major areas of impact in Figure 3.

Off-grid appliances support progress toward **SDG 1 (poverty reduction)** by providing livelihood opportunities for economically disadvantaged populations who can use them to earn or augment incomes. Recent Global LEAP survey data from Uganda shows, for instance, that micro and small enterprises (MSMEs) who had purchased off-grid refrigerators, increased their daily incomes 2.5-fold on average (from USD 29 to USD 70); half of these enterprises used the off-grid refrigerator to expand into new business lines (i.e., food and drink sales).[44] While rigorously quantified impact data is not available, beyond refrigerators, other off-grid household appliances (or 'dual-use' appliances suitable for both household and business use) with known income generation effects include televisions, electric shavers, and electric cookers. Off-grid appliances also help alleviate poverty by removing the need for poor households to pay for generator fuel or other costly energy sources. Even partial displacement of cooking kerosene and charcoal via electric cookers, for instance, is meaningful given the current cooking energy bill of USD 150-350 dollars annually for an average urban or peri-urban household cooking with such fuels in Africa.[45]

Off-grid refrigerators can contribute to improved **food security (SDG 2)** by helping to reduce post-harvest food waste and loss. Food losses in Sub-Saharan Africa are USD 4 billion annually; in India, alone, estimated annual losses range from USD 4.5-13 billion, of which roughly a third is food loss and waste at the point of household consumption.[46] Widespread refrigerator use by off-grid and weak-grid households and small businesses should therefore generate USD billions in annual savings.

Household off-grid appliances can also have significant positive impacts on **health (SDG 3).** Electric off-grid cooking solutions, including off-grid electric pressure cookers and induction stoves, can help to significantly lower the mortality and morbidity burden of indoor air pollution (IAP), which even in conservative estimates results in more than 4 million deaths annually, a greater public health burden than malaria, tuberculosis, and HIV/AIDS combined.[47] Off-grid refrigerators enable vaccine distribution and storage in remote areas. While this typically requires highly specialized cooling devices that

42. McCall, M. & Santana, S., *Closing the Circuit: Stimulating End-Use Demand for Rural Electrification,* Rocky Mountain Institute, 2018, https://rmi.org/wp-content/uploads/2018/10/RMI_SEED_Demand_Stimulation_2018.pdf.

43. See Hankin, E., *Buying Modernity? The Consumer Experience of Domestic Electricity in the Era of the Grid,* Manchester University, UK, 2012. https://www.research.manchester.ac.uk/portal/files/54530980/FULL_TEXT.PDF.

44. LEIA survey data. See also Lai, E. et al., *Off-grid appliance performance testing: results and trends for early-stage market development,* Efficiency for Access Coalition, 2019, https://efficiencyforaccess.org/publications/off-grid-appliance-performance-testing-results-and-trends-for-early-stage-market-development.

45. Dalberg calculations based on average fuel prices and household cooking fuel consumption data from World Bank multi-tier framework (MTF) surveys and proprietary country level survey work in Africa.

46. See FAO, *How access to energy can influence food losses: A brief overview,* 2016, http://www.fao.org/3/a-i6626e.pdf. In contrast to the FAO estimate, the high end food loss and waste estimate for India is Rs 92,000 crore, or roughly USD 13 billion. Central Institute of Post-Harvest Engineering and Technology (CIPHET), 2014.

47. World Bank (ESMAP) & Dalberg Advisors, T*he State of the Global Clean and Improved Cooking Sector,* 2015. See also, Access to Energy Institute (A2EI), *The Desirability of Clean Cooking in Off-Grid Households,* 2019, https://a2ei.org/resources/uploads/2019/06/A2EI_The_Desirability_of_Clean-Cooking_in_Off_Grid_Households.pdf.

Figure 3: Household Off-Grid Appliances and SDG Linkages

Sustainable Development Goal Linkages in Detail

All appliances expand access to modern energy services (SDG 7) by allowing consumers to maximize their solar home systems and achieve higher tiers of energy access.

However, appliances also deliver critical energy services such as refrigeration, cooling, and communications that improve the lives and incomes of under-served households and communities.

Improve efficiency, reduce drudgery, and provide new farmers with new income-generating opportunities.

Reduce post-harvest loss and give small business new opportunities, such as cold beverage sales.

Extend potential working hours for households and businesses.

1 NO POVERTY

2 ZERO HUNGER

Improve the efficiency & quantity of food production, particularly for staple crops.

Improve crop yields and climate resilience.

Reduce food waste and post-harvest loss.

Reduce food insecurity by providing households with better nutrition.

Reduce indoor air pollution and health risks caused by inefficient biomass stoves/open fires.

Expand access to quality medical care and reduce maternal and childhood mortality.

Reduce drudgery and save time, allowing women and girls to pursue other opportunities or an education.

5 GENDER EQUALITY

8 DECENT WORK AND ECONOMIC GROWTH

Improve productivity and income-generating opportunities for farms and households.

Create a more informed and educated workforce and expand income-generating opportunities.

Improve the quality of working environments by expanding access to cooling technologies.

perform to WHO vaccine storage standards,[48] household off-grid refrigerators can likely be adapted to other beneficial cold storage uses in off-grid, low resource medical settings such as rural clinics. Off-grid refrigerators can impact health outcomes by improving food safety and nutrition diversification via longer food shelf lives at the household level.[49] Finally, off-grid fans improve general household wellbeing in hot and humid climates and can be lifesaving during heatwaves,[50] which are forecasted to increase in severity and frequency, leading to nearly 100,000 deaths annually by 2030.[51] Recent studies also suggest that solar-powered fans can address the thermal discomfort that serves as one of the major barriers to more widespread nighttime use of anti-mosquito nets, thereby helping increase mosquito-net adoption and, by extension, reducing malaria prevalence.[52]

Access to news and information via off-grid televisions and connectivity devices (e.g., off-grid Wi-Fi routers) can lead to higher levels of **education access and achievement (SDG 4)** and foster positive behavior change, including financial decisionmaking, family planning, literacy, and political participation and voice. A widely-cited study in India, for instance, concluded that increased access to television resulted in improved status of women in rural households; the effects included improved behavioral changes in low preference for female children, attitudes toward spousal abuse, and efforts toward child education.[53] Research has also found that social messages embedded in serial dramas with gripping storylines change financial decisionmaking, family planning, literacy, and health in Africa, Latin America, and Asia.[54] Electric fans can also improve educational attainment by improving school attendance.[55]

Household off-grid appliances such as electric cookstoves and refrigerators, and at higher energy levels, washing machines and clothing irons, can also be important contributors to greater **gender equality (SDG 5)** when they reduce time poverty for women. In the case of electric cookstoves, this could mean up to 4 hours of daily time savings for women from reduced or eliminated wood fuel collection times, shorter cooking times, and the reduction in household clean-up chores.[56] While data for such impacts in off-grid settings is currently scarce, in the developed world, electrification and hours spent on housework have been highly correlated historically. For example, the time burden of housework for women in the United States has decreased by approximately 70% from 45 to 15 hours weekly over the 80 year period during which the penetration of modern refrigerators, vacuums, irons, washing machines, stoves, and other household appliances has seen broad uptake from levels typical in rural Africa and South Asia today to nearly universal penetration and use.[57]

Off-grid appliances also contribute to **jobs and entrepreneurship (SDG 8)** by creating new jobs for appliance manufacturing, distribution, and after-sales support and, more directly, via new income generating activities through household appliances that have productive uses and, naturally, via all off-grid non-household productive appliances which are not the focus of this report. While there is little data on the specific job creation impacts of household off-grid appliances, there is a growing literature on the very significant jobs impacts of the overall off-grid solar energy ecosystem. Power for All conducted a jobs census in the distributed renewable energy sector and found that in 2017-2018 the sector provided 109,000 direct, formal jobs across Nigeria, India, and Kenya.[58] A recent analysis from GOGLA estimates that the off-grid solar industry will support over 1.3 million jobs by 2022 including around 220,000 high skill jobs, 290,000 medium skill jobs and 800,000 lower skill positions.[59]

Off-grid appliances are increasingly becoming a critical element of the broader global push towards greater energy efficiency and greenhouse gas emissions reduction. Satisfying the appetite for energy access and modern life-changing appliances with super-efficient off-grid and weak-grid appliances represents a major opportunity to ensure that the next billion households to be electrified will start from the outset with high quality energy-efficient devices that minimize costs to the consumer and net impacts to the environment thereby contributing to **climate action (SDG 13).** The efficiency improvements required to develop these appliances should in time also influence the conventional appliance segment as the industry converges. The positive impacts of efficient appliances on climate change mitigation and adaptation has been long-established in the developed world context,[60] and is increasingly the focus of research on off-grid and mini-grid energy solutions and off-grid appliances for the developing world.

48. CLASP, *Off-grid Refrigeration Technology Roadmap,* Efficiency for Access Coalition, 2019, https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/Refrigeration-Roadmap_FINAL.pdf
49. FAO. *Nutrition-sensitive agriculture and food systems in practice* (2017), http://www.fao.org/3/a-i7848e.pdf.
50. Ravanelli, N. M., "Electric fan use in heat waves: Turn on or turn off?", *Temperature,* 3(3): 358–360, 2016, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5079223/.
51. World Health Organization (WHO), Climate Change and Health Resource Document, 2018, http://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.
52. Jaeger, M. et al., "Perceptions on the effect of small electric fans on comfort inside bed nets in southern Ghana: a qualitative study", Malaria Journal, 2016, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5134074/.
53. Jensen, R. & Oster, E., "The Power of TV: Cable Television and Women's Status in India," *The Quarterly Journal of Economics,* 2008, http://bit.ly/1V42jx5.
54. See television impact case studies covered in CLASP & Dalberg Advisors, *The State of the Global Off-grid Appliance Market,* Global LEAP, 2017, https://efficiencyforaccess.org/publications/the-state-of-the-global-off-grid-appliance-market-2017.
55. Rewald, R., *Energy and Women and Girls: Analyzing the Needs, Uses, and Impacts of Energy on Women and Girls in the Developing World,* Research Backgrounder Series, Oxfam, 2017, https://www.oxfamamerica.org/static/media/files/energy-women-girls.pdf.
56. See World Bank (ESMAP) & Dalberg Advisors, *The State of the Clean and Improved Cooking Sector,* 2015, http://www.esmap.org/sites/esmap.org/files/DocumentLibrary/ESMAP_State_of_Globa_Clean_Improved_Cooking_sector_Optimized.pdf
57. Greenwood, J. et al., "Engines of Liberation", *Journal of Economic Studies,* 2016, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.820.3630&rep=rep1&type=pdf.
58. Power for All, *"Powering Jobs Census 2019: The Energy Access Workforce",* 2019. https://www.powerforall.org/resources/reports/powering-jobs-census-2019-energy-access-workforce
59. GOGLA and Vivideconomics, *Off-Grid Solar, A Growth Engine for Jobs Off-grid Solar: On the level, nature and wider impact of employment opportunities in the off-grid solar sector,* GOGLA, 2019, https://www.gogla.org/sites/default/files/resource_docs/gogla_off_grid_solar_a_growth_engine_for_jobs_web_opt.pdf
60. In the context of the United States, see for example, ACEEE, *The Greatest Energy Story You Haven't Heard: How Investing in Energy Efficiency Changed the US Power Sector and Gave Us a Tool to Tackle Climate,* 2016, https://aceee.org/research-report/u1604.

What are the objectives of this report?

This report analyzes major trends in the off-grid appliance sector, establishes the sector's position as a fast-growing and attractive market, and seeks to mobilize investment and policy support to accelerate the sector's growth. The report seeks to build on the seminal *The State of the Off-grid Appliance Market* report, published in 2016 by the Global LEAP program, which was the first comprehensive report on the state of the global off-grid household appliance sector.[61] It provided the first-ever snapshot of the global off-grid appliance market via data-driven analysis of the scale, market trends, and barriers for three important and promising appliance categories: televisions, refrigerators, and fans. This report refreshes the 2016 analysis and builds upon the earlier findings, adding further data from recent Efficiency for Access Coalition research, GOGLA survey data on appliance sales, a review of the broader scholarly literature, updated interviews with key off-grid appliance enterprises, and country deep-dive profiles for eight countries across South Asia and Sub-Saharan Africa to illustrate the diversity of sector challenges and opportunities.

Specifically, to support the Efficiency for Access Coalition and other industry actors, this report seeks to:

- Build on the evidence base established in the 2016 State of the Off-Grid Appliance Market report to share the latest information and insights about the rapidly evolving off-grid appliance space
- Make a case for why off-grid appropriate appliances are critical to energy access
- Attract technology start-ups and major appliance manufacturers into the appliance space
- Mobilize capital for off-grid appliance R&D, growth equity, working capital, and consumer finance
- Support continuous improvement in the quality of product offerings
- Identify pathways to accelerate growth in the off-grid appliance market
- Raise a call to action to industry actors for greater investment, collaboration, and innovation in the spirit of building a thriving off-grid appliance market.

What is the scope of the report?

This report focuses on the market for efficient off-grid and weak-grid household appliances.

Three of the off-grid household appliances most in-demand globally are televisions, fans, and refrigerators.[62] This report focuses specifically on these three appliances as a broader proxy for overall off-grid household appliance trends.[63] These appliances are appropriate for off-grid and weak-grid energy settings because they require less energy than other household appliances that households find desirable, such as electric off-grid cookers, air conditioners, and clothing irons. For the same reason, they are the furthest along in product development, but are still characterized by very nascent market development and relatively fast-growing sales.

Off-grid televisions, in particular, are in very high demand. Consumers view television ownership as a key marker of economic and social status, and a critical access point to information and entertainment. Fans are very popular in South Asia due to the hot and humid temperatures, and demand in select markets in West Africa is growing. Refrigerators are the next most desired appliance. However, they remain unaffordable for most off-grid and weak-grid customers, even when financing is available.

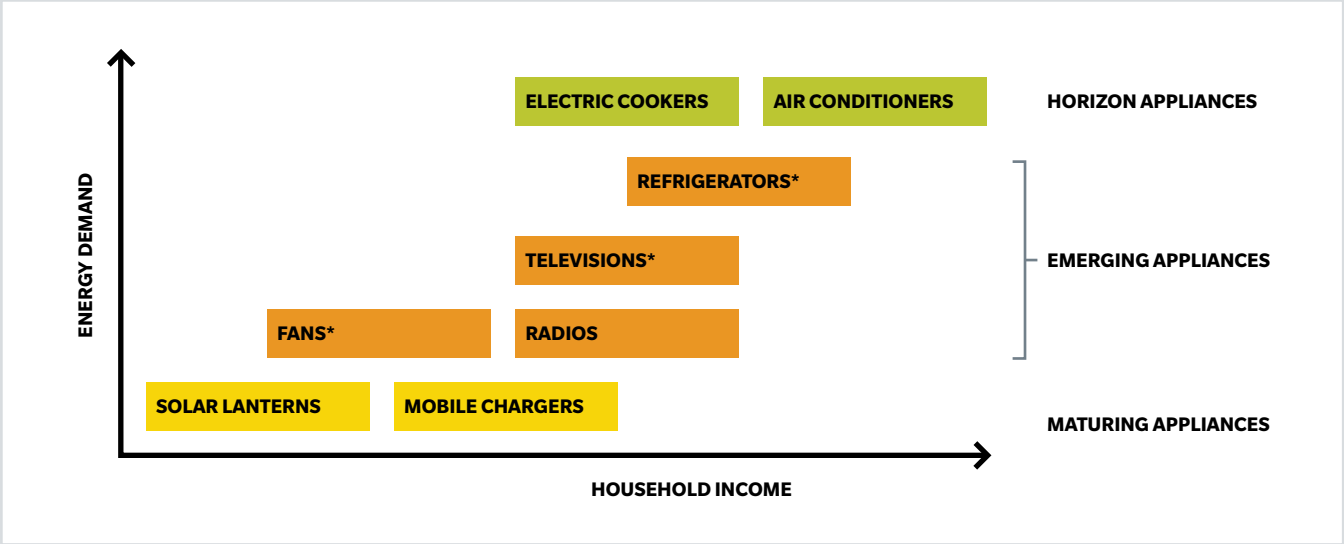
Other household off-grid appliances, noted in this report but not covered in depth, are also beginning to pique market interest and consistently rate highly in off-grid and weak-grid consumer surveys – most notably these include off-grid laptops and tablets, connectivity devices (e.g., Wi-Fi routers), and electric pressure cookers and induction stoves. In addition to these household appliances, agricultural off-grid appliances appropriate for smallholder farming (e.g., off-grid appliances for irrigation, cooling, processing, and drying) and off-grid productive-use equipment for small-scale industrial uses (e.g., welding, carpentry, construction) are likewise generating significant interest and growing research & development (R&D) spending from off-grid and mini-grid developers and several donors, most notably the World Bank Group, the Germany Corporation for International Cooperation (GIZ), the UK Department for International Development (DFID), and the US Agency for International Development (USAID), and philanthropic funders such as IKEA Foundation and Shell Foundation; all members of the Efficiency for Access Coalition.

61. The earlier report was published with the support of with the support of the Global Lighting and Energy Access Partnership (Global LEAP), a Clean Energy Ministerial initiative led by the U.S. Department of Energy. See https://www.gogla.org/sites/default/files/resource_docs/global_leap_-_the_state_of_the_global_off-grid_appliance_market_2016.pdf

62. CLASP, *Off-Grid Appliance Market Survey: Perceived Demand and Impact Potential of Household, Productive Use and Healthcare Technologies,* Efficiency for Access Coalition, 2018, https://efficiencyforaccess.org/publications/off-grid-appliance-market-survey.

63. Other appliances in the top 5 in terms of demand are radios and mobile phones. Off-grid radios are not covered in this report given the low cost of such appliances, their relative ubiquity in the off-grid market, and their lower impact potential relative to other appliances. Mobile phones, most notably smartphones, are a critically important appliance, but are also excluded from this report due to the portable nature of such devices and other unique market demand and supply dynamics

Figure 4: Energy stack of off-grid appropriate household appliances



Source: CLASP and Dalberg Advisors, 2019
Note: Focus appliances for this report are marked with an asterisk

Figure 5: Representative country selection for off-grid appliance market

COUNTRY	% POPULATION OFF-GRID	OFF-GRID POPULATION (MILLIONS)	TELEVISION PENETRATION	REFRIGERATOR PENETRATION	FAN PENETRATION
CÔTE D'IVOIRE	40%	10	21%	n/a	n/a
ETHIOPIA	55%	58	2%	0.4%	n/a
INDIA	13%	168	54%	16%	69%
KENYA	27%	13	19%	1.5%	n/a
MYANMAR	44%	24	47%	6%	13%
NIGERIA	40%	77	28%	11%	26%
SIERRA LEONE	80%	6	2%	n/a	n/a
UGANDA	80%	34	7%	1.8%	n/a

Complementary Coalition reports, such as the Solar Water Pump Outlook 2019: Global Trends and Market Opportunities, cover the market potential for other productive use and household appliances.

Sub-Saharan Africa and South Asia are home to the largest off-grid and weak-grid populations in the world. For this report, we undertook a deeper analysis for a representative selection of markets to highlight different levels of market maturity. In doing so, we considered the market need for off-grid appropriate appliances (due to insufficient electrification), the current penetration of appliances, and the dynamism of the market—both in terms of local actors and the policy environment. These characteristics allowed for an analysis of how market characteristics define the opportunity, and how business models have evolved within varying enabling environments and among different consumer dynamics. The focus markets of this report are India, Myanmar, Kenya, Uganda, Ethiopia, Nigeria, Sierra Leone, and Côte d'Ivoire.

Following this introductory **Chapter 1,** the report consists of the following sections:

Chapter 2: Sizing the market: This section provides an overview of current off-grid appliance market demand and sizes the potential market from now through 2030, including an analysis of the obtainable market when factoring in affordability and distribution constraints.

Chapter 3: Supply market dynamics: The supply landscape has evolved with rapid growth in sales and entry of many new actors. While noting data limitations, this section provides a snapshot of supply market status and trends, and an overview of key player types and business models. In addition, this section highlights the role of consumer financing model innovation in driving market growth.

Chapter 4: Overview of products and technologies: Technology and product design continue to evolve as the off-grid appliance market grows, driving greater product efficiency and affordability. This section provides the latest data on energy performance and pricing trends. It also highlights evolutions in product design, with a particular focus on new technology features from recent product launches.

Chapter 5: Insights into consumer needs and behaviors: Consumer demand is essential to the growth of the off-grid appliance market, yet the potential consumer is not yet fully understood. This section profiles current and potential customers and describes their decision drivers for product purchase and use.

Chapter 6: Conditions for growth: The enabling environment for energy access, particularly government policy, currently focuses on energy supply rather than energy demand. This section looks at how various policy tools for off-grid appropriate appliances such as subsidies, results-based financing, and value added tax (VAT) and duty exemptions are beginning to evolve with the growing market and where they may be constraining the market.

Chapter 7: Charting the path forward: Looking toward the future, the final report section provides insights into pathways for growth. We specifically seek to understand where the market could be in 2030, and highlight several recommendations for further accelerating sector growth.

What is the methodology of the report?

DATA SOURCES

The Low Energy Inclusive Appliances (LEIA) program,[64] the Global LEAP Awards,[65] and GOGLA[66] have built a significant compendium of regularly updated data and information. This report benefited tremendously from access to non-confidential data from the GOGLA Off-Grid Solar Market Report, which, in 2018, collected appliance-specific data for the first time. This data set, while still limited today, will become more valuable over time with greater industry participation. Global LEAP technical test data informed the analysis of product trends. LEIA retail market data provided important, market-specific nuance regarding distribution and pricing. And finally, Global LEAP customer data on televisions and refrigerators offered insights into the current users of off-grid appliances.

FURTHER PRIMARY RESEARCH

We conducted over 45 interviews with industry actors across a variety of appliance types and markets.[67] These actors represented multiple stages along the value chain, including manufacturers, distributors, donors, and financiers. The interviews revealed important trends in the market, helped verify key data points, and identified some of the critical barriers to growth facing the industry today. The annex contains a full list of interviewees.

SECONDARY RESEARCH

This report also brings together insights and supporting data from literature about access to energy, access to finance, and appliance-specific technical information. This secondary research provides a rigorous background for primary research and subsequent recommendations. The annex contains a complete bibliography.

MARKET SIZING METHODOLOGY

The methodology for the market sizing included in this report focuses on the *obtainable* market—customers who can afford appliances and are reachable by distributors. We made this calculation for the eight focus countries and extrapolated it to regional and global levels. We then projected market sizes for 2025 and 2030 based on assumptions of income growth, increased electrification, and decreased appliance prices.

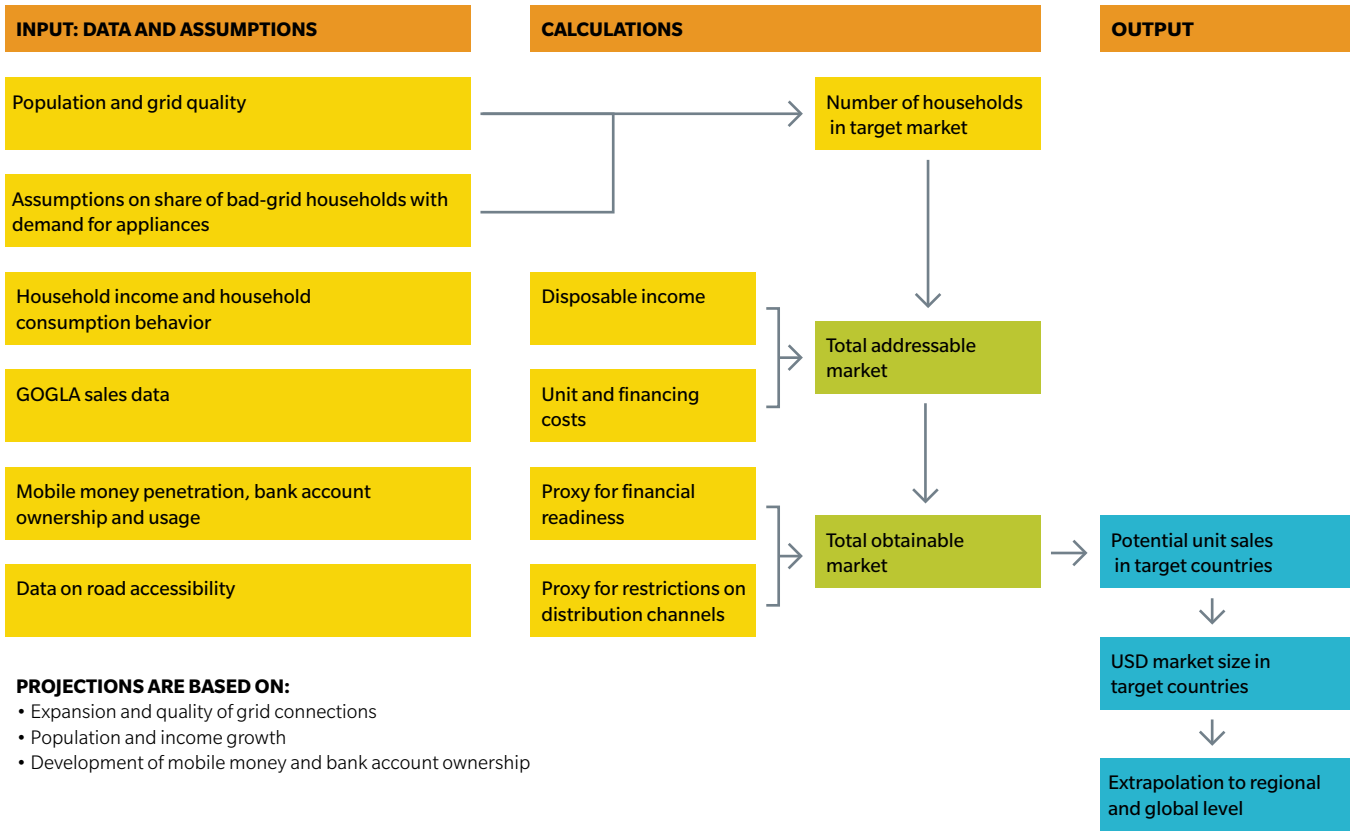
64. Low-Energy Inclusive Appliances (LEIA) Program is a research and innovation program that seeks to double the efficiency and half the cost of a range of electrical appliances suited for off- and weak-grid household, small business, and industrial consumers.
65. The Global LEAP Awards is an international competition to identify and promote the world's best off-grid appliances, accelerating market development and innovation.
66. GOGLA is the global association for the off-grid solar energy industry that represents over 150 members as a neutral, independent, not-for-profit industry association.
67. The names of all stakeholders interviewed is included in Annex 2.

The *obtainable* market provides a realistic benchmark for the industry, given current pricing, access to finance and the costs of rural distribution. We developed a model to describe the market opportunity using two main steps:

First, we identified the *addressable* market, which describes the market for off-grid appliances and considers the customer's ability to pay. It uses average product size and price and applies this figure to the disposable income customers have available for energy and household appliance expenditure. This calculation assumes that consumer financing or installment payments are available.

Second, we sized the *obtainable* market, which is a subset of the addressable market and describes the capturable share of the market given current demand-side and supply-side constraints. It considers financial readiness, and factors in mobile money penetration and/or active bank account ownership.[68] It also accounts for the supply-side constraints of accessing difficult to reach, off-grid customers. In this report, we use road connectivity, based on the World Bank's Road Access Index, as a proxy for such supply-side constraints.

Figure 6: Logic of off-grid appliance market sizing model



Source: Dalberg Analysis

68. Bank account ownership is used as a proxy in markets where mobile money penetration is below 40%.

What is the current demand for off-grid appliances?

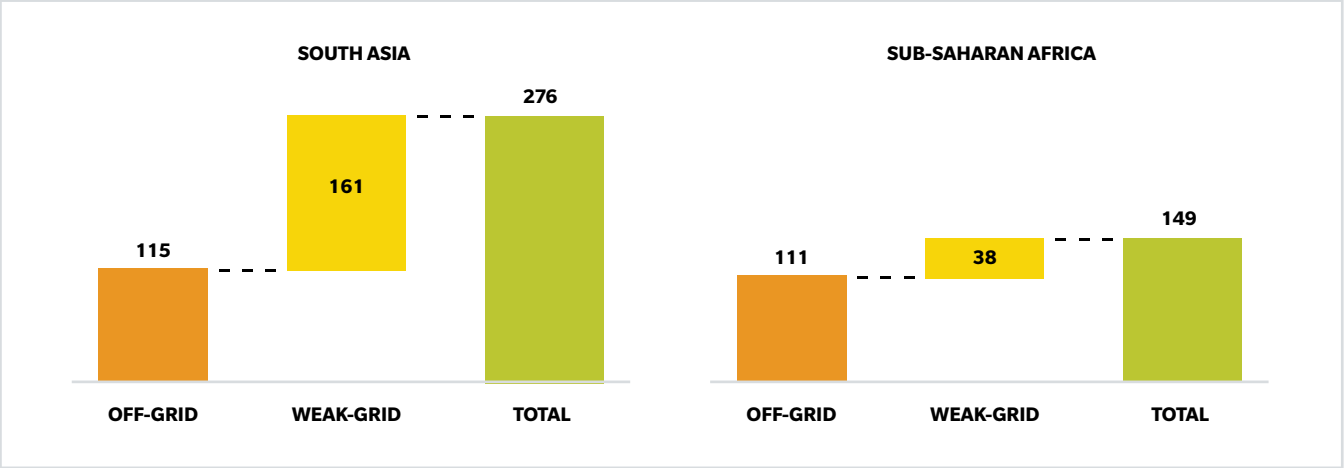
Large off-grid and weak-grid populations, and the growing adoption of solar home systems and mini-grid solutions by such populations, are the key drivers of global off-grid appliance demand.

There are 475 million households worldwide with no grid access, or with only unreliable, intermittent access to electricity.[69] Of this total, 250 million have no access to electricity and more than 225 million are 'weak-grid' households—households that lack reliable access to the grid for at least half of the day, particularly during morning and evening peak use periods—limiting their ability to use and benefit from conventional household appliances. The vast majority (90%) of off-grid and weak-grid households are in Sub-Saharan Africa (149 million) and South Asia (275 million).[70] These two regions are therefore the largest potential markets for off-grid appliances and the primary focus for this report.

While governments are working to extend the grid, the challenging economics of grid infrastructure—most notably the factors of low population density in rural areas, absent or difficult road connections, and the limited availability of financing—mean that even the best efforts will not be sufficient to connect most of these households to the grid. As a result, these communities will not be able to benefit from the potentially transformative effects of electrification without access to off-grid solar or mini-grid electrification combined with appliances that are optimized for such off-grid energy sources.

Renewable energy technologies, especially solar, are helping to bridge this energy access gap. As of 2018, the fast growing market for off-grid solar systems, including small-scale ('pico') photovoltaic (PV) lighting products and larger solar home systems, was already providing more than 73 million households, or 360 million people, with access to basic energy services globally.[71] In addition, solar and solar hybrid mini-grids, also known as micro-grids, reached an estimated 10 million households by 2019.[72] While the mini-grid market is more nascent than that for stand-alone solar home systems, mini-grid penetration is projected to grow quickly in the next few years. Recent World Bank forecasts target 100-120 million mini-grid households by 2030 due to major inflows of funding, falling mini-grid component costs, and ongoing business model innovation.[73] Even if mini-grid growth falls far short of this target, existing funding commitments make it highly likely that we will see tens of millions of new mini-grid customers in the coming years.

Figure 7: Estimated number of off- and weak-grid households (millions of households, 2018)



Source: IEA World Energy Outlook, country grid quality surveys (e.g., Afrobarometer), and Dalberg analysis

69. Dalberg market sizing, based on IEA World Energy Lookout, and publicly available data on grid quality such as Afrobarometer. Estimates on the regional level are extrapolated from the eight countries focused on in this study.
70. Dalberg estimate based on extrapolation from IEA and country grid quality data
71. World Bank & Dalberg Advisors, *Off-grid Solar Market Trends Report,* World Bank Lighting Global Program, 2018, https://www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report/.
72. For the mini-grid estimate of 47 million people covered by mini-grids, roughly 10 million households assuming 4.5 people per household, primarily in Asia, see World Bank, *Mini-Grids for Half a Billion People: Market Outlook and Handbook for Decisionmakers,* 2019, https://openknowledge.worldbank.org/bitstream/handle/10986/31926/Mini-Grids-for-Half-a-Billion-People-Market-Outlook-and-Handbook-for-Decision-Makers-Executive-Summary.pdf?sequence=1&isAllowed=y.
73. Ibid.

Levels of household energy consumption and appliance use in Sub-Saharan Africa and South Asia are very low relative to higher income countries, suggesting immense latent demand.

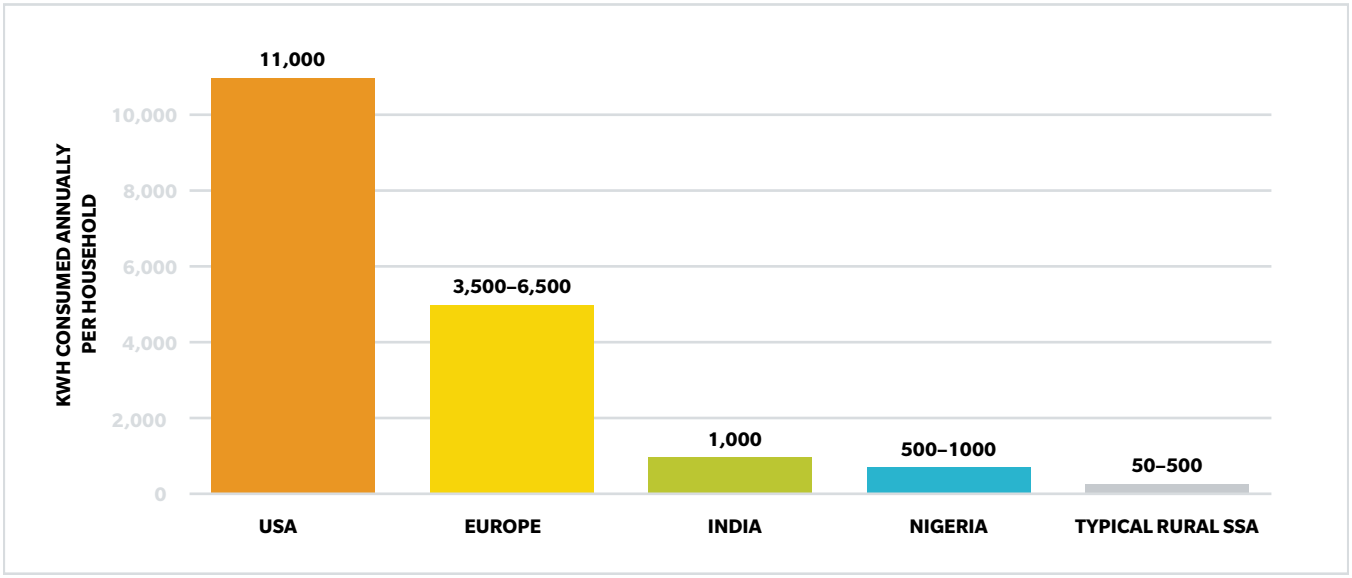
The average household energy consumption in these regions is orders of magnitude lower than that in developed countries. For example, annual household energy consumption in the United States and Western Europe is 5-10 times greater than that for an average household in India, 10-20 times greater than for an average household in a country like Nigeria, and 20-200 times greater than for households in most of rural Africa[74] (see Figure 8).

Statistics on household electric appliance access are equally stark. Considering the number of appliances owned by an average household, including small appliances like mobile phones, survey data indicates that households in high income countries have 15-40 appliances per household on average,[75] 3-10 appliances for the average household in India, and 2-5 electric appliances per household in most of rural Africa.[76]

In terms of appliance penetration, in contrast to nearly universal TV and refrigerator ownership in high-income countries, we estimate that only 17% of all households in Sub-Saharan Africa (SSA) have refrigerators and 35% have TVs.[77] Electric fan penetration, though data is very limited, is greater than 12%, but unlikely to exceed 18% of all households in the SSA region today.[78]

Penetration of appliances in South Asia is generally at a much higher level than in Africa. For instance, in India, based on 2016 national household survey data, appliance penetration was nearly 2 times that of the SSA region – 30% for refrigerators, 66% for TVs, and 78% for fans.[79] In poorer South Asian countries like Bangladesh and Myanmar the data is comparable to SSA averages with respect to refrigerators and TVs, but is much higher for fans. In Bangladesh, for instance, based on the most recent data available, penetration was 20% for refrigerators, 44% for televisions, and 59% for fans.[80]

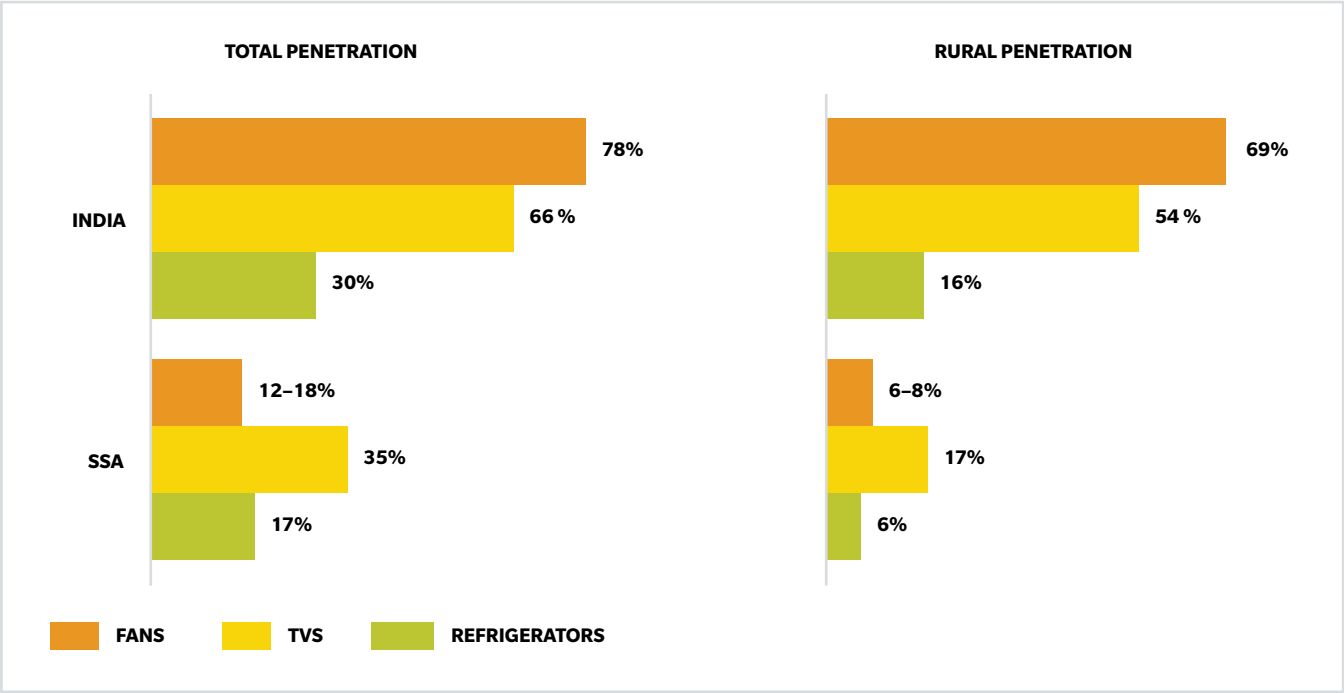
Figure 8: Average annual household energy consumption (kWh)



Source: World Energy Council, IEA, GOGLA, and Dalberg analysis

74. Average annual household energy consumption is approximately 11,000 kWh in the US (of which 35-40% is linked to household appliance use), in the 3,500-6,500 kWh range for Western Europe, 900-1200 kWh in India, 500-1000 kWh in Nigeria, and only 50-500 kWh for most rural Africa, in line with the IEA rural energy poverty line of 50 kWh per capita, or roughly 250 kWh per household annually (based on World Energy Council, GOGLA, and IEA data). Dalberg analysis based on US DOE, World Energy Council, GOGLA, and IEA data, 2019.
75. The developed world average is based on the average household appliance figures for the United States, UK, Spain, Korea, Singapore, and Japan based on national energy census and utility survey data. For example, for the UK, see: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/208097/10043_R66141HouseholdElectricitySurveyFinalReportissue4.pdf. For Spain household appliance ownership, see https://ec.europa.eu/eurostat/cros/system/files/SECH_Spain.pdf. For Korea, see https://www.scientific.net/AMM.672-674.2165.
76. India and Africa estimates based on proprietary Dalberg survey data, field interviews, and publicly available energy surveys. For examples of national appliance surveys in the public domain, see analysis of appliance ownership in rural Kenya in Lee, K. et al., "Appliance ownership and aspirations among electric grid and home solar households in rural Kenya," *American Economic Review,* 2016.
77. SSA appliance penetration was estimated by aggregating the most recently available appliance ownership data from Development Health Surveys (DHS) for 20 of the region's biggest countries, which account for approximately 84% of the total regional population. Appliance penetration for the rest of the remaining population in the region was estimated by applying the regional average (adjusted to exclude middle-income South Africa to avoid biasing the numbers).
78. DHS and other national survey data on electric fan ownership is available for 11 of the top 20 SSA countries by size of population, and represents a penetration of 28% of households for these 11 geographies. For other countries on the continent, based on interviews and anecdotal data, fan ownership rates are negligible, in the 1-10% range. Even if one assumes zero fan ownership in other African countries, at the very minimum the known data suggests that SSA region electric fan penetration is above 12%. We conservatively assume fan ownership rates of 5-10% for the rest of Africa (i.e., countries where fan data is not available) to get to a total estimated fan penetration of 12-18% of SSA households.
79. IIPS, India 2015-2016 National Family Health Survey (NFHS-4), Government of India, 2016, https://dhsprogram.com/pubs/pdf/FR339/FR339.pdf
80. Bangladesh DHS, 2014.

Figure 9: Appliance ownership in sub-Saharan Africa and India (% of households owning an appliance)



Source: Latest available DHS and other national survey data (2012-2018); Dalberg analysis

Rural households exhibit significantly lower rates of appliance ownership compared to the average. On average across the top 20 Sub-Saharan Africa countries by size of population, fewer only 6.3% of rural African households have refrigerators and roughly 17.5% have TVs.[81] In some sub-regions like East Africa, average rural refrigerator penetration in well below 2%, and rural TV penetration is below 10% (see country table on the next page). Excluding the middle-income outlier of South Africa, rural appliance penetration in SSA is even lower, averaging around 4% for refrigerators.

Even in middle income India, only 16% of rural households have refrigerators and roughly half have TVs.[82] Electric fan ownership in rural areas is also very low—only 14% of all rural households in the 10 SSA countries where rural fan penetration data is available have an electric fan. Since fan ownership in the region is highly concentrated in the handful of tropical countries where fan use is common—most notably West African countries such as Nigeria, Angola, Senegal, Côte d'Ivoire, Mali, and Cameroon—overall regional penetration of electric fans in rural Africa is even lower, likely in the 6-8% range. [83]

As can be seen in the Figure 10, these aggregated regional averages for appliance ownership rates naturally encompass a great deal of variation across individual countries.

In comparison to high income countries these rates of appliance ownership are extremely low. In the case of Africa, these levels of appliance penetration translate to a total of roughly 33 million fans, 35 million refrigerators, and a mid-range estimate of 80 (between 73 and 88) million TV sets in use today across the entire region.[84] In absolute terms, this means that the entire SSA region has 25% fewer refrigerators and TVs than Japan, which has almost a tenth of Africa's population.[85] Similarly, the SSA region has 2.5 times the number of TVs and refrigerators than the UK despite having 40 times more people.

81. Dalberg analysis of the most recent regional DHS datasets (2012-2018) and using 2018 population and urban/rural share data.
82. Ibid. See the 2016 India DHS data for details.
83. In the case of no rural penetration of fans outside of countries where this information is known, the regional penetration of electric fans in rural Sub-Saharan Africa would be 6%. Assuming 5% penetration in such countries, the total rural penetration would be no greater than 8%.
84. The bottom range estimate of 73 million derived by applying appliance penetration rates from DHS data to 2018 population actuals for the top 20 countries and estimating the remainder based on regional averages. At the top of the range (88 million televisions), assumes up to 1.2 televisions per household based on Nigeria and Ghana energy survey data. For both fans and refrigerators we assume only one appliance per household.
85. Japan estimate extrapolated from Matsumoto, S., "Household Income Structure and Electrical Appliance Ownership: Evidence from Japanese National Household Survey", *IJEEP*, 2016, https://www.econjournals.com/index.php/ijeep/article/view/1483/929.

Figure 10: Household Penetration of Televisions, Refrigerators, and Fans (2012-2018, latest known)

	TELEVISIONS			FANS			REFRIGERATORS		
TOP 20 SSA COUNTRIES*	**RURAL**	**URBAN**	**TOTAL**	**RURAL**	**URBAN**	**TOTAL**	**RURAL**	**URBAN**	**TOTAL**
ANGOLA	13.5%	75.0%	51.2%	4.0%	55.5%	35.5%	2.1%	38.9%	21.4%
BURKINA FASO	13.2%	65.7%	25.0%	1.0%	22.6%	5.8%	n/a	n/a	n/a
CAMEROON	17.3%	72.8%	45.6%	2.2%	27.5%	15.1%	2.9%	40.8%	22.5%
DRC	1.7%	43.7%	15.0%	0.1%	14.1%	0.5%	n/a	n/a	n/a
ETHIOPIA	2.1%	59.4%	13.8%	0.4%	24.4%	5.3%	n/a	n/a	n/a
GHANA	42.2%	77.7%	61.7%	16.4%	50.5%	35.1%	35.0%	75.0%	57.0%
IVORY COAST	21.0%	69.8%	43.2%	3.5%	20.8%	11.3%	3.0%	12.7%	7.9%
KENYA	18.9%	56.0%	34.5%	1.5%	12.7%	6.2%	n/a	n/a	n/a
MADAGASCAR	12.1%	56.6%	17.1%	1.5%	3.1%	1.7%	2.0%	10.0%	4.0%
MALAWI	5.6%	45.3%	11.7%	2.3%	26.7%	6.0%	n/a	n/a	5.0%
MALI	32.4%	78.2%	42.6%	4.3%	31.5%	10.3%	9.1%	39.2%	15.8%
MOZAMBIQUE	5.7%	48.8%	18.6%	2.1%	32.5%	11.3%	2.3%	28.5%	12.0%
NIGER	43.6%	82.8%	50.0%	0.5%	17.7%	3.3%	n/a	n/a	n/a
NIGERIA	28.4%	74.8%	46.9%	11.0%	41.0%	23.0%	26.1%	73.2%	44.8%
SENEGAL	28.9%	82.7%	56.7%	9.0%	46.0%	28.0%	5.6%	39.0%	26.8%
SOUTH AFRICA	66.2%	81.8%	76.8%	67.8%	77.9%	74.7%	n/a	n/a	n/a
TANZANIA	6.4%	46.6%	19.7%	1.3%	22.1%	8.3%	1.0%	15.0%	6.0%
UGANDA	7.4%	44.3%	16.9%	1.8%	16.6%	5.6%	n/a	n/a	n/a
ZAMBIA	16.1%	66.0%	36.9%	2.9%	43.9%	20.0%	n/a	n/a	n/a
ZIMBABWE	19.2%	73.4%	37.4%	6.6%	61.0%	24.8%	n/a	n/a	n/a
SOUTH ASIA*									
INDIA	52.0%	85.0%	63.5%	54.2%	54.2%	29.6%	69.1%	95.1%	78.2%
BANGLADESH	33.0%	70.6%	43.5%	40.6%	40.6%	20.2%	48.5%	85.9%	59.0%
MYANMAR	46.9%	85.3%	57.1%	44.8%	44.8%	16.0%	12.5%	67.0%	27.0%

* Top 20 SSA countries by 2018 population size which account for 84% of total SSA region population

Source: Various national surveys including Demographic and Health Surveys, FinScope Consumer Surveys, UNICEF Multiple Indicator Cluster Surveys, etc.

These disparities in energy consumption and appliance use point to substantial latent demand.

Potential demand for appropriately designed and efficient off-grid appliances is high. The gap in household appliance access and use in urban and rural Africa and South Asia is a strong indicator of the immense latent market demand for off-grid appliances. We know from the purchase behavior of electrified households in the same income segment that demand for off-grid appliances like televisions, fans, and refrigerators, radios, and mobile phones is high, along with growing demand for newer types of off-grid appliances like irons, hot plates, and internet connectivity devices.

Industry surveys and self-reported purchasing preferences suggest very high levels of latent demand. A 2018 CLASP survey of off-grid appliance enterprises (see Figure 12) showed, for instance, that apart from room lighting and mobile smartphones, televisions, refrigerators, and fans were projected to be the highest demand appliances over the next three years. Consumers consistently report the same thing. A large-scale mobile survey of off-grid households across 10 countries in Sub-Saharan Africa published in 2018 revealed that, on average, 28% of African households (18-35% range depending on country) intended to purchase a television and an average of 14% (6-24% range by country) had an interest in purchasing a refrigerator upon gaining access to electricity.[86]

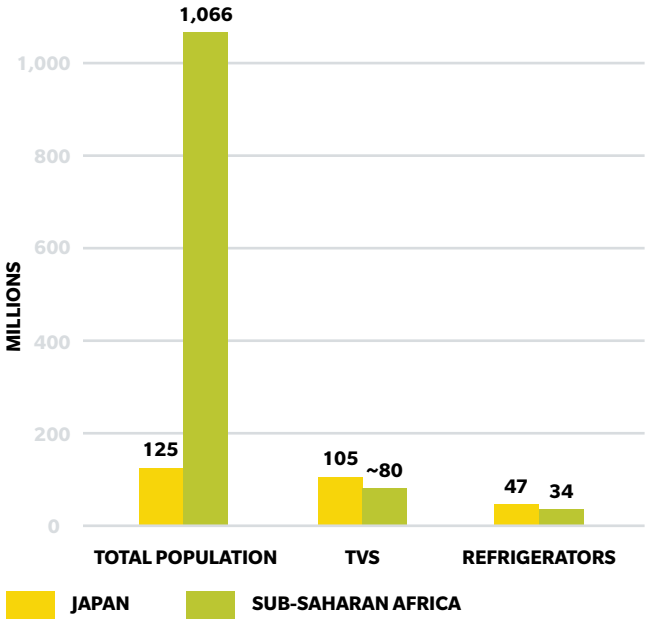
86. Leo, B., et al, *What Can We Learn About Energy Access and Demand from Mobile-Phone Surveys? Nine Findings from Twelve African Countries*, CGDEV, 2018, https://www.cgdev.org/sites/default/files/what-can-we-learn-about-energy-access-and-demand-mobile-phone-surveys.pdf.

Demand for off-grid appliances is particularly high for households that have already experienced some of the benefits of energy access via basic solar home systems or even intermittent grid access. For instance, a 2016 survey of solar home system households in Kenya showed that 37% of such households had a strong interest in buying a television and demand was also high for appliances such as radios (28%), irons (26%), refrigerators (24%), and cookstoves (23%).[87]

What is the size of the potential off-grid appliance market today?

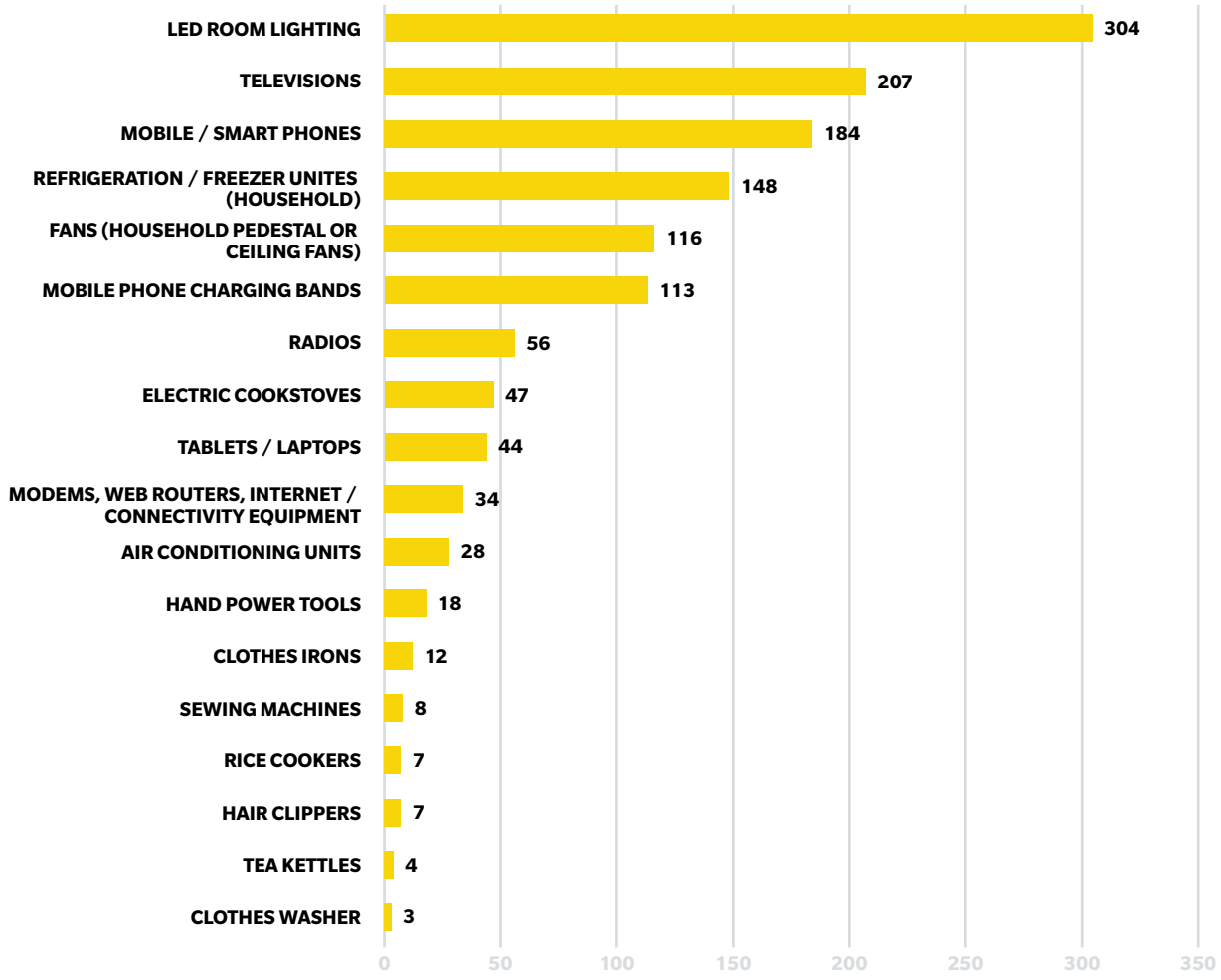
We estimate that the total addressable market for off-grid appliances—using TVs, fans, and refrigerators as a proxy—is up to half of all off-grid and weak-grid households globally. The addressable market, defined as the number of households which could acquire an off-grid appliance if financing was available, is linked to the current price of any given appliance and consumers' disposable incomes. Of the 475 million off- and weak-grid households globally, we estimate that around 221 million (47%) to 232 million households (49%) would have been able to afford off-grid TVs and fans, respectively, at the end of 2018 if affordable consumer financing was available

Figure 11: Household appliances in use in sub-Saharan Africa vs. Japan (millions)



Source: UN population data, national appliance surveys for Japan and the UK, DHS appliance data for 20 largest countries in SSA region; Dalberg analysis

Figure 12: Relative demand for household appliances in next 3 years (number of stakeholder survey responses)



Source: Efficiency for Access Off-grid Appliance Market Survey, 2018

87. Lee, K. et al., "Appliance ownership and aspirations among electric grid and home solar households in rural Kenya," *American Economic Review,* 2016.

Key market sizing definitions

OFF-GRID AND WEAK-GRID HOUSEHOLDS:

The total number of households who have no access to grid electricity or have 'weak-grid' connectivity, defined as an unreliable or intermittent grid connection that on average provides electricity to the customer for <50% of the day.

ADDRESSABLE MARKET:

The subset of off-grid and weak-grid households who could afford an off-grid appliance provided they had access to financing.

OBTAINABLE MARKET:

The subset of the total addressable market that is serviceable for off-grid solar companies, taking into account both access to financing and the physical accessibility of households to distributors (estimated in report based on proximity to roads)

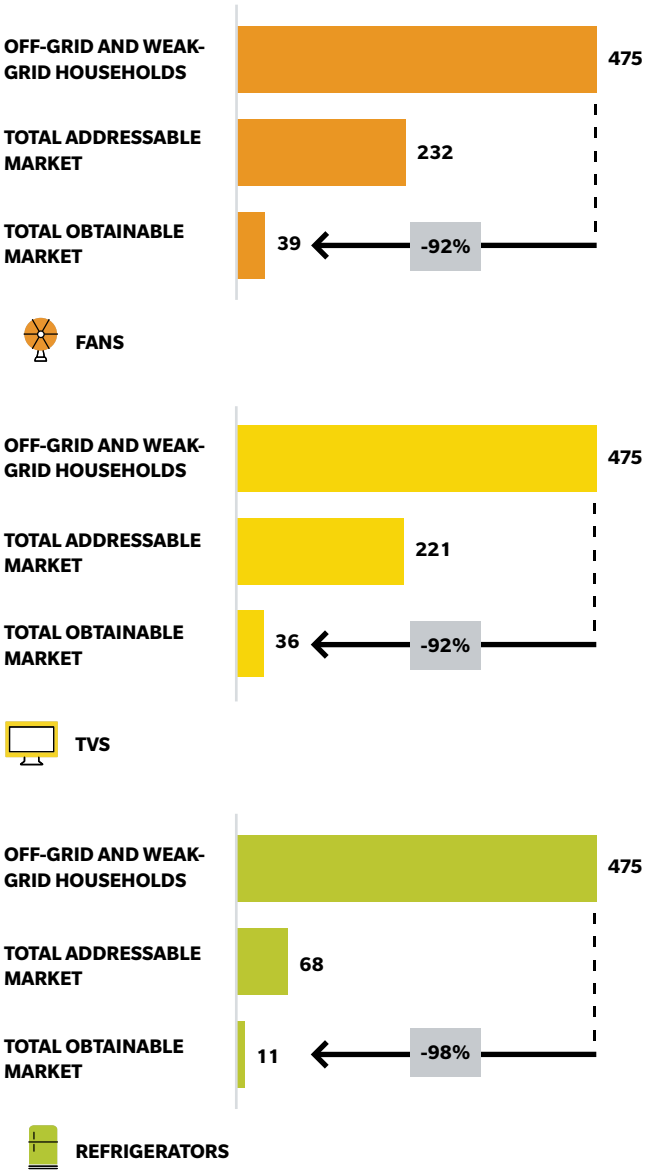
to decrease upfront costs. For refrigerators, which are relatively more expensive, approximately 68 million households, which constitute roughly 15% of all off-grid and weak-grid households, could afford today's average off-grid refrigerator if financing was available.[88]

The total *obtainable* market for off-grid appliances, while still large, is significantly smaller today than the addressable market. The greatest constraint on the addressable market is access to consumer finance, which is highly limited for most off-grid and weak grid households in Sub-Saharan Africa and South Asia. Customer accessibility is a further constraint—distributors must be able to reach households physically to sell, service, and, if necessary, reclaim appliances. Factoring in the access to financing and physical accessibility challenges reduces the number of obtainable households to around 39 million for fans, 36 million for TVs, and 11 million for refrigerators.[89]

The upfront cost of off-grid appliances and limited availability of consumer financing is a major constraint to uptake. For most consumers, the upfront cost of off-grid appliances is still prohibitive. We estimate that only 4.5 million households – 1% of all off- and weak-grid households globally – are able to afford an off-grid TV in a cash sale, assuming that off-grid consumers are only able to spend up to two months' income on an appliance at any given time.

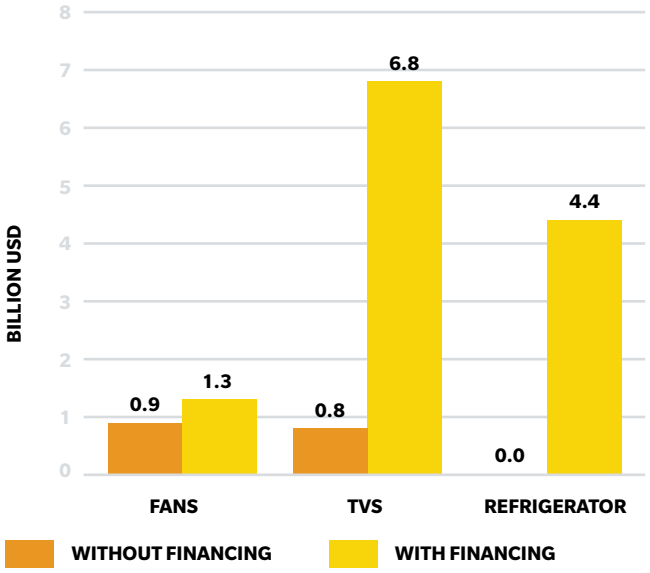
This represents a market of around USD 0.8 billion (Figure 14). For off-grid fans (relatively less expensive), we estimate that approximately 27 million households (or around 6% of all off- and weak-grid households globally) are able to afford to pay in full upfront, comprising a market opportunity of USD 0.9 billion. For off-grid refrigerators, very few households that live off-grid can purchase a unit upfront at current prices. Including consumer financing doubles the number of SSA households in the obtainable fan market and increases the obtainable TV market by the factor of 8.

Figure 13: Breakdown of off- and weak-grid households—addressable and obtainable markets (including financing)



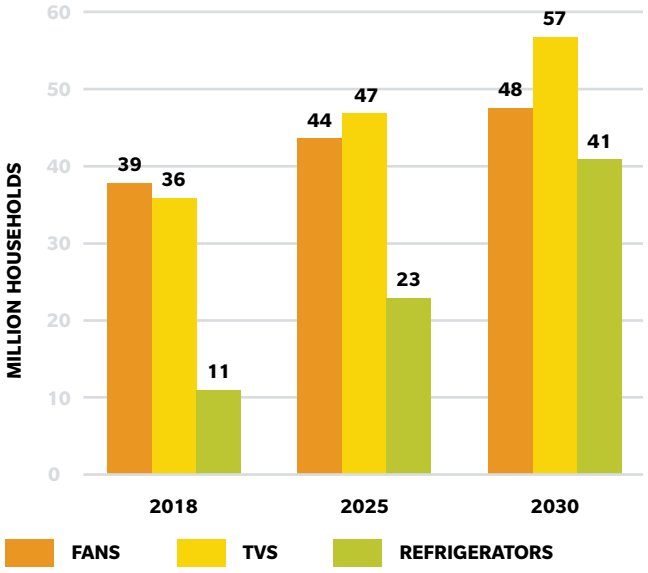
88. For an overview of the market sizing methodology, see Figure 6 in the Introduction chapter of this report.
89. Accessibility is built into the market sizing using the World Bank's Rural Access Index, which reports access and mobility of rural populations.

Figure 14: Cumulative global market opportunity, cash vs. financed sales (USD billions)



Source: Dalberg market sizing model, 2019

Figure 15: Obtainable households for the off-grid appliance industry, globally 2018-2030 (million households)

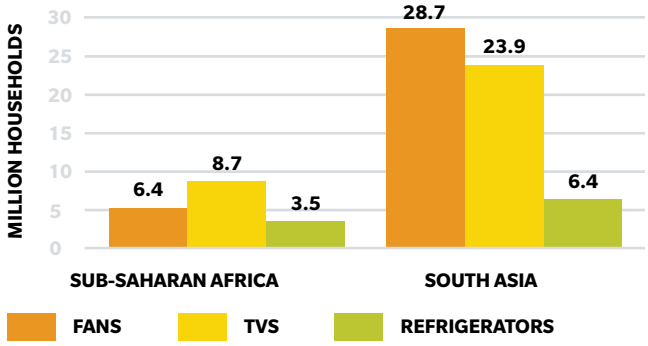


Source: Dalberg market sizing model, 2019

The model takes into account consumer financing and uses this as a proxy for other methods to reduce the upfront cost for consumers. It estimates the number of households that can afford and access a solar home system with an off-grid TV, fan or refrigerator. Based on average industry terms, the market sizing applies financing terms that include a 28-month repayment period, a 10% down payment, and a 70% mark-up for servicing and financing.[90] While these financing assumptions are based on a set of typical financing terms in the industry, their role in the market sizing calculation is only to estimate the reduction in upfront costs and to determine expected loan payments.

Beyond consumer financing, there are a number of levers which can expand the obtainable market and/or increase market penetration, including competition, targeted subsidies, and fiscal exemptions. The market sizing calculations do not explicitly include these factors. For example, to date, results-based financing under the Global LEAP program has catalyzed the procurement of over 240,000 TVs, fans, and refrigerators in Kenya, Uganda, Tanzania, Rwanda, and Bangladesh, providing new or enhanced energy access to more than 1,125,000 people. Other factors that could impact the market size include supply-side actions such as the introduction of subsidies or fiscal policies (e.g., reductions in taxes). On the demand side, factors ranging from income growth among off-grid populations (e.g., as the result of successful agricultural transformation initiatives) to national electrification investments and grid expansion could also affect market demand. Though relevant, these factors are not included in the market sizing model because they are not fully predictable and/or because the needed data is not available. Instead, the model uses consumer financing as a proxy for a set of possible outcomes that could drive down the upfront costs of appliances.

Figure 16: Obtainable households for the off-grid appliance industry, per region, 2018 (million households)



Source: Dalberg market sizing model, 2019

This total *obtainable market* comprises up to 39 million households globally, including approximately 29 million in South Asia and 9 million in Sub-Saharan Africa. Most solar home systems are able to power one TV or refrigerator at the time. Assuming households only buy one type of appliance, the fan market comprises 39 million households; the TV market comprises 36 million households; and the refrigerator market around 11 million households globally. In practice, households may purchase more than one appliance by category, especially cheaper appliances such as fans. There is an expectation that this will develop over time, and more data should be gathered to validate purchase and usage patterns. As of today, the Sub-Saharan Africa market for off-grid appliances comprises 8.7 million households using the highest demand TV segment as a proxy compared to 28.7 million households in South Asia using fan demand as a proxy.

90. The 70% markup for financing and servicing costs reflect a typical loan term for fans and TVs purchased with PAYGO financing. The 28-month repayment period for TVs and fans reflects a long loan duration that would enable more consumers to afford off-grid appliances. Assumptions are assumed to be constant across the 8 countries included in the market sizing analysis. For refrigerators, the model assumes an upfront payment of 15% and a repayment period of 24 months.

Figure 17: Total obtainable market: households for the off-grid appliance industry by country, 2018 (thousands)

	CÔTE D'IVOIRE	ETHIOPIA	INDIA	KENYA	MYANMAR	NIGERIA	SIERRA LEONE	UGANDA	GLOBAL
FANS	140	10	17,760	20	340	1,480	20	10	39,000
TELEVISIONS	110	170	14,800	280	320	1,040	–	260	36,000
REFRIGERATORS	40	50	4,930	70	70	740	–	–	11,000

Source: Dalberg market sizing model, 2019

Figure 17 shows that there are significant differences at a country level, driven by population, income levels, access to finance, and rural distribution infrastructure.

The potential market for off-grid appliances was nearly $12.6 billion in 2018.

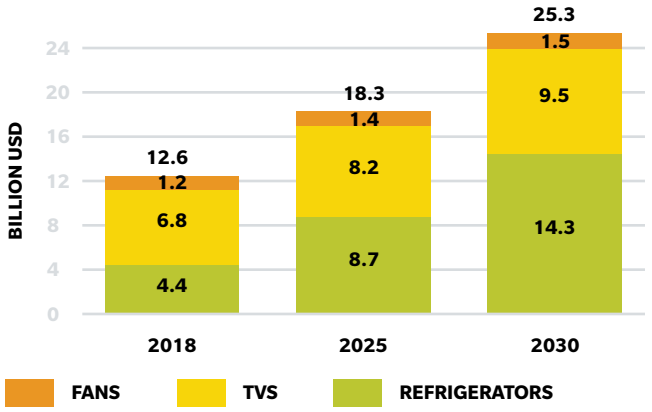
***The total obtainable market* globally for off-grid fans, TVs, and refrigerators is estimated at USD 12.6 billion at the end of 2018.**[91] Using this market sizing data and applying current appliance prices gives us the total obtainable market size in value terms. This comprises a USD 6.8 billion potential market for TVs, a USD 4.4 billion potential market for refrigerators and a USD 1.3 billion potential market for fans. Sub-Saharan Africa and South Asia represent a large share of the global market opportunity for off-grid TVs, fans, and refrigerators.[92] The current cumulative market for off-grid TVs, fans and refrigerators is estimated at around USD 3.6 billion in Sub-Saharan Africa and USD 7.7 billion in South Asia.[93]

What is the market opportunity in the next ten years?

In 2030, the global market opportunity for household off-grid appliances could double to USD 25.3 billion, driven by greater levels of affordability and population growth. Given their high demand and value, we estimate that in the next decade TVs and refrigerators will drive the global market potential. The global market for off-grid TVs could increase by almost 40% from USD 6.8 billion in 2018 to a global market opportunity of USD 9.5 billion. Driven by greater affordability, the market for off-grid refrigerators could see a yearly increase of up to 10% by 2030, growing cumulatively by well over 200% from USD 4.4 billion in 2018 to USD 14.3 billion in 2030.

From a regional perspective, the market opportunity could be as high as USD 7.1 billion in Sub-Saharan Africa and USD 15.5 billion in South Asia by 2030, following relatively similar growth trajectories.

Figure 18: Cumulative global market potential



Source: Dalberg market sizing model, 2019

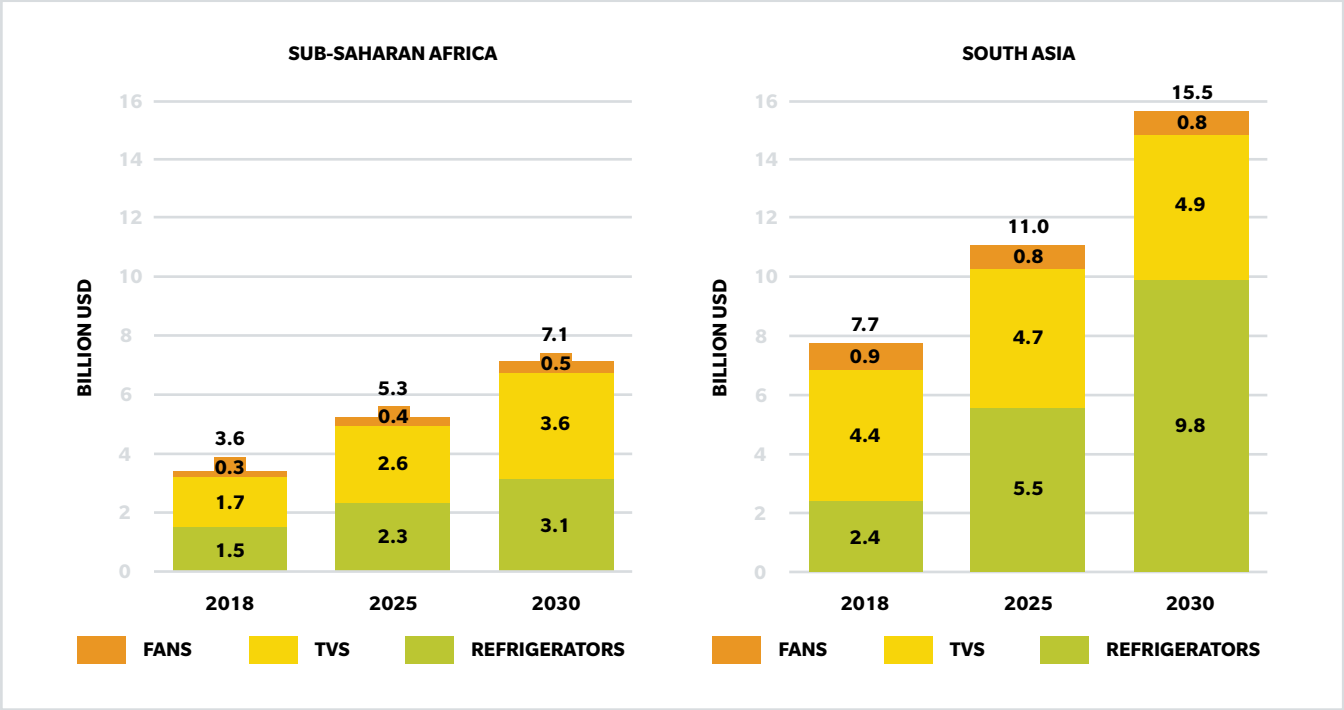
The market growth drivers are subject to extensive uncertainty—a significantly bigger potential market is possible by 2030.

Population and income growth, better financing access, lower appliance prices, and underlying solar off-grid and mini-grid market dynamics are the key drivers of this market growth. While many growth factors such as population and income growth are fairly predictable over the next decade, others are far less so.

For instance, our baseline market sizing model assumes annual appliance price reductions of 1% annually across all three of the off-grid appliance categories by 2030. This conservative forecast for product prices is justifiable because appliance prices are subject to a great deal of uncertainty due both to technology development risks (e.g., uncertainty in the pace of efficiency improvements and in key manufacturing cost drivers such as labor costs) and market dynamics. Historical appliance price trends suggest, however, that it is fully possible that off-grid refrigerators, TVs, and fans could see much more aggressive price reductions in the range of 2-5% annually over the next

91. Dalberg market sizing model, 2019.
92. Ibid.
93. Ibid.

Figure 19: Cumulative market potential (USD billions)



Source: Dalberg market sizing model, 2019

decade, significantly increasing the size of the addressable and obtainable markets.[94] This could be due to faster than predicted translation of improved appliance efficiency into lower prices or due to supply market dynamics such as lower production costs from unanticipated economies of scale in manufacturing and more intensive price competition in appliance sales.

Another major area of uncertainty is the future growth trajectory for the off-grid and mini-grid markets, which both drive off-grid appliance demand and, in turn, are stimulated by off-grid appliance sales.

In the case of the off-grid solar home system market, despite recent headwinds such as saturation of the most easily addressable customer segments, more intensive (and costly) government regulation, consumer credit risks, and market consolidation as seen in a few recent PAYGO enterprise failures and mergers, most analysts predict ongoing robust (and potentially accelerated) sales growth for the off-grid solar industry as the sector approaches full commercial viability.[95]

In the case of the much less commercially mature mini-grid market, there are even greater uncertainties about both the pace and format of mini-grid development (i.e., DC vs. AC mini-grid distribution models), which will have implications for off-grid appliance market growth. By the end of 2018, around 80% of corporate-level investment into off-grid energy access had gone into the solar off-grid home system market, particularly the PAYGO sector; mini-grids, despite their very high capex development costs, have attracted only 15% of the total investment.[96] Historically, the lack of financing and other business model challenges have meant that mini-grid sector growth has been relatively anemic to date, particularly in Africa where most mini-grid deployments are still very small scale and early stage. If the recent predictions of key market actors like the World Bank come to fruition, however—a forecast of over 100 million new mini-grid households, most in Africa, by 2030[97] —this would lead to a dramatic growth in the potential off-grid appliance market, especially if a significant proportion of new deployments would be DC mini-grids which are most compatible with off-grid appliances.

Faster than anticipated off-grid solar growth or such a leap in mini-grid connections are not currently modeled in our market forecast and, while difficult to quantify, should grow the off-grid appliance market dramatically beyond our baseline 2030 forecasts, both directly, through many new consumers seeking off-grid appliances, and indirectly via improved economies of scale in off-grid appliance production and via a greater variety of off-grid DC appliances available in the market to compete with AC appliances.

94. As noted in the technology trends chapter (Chapter 4), product efficiency is improving rapidly and at least some of these efficiency improvements have translated into lower product prices with TVs prices, in particular, on track to fall by more than 30% over the past 5 years.
95. Dalberg stakeholder interviews, 2019. See also market dynamics section of GOGLA, Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data July-December 2018, Public Report, 2019, https://www.gogla.org/sites/default/files/resource_docs/global_off-grid_solar_market_report_h2_2018_opt.pdf
96. See, e.g., Sadouki, M., "The Land of Opportunity for Off-Grid Solar", Greentech Media, 2019, https://www.greentechmedia.com/articles/read/the-land-of-opportunity-for-off-grid-energy#gs.5hzjr6
97. *World Bank, Mini-Grids for Half a Billion People: Market Outlook and Handbook for Decisionmakers,* 2019.

How does the market opportunity for off-grid appliances vary across countries?

The off-grid appliance market potential differs dramatically across countries based on local conditions—a more nuanced view is needed to identify appropriate market support models.

The global and regional market sizing estimates in the preceding discussion can obscure the fact that development of the off-grid appliance market must inevitably happen at the level of individual country markets. In the coming decade we will see a great deal of inter-country variation in off-grid appliance market development based on conditions on the ground. Developing a more nuanced view of market readiness is important both to track market evolution in the coming years and to identify appropriate government, donor, and private sector approaches that are tailored to each market.

There are several key factors which determine the relative attractiveness and "readiness" of a market for the uptake of off-grid appliances.

- **The size of the off- and weak-grid population and rate of electrification.** Countries are electrifying at different speeds, and there are often geographical and demographic challenges which make universal electrification through the national grid difficult to achieve in the near to medium term.

- **Relative income levels** determine the share of off- and weak-grid households who can afford off-grid appliances. As we have described above, this can significantly impact the obtainable market size in a given country.

- **Level of access to finance** in a market will determine whether off- and weak-grid households can purchase off-grid appliances on credit. This varies depending on the state of formal credit channels, such as banks and MFIs, and the extent to which they are willing to lend against an asset sale to off-grid customers. This also varies depending on the maturity of the mobile money ecosystem, which can facilitate PAYGO financing models.

- **Relative maturity of the off-grid solar industry** in a market determines the level of consumer awareness of solar products, the depth of existing distribution channels into off-grid regions, and the penetration of solar home systems or DC mini-grid connections which can power an off-grid appliance. Countries with a developed off-grid solar industry, such as Kenya and India, have a significant head start in terms of uptake of off-grid appliances.

- **Policy environment** can play a key role in shaping the trajectory of the market for off-grid appliances. For example, countries with unrestrictive import policies and favorable tax treatment for appliances make it easier for distributors to reach off-grid customers at more affordable prices.

There are, of course, other factors which impact the market for off-grid appliances, however these are particularly important ones.

Based on the above factors, this report proposes a country typology of *ready for scale-up, high potential,* and *nascent* off-grid appliance markets. Given the early stage of the off-grid appliance industry, there are no "mature" markets as the industry is still evolving rapidly. Further research would need to be done for a robust market categorization. However, at this stage, it is possible to identify which markets are most "ready" to scale the market for off-grid appliances. Broadly speaking, these market types can be defined as follows

i) ***Ready for scale-up*** markets have a medium to large off- and weak-grid population, relatively high per capita income levels, a mature off-grid solar industry and/or a large and viable DC mini-grid sector, high levels of access to finance, and mid-to-high levels of government support for off-grid appliances.

ii) ***High-potential*** markets have a medium to large off- and weak-grid population, relatively high disposable incomes, rapidly growing but immature off-grid solar and DC mini-grid industries, more limited access to finance, and lower levels of government support than markets ready for commercial scale-up of off-grid appliances.

iii) ***Nascent*** markets have a small to medium off- and weak-grid population, relatively low per capita income levels, an immature off-grid solar industry, limited access to finance, and low levels of government support for the off-grid appliance ecosystem.

Ready for commercial scale-up: Kenya and India are two of the largest and most attractive markets for off-grid appliances globally.

Kenya is the leading market for off-grid solar and PAYGO financing in Sub-Saharan Africa, with the largest number of off-grid households electrified by stand-alone solar home systems. This means that Kenya has a large pool of off-grid customers who have access to an energy source which can power off-grid appliances, and in many cases have a relationship with an off-grid solar firm which enables them to purchase off-grid appliances on credit. Given the maturity of its off-grid solar industry, there are established networks of firms and channels for distribution of off-grid appliances. Also much less developed than the solar off-grid market, Kenya is also increasingly a focus for mini-grid development, another potential driver for off-grid appliance off-take. In addition, Kenya benefits from a relatively mature financial sector that loans to target consumers through a wide variety of sources. Strong rural connectivity and high mobile phone ownership rates underpin the broad use of mobile money in Kenya, and this, in turn, has enabled the use of PAYGO financing for the purchase of off-grid solar appliances. Kenyan appliance customers can also access financing through informal savings cooperatives, microfinance institutions (MFIs), and loans from commercial banks that target customers at the base of the pyramid.

India is a leading market in the off-grid appliance sector due to its large population, relatively high income levels, highly developed and competitive microfinance industry, mature off-grid solar industry, one of the world's leading mini-grid sectors, and local appliance manufacturing and government support. India may see slower growth in the cumulative market as the government continues to increase access to grid electricity for large parts of the population, but will nonetheless remain the biggest market off-grid appliance market over the next decade due to its large population and higher incomes.

Categorization of markets

This report focused on eight deep dive countries—Kenya, Uganda, Ethiopia, Nigeria, Sierra Leone, and Côte d'Ivoire in Africa and India and Myanmar in Asia—to illustrate this country typology. Additional information about these markets is available in available in the country profiles, an annex to this report. The market categorization is based on insights gathered through research in these eight markets and presents an initial framework to understand the dynamics of different off-grid markets better. Further in-depth research on a larger variety of markets is needed to develop a thorough segmentation of off-grid markets.

Figure 20: Market categorization of off-grid appliances

	COUNTRY	MARKET POTENTIAL (MILLION USD, 2018)	MARKET POTENTIAL (MILLION USD, 2030)
READY FOR SCALE-UP	INDIA	6,397	9,387
	KENYA	84	264
HIGH POTENTIAL MARKETS	NIGERIA	537	929
	MYANMAR	70	221
	CÔTE D'IVOIRE	49	127
	UGANDA	26	39
NASCENT MARKETS	ETHIOPIA	52	234
	SIERRA LEONE	2	10

Source: Dalberg market sizing model, 2019

High potential markets: Uganda, Côte d'Ivoire, Myanmar, and Nigeria are high-potential markets with a strong outlook for off-grid appliance sales in the future.

Among the focus countries of this study, **Nigeria** is the largest high potential market, driven by its large off- and weak-grid population. With a renewed policy focus, and the clear opportunity of switching households from diesel generators, Nigeria has high potential for becoming the continent's largest off-grid appliance market.

Uganda has been one of the fastest-growing markets for bundled appliances in Sub-Saharan Africa in recent years. Relatively lower income levels constrain uptake, so the country's projections for economic growth are moderate, leading to more conservative projected appliance sales figures.[98] In the event that the Ugandan economy strengthens, the market size could accelerate significantly.

Côte d'Ivoire is a more recent off-grid appliance focus market; however, the increasing access to mobile money and appliance affordability make it a high-potential market. Many solar home system companies have recently expanded into the market and are seeing significant off-grid appliance sales, particularly for televisions but also a fast-growing fan market.

Myanmar, like Côte d'Ivoire, is a market that is more recently garnering attention from industry players. Its large off-grid population and the increasing affordability of off-grid appliances as its economy grows both point toward a strong potential market for off-grid appropriate appliances.

Nascent markets: Ethiopia and Sierra Leone, among the deep dive markets for this report, illustrate more nascent markets in the off-grid appliance sector.

Sierra Leone's market is constrained mainly by its smaller off-grid population in absolute terms compared to other markets, as well as low levels of disposable household income.

Ethiopia's market, while large in terms of off-grid and weak grid population, is held back by its restrictive financial sector and low mobile money penetration rates. In the case that access to foreign capital increases or the mobile sector becomes privatized, Ethiopia could quickly become a high-potential market.

98. Market growth rates are based on IMF projections and historical data

How has the off-grid appliance sector evolved in recent years?

While the off-grid appliance market is nascent overall, appliance sales are growing rapidly and are starting to reach commercial scale for some products.

In the three years since our last sector landscaping report on off-grid appliances[99] the market has grown significantly. Comprehensive data on off-grid appliance sales are not currently available, but our research suggests that a substantial number of households are currently being reached by off-grid appliances.

As of early 2019, GOGLA has been able to gather the most comprehensive dataset on off-grid appliance sales through an appliance-specific module in their bi-annual off-grid solar industry survey. While this data only represents a subset of the market as it excludes companies not known to GOGLA or the LEIA program, we estimate that it represents between 20 to 75% of off-grid appliance sales depending on the country in Africa.[100] In Asia, off-grid solar providers distributing branded appliances are the exception rather than the rule, and generic appliances predominate the market. When combined with additional sales data collected by CLASP and Dalberg in sector interviews, GOGLA's appliance sales data—despite its obvious gaps—provides a directional sense for the market's current reach and growth trends.

We estimate that the total number of off-grid TVs, refrigerators, and fans in use today in homes and small businesses across the developing world is in the low millions.[101] Assuming a 20-50% share of GOGLA affiliate sales to the overall off-grid appliance market and 50-80% annual growth rate in sales results in a sales estimate of 1.4 to just over 5 million TVs, refrigerators, and fans since 2013-2014. This number is likely a good estimate for Sub-Saharan Africa, but may significantly underestimate generic off-grid appliance penetration in Asia, which is largely not reflected in GOGLA data. For instance, more than 5 million households in Bangladesh, the world's largest off-grid market today, had a solar home system by early 2019.[102] A significant portion of these households have purchased and use off-grid appliances, in particular televisions and fans. Survey data suggests that at least 12-50% of these households use televisions with their

Notes on data sources for off-grid appliance supply market dynamics

Sales data for off-grid appliances is not readily available. Many off-grid appliance manufacturers are not as engaged with development partners as the distribution-focused, off-grid solar energy access companies, which makes them harder to reach. GOGLA's industry survey collected appliance-specific data for the first time in the second half of 2018 but received relatively limited responses from participants. Data quality is expected to improve as the industry matures. This analysis uses GOGLA data to provide insights into today's market, and other data sources to project where the off-grid appliance market is heading. Due to a lack of comprehensive sales data, reliable calculations of current market penetration are not yet possible.

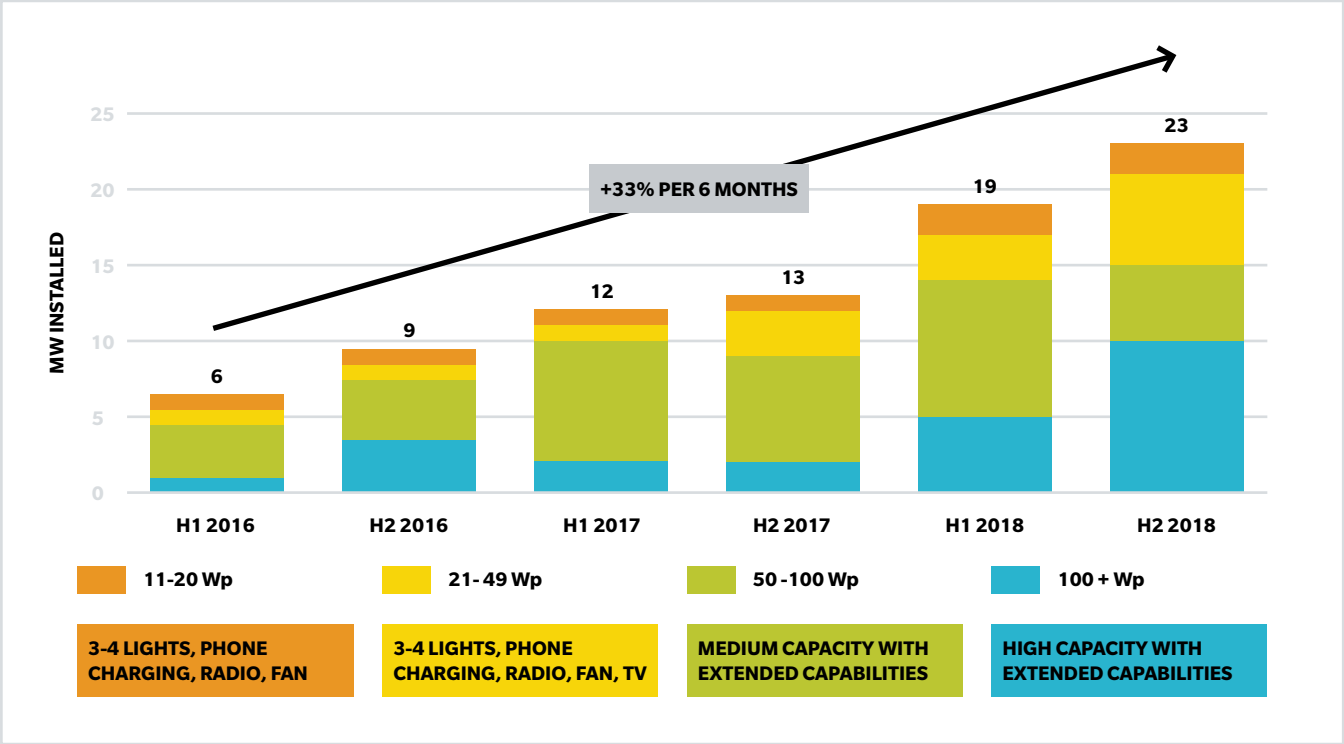
99. CLASP & Dalberg Advisors, *The State of the Off-grid Appliance Sector Report,* 2017, https://efficiencyforaccess.org/publications/the-state-of-the-global-off-grid-appliance-market-2017

100. Directional estimate from interviews; detailed market survey work required for more precise estimates as the sales volumes of generic off-grid appliance products are extremely difficult to quantify. Proprietary Dalberg data on branded vs. generic off-grid solar sales in markets such as Kenya, Tanzania, Uganda, Nigeria, and Zambia suggests that a 20-80% branded appliance share is appropriate and is likely less than 50% in most countries outside of Kenya where GOGLA affiliates that reported data in the survey were heavily concentrated.

101. Dalberg and CLASP analysis based on GOGLA and other market data, 2019.

102. Bangladesh Solar and Renewable Energy Association and IDCOL, 2019

Figure 21: Growth in newly installed global SHS capacity, by SHS size (MW installed)



Source: GOGLA, Dalberg Analysis

solar home system and as many as 40-80% use fans,[103] which would translate into 0.6-2.5 million televisions and 2.5-4 million fans for Bangladesh alone. Adding in countries like India, the aggregate number of off-grid fans, refrigerators, and televisions in use across the developing world is likely to be in the **5-10 million units range.** Of these, we estimate that the highly efficient branded off-grid appliances, which we have referred to as 'off-grid appropriate appliances' earlier in this report, are still a minor (10-30%) share of total sales to date.[104]

While data is scarce, proxies indicate that sales of off-grid appliances could be growing at a rate of up to 80% year-on-year. Due to the off-grid consumer market for appliances still being nascent, there is not yet enough data available to derive growth estimates for sales by appliance type. The GOGLA survey data, with its new appliance-specific module, should in time provide a clearer and more granular picture of sales growth. In the meantime, we can look at solar home system kit sales (also from GOGLA survey data) as a proxy, given these are increasingly bundled together with add-on appliances. In the past three years, medium- and high- capacity systems combined (defined as 50-100 and 100+ watt systems respectively) have seen a 33% growth increase per half-year period, equivalent to approximately 80% annually.[105] Since the main application of higher capacity systems is to power appliances, this growth in sales of larger systems can be seen to indicate a corresponding growth in sales of off-grid appliances.

When asked about market growth directly, individual appliance manufacturers and distributors, including those outside of the solar off-grid ecosystem, suggested that sales for off-grid appliances such as off-grid televisions, fans, and refrigerators have grown at **30-80% annually in aggregate,** but this estimate will need to be confirmed with future sale data reporting.[106]

There are several reasons for the rapid sales growth of the off-grid appliance market. One cross-cutting driver has been the rapid growth of the off-grid solar sector. Based on our interviews with solar home system distributors and select appliance manufacturers, depending on the specific company and geography, **25-85% of solar home system kit sales,** of which there are well in excess of a million annually across the developing world, now include an off-grid appliance.[107] This

103. A survey of a few hundred Bangladesh households from 2017, shows 12-27% penetration of off-grid televisions and 40-80% penetration of fans in households that are SHS users vs. SHS users who also have some grid access at the top of the range. See Batteiger, A. and Rotter, V., "Material Implications of Rural Electrification—A Methodological Framework to Assess In-Use Stocks of Off-Grid Solar Products and EEE in Rural Households in Bangladesh," Recycling, 2018, https://www.mdpi.com/2313-4321/3/1/7/pdf.
Another survey found that 37% of SHS households in Bangladesh purchased and used a TV with their solar home system , see survey data in Khandker, S. et al., Surge in Solar-Powered Homes Experience in Off-Grid Rural Bangladesh, World Bank Group, 2014, http://documents.worldbank.org/curated/en/871301468201262369/pdf/Surge-in-solar-powered-homes-experience-in-off-grid-rural-Bangladesh.pdf. More recent (proprietary) small scale surveys of Bangladesh SHS users and Dalberg interviews suggest that today the off-grid TV penetration of Bangladesh SHS homes is closer to 50%.
104. Dalberg guesstimate based on known market data; efficient off-grid appropriate appliances, primarily fans and TVs, are likely in the 1-2 million unit range, to be refined based on future GOGLA reporting.
105. Off-grid TVs require a larger solar home system of generally at least 30 – 50 Wp while efficient refrigerators require at least a 50 – 100+ Wp solar home system. Wp: Watt peak. The output power achieved by a Solar module under full solar radiation.
106. Dalberg stakeholder interviews, 2019.

strongly supports the idea of using large solar off-grid system sales as a proxy for market growth. Mini-grid deployments focused on off-grid households are still too small-scale to matter for the market in the African context, but many DC mini-grid companies consulted for this report likewise reported appliance bundling. Other drivers of sales growth include ongoing improvements in off-grid appliance performance and quality, growing investment into off-grid appliance manufacturers and distributors which allows them to build out their distribution networks, and—importantly—growing appliance affordability for some categories of products. The average retail price of off-grid televisions tracked by CLASP, for example, fell by 23% (from USD 150 to USD 115) between 2015 and 2018 and is on track for a more than 30% decline by next year.

Televisions have become a critical driver of off-grid solar uptake in many markets. Fans sales are gaining momentum in hot and humid markets – most notably in South Asia, South East Asia, and in specific markets in West Africa—and are seen as important "add-ons" to solar home system kits. While refrigerators and other large appliances continue to generate a lot of interest, products are not yet sufficiently affordable to enable distribution at scale, at least not for household use. Other in-demand household appliances like electric off-grid cookers, with an immediate focus on electric pressure cookers, are at an even earlier stage of product development and evolution.

TELEVISIONS

Televisions represent the most in-demand appliance for off-grid households, the primary add-on for solar home system kits, and are approaching commercial maturity in leading markets. Reported off-grid TV sales for sub-Saharan Africa are high, estimated at 147,000 TVs in the second half of 2018 alone based on GOGLA data. Of those, approximately half were sold in Kenya, followed by Uganda and Côte d'Ivoire as the next best-selling markets. The majority of TVs sold were between 24 and 29 inches, but screen sizes of 30 inches and above are increasingly becoming the norm. The pay as you go (PAYGO) sector currently dominates off-grid TV distribution in Africa. Key PAYGO enterprises engaged in TV distribution include M-KOPA, BBOXX, d.light, Azuri, GreenLight Planet, Fenix International, Mobisol (Engie), PEG, and SolarNow in Africa. In Asia, the structure of the market is entirely different. While several PAYGO actors are involved in off-grid TV distribution such as Simpa Networks in India and SolarHome in Myanmar, most off-grid TVs are bought as part of a package from more conventional (non-PAYGO) solar home system distributors or are bought by households directly from retailers of generic off-grid appliances. The volumes of such off-grid TVs in Asia are large, an average estimate of 1.5 million TVs (0.6-2.5 million range) in Bangladesh alone as noted earlier in this chapter.

The Off-grid TV Market in Kenya

Kenya is the market where sales of off-grid TVs have been highest; even so, we estimate that only a small share of the market has yet been captured. Kenya is one of the most advanced markets for off-grid TVs, and one for which GOGLA sales data is most robust. GOGLA affiliates sold approximately 70,000 off-grid TVs in Kenya in the second half of 2018. We estimate there to be around 870,000 off-grid households in Kenya who can afford TVs at current retail prices. Assuming that GOGLA data captures around 75% of the market, sales of off-grid TVs in the second half of 2018 represented around 11% of those customers, and only about 1% of all off- and weak-grid households.[108] This indicates that there is still a large market to be addressed in Kenya and, as the prices of these appliances decline, the market opportunity will expand to more off- and weak-grid households.

107. Ibid.

108. All sales data are from GOGLA's proprietary sales database. If the reported 70,000 off-grid TV sales represent 75% of sales, then approximately 95,000 TVs were sold in Kenya in H2 2018. This represents about 11% of the 870,000 off-grid households who can afford TVs and about 1% of all off-grid households.

FANS

Electric fans are the biggest off-grid appliance segment in terms of volume of units, but demand is highly unequal across geographies. The GOGLA survey results show that fan sales are most concentrated in South Asia, where an estimated 175,000 fans were sold in the second half of 2018.[109] By contrast, fan sales are near non-existent in East Africa, yet have pockets of high demand in West Africa where the climate is hot and humid. Based on current fan penetration data, key African potential markets for off-grid electric fans include Nigeria, Ghana, Senegal, Côte d'Ivoire, Cameroon, and Angola in West Africa and Tanzania and Madagascar in East Africa.

While it is important to establish a baseline for fan sales, it is clear that the GOGLA sales data is not representative of the total fan market. In particular, in India and Bangladesh, both major markets for off-grid fans, there are many generic and non-branded fans in the market which are not captured in the GOGLA data. For example, in 2018, a Bangladesh results-based financing program supported by Energizing Development (EnDev) led to the sale of over 120,000 fans, all meeting high performance requirements – but these sales were not reflected in the GOGLA data.[110] Total off-grid fan numbers, including generic fans, are in the millions – likely north of 3 million in Bangladesh alone, assuming at least 40% penetration of SHS households.

REFRIGERATORS

Sales of off-grid refrigerators are nascent; the industry has been focused on specialized uses but is now starting to target the household and small business market more broadly. DC refrigerators tailored for off-grid use have been in the market for some time, primarily focused on high-end commercial applications such as vaccine storage. The development of off-grid refrigerators appropriate for the mass market (households and small businesses) is recent. There are now numerous firms focused on product innovation and market testing for off-grid refrigerators, supported by the Global LEAP Awards and other development initiatives. The GOGLA survey data reflects that the market is still very early stage. In the second half of 2018, GOGLA members reported sales of approximately 5,900 refrigerators combined (of which two-thirds were in sub-Saharan Africa[111]), significantly lower than for fans and TVs. This number is expected to rise significantly as more firms leverage existing and new distribution channels to bring innovative and more affordable products that are designed specifically to better meet the needs of off-grid domestic and commercial users.

Total off-grid refrigerator sales, while unknown, are unlikely to exceed tens of thousands based on known sales data and SHS household appliance ownership surveys.[112]

The off-grid appliance market is rapidly growing in complexity, scope of products sold, and number of market actors.

Alongside sales, other clear indicators of market growth include the number of manufacturers, distributors, and products in the market for off-grid appliances. Just 5 years ago, branded manufacturers of off-grid televisions, fans, and refrigerators which specialized in products designed for developing world off-grid and weak-grid consumers numbered just 2-5 enterprises per product category, with only a handful of products visible in Africa and South Asia during market visits.[113] By 2017, as part of the Global LEAP Awards program, CLASP was already tracking dozens of high-quality, off-grid appropriate appliance manufacturers – 11 refrigerator manufacturers with 20 products, 8 television manufacturers with 15 products, and 7 off-grid fan manufacturers with 17 products.[114]

These numbers have continued to grow. As part of the 2019 Global LEAP Awards round for off-grid refrigerators, CLASP has received 39 submissions from 21 manufacturers across 15 countries and Hong Kong - 67% of manufacturers were first time participants. The resulting growth in manufacturer numbers and product variety is already visible on the ground. For example, in 2018, during a survey of off-grid appliances available for sale in 10 rural markets in Tanzania, CLASP identified 16 unique brands across 12 TVs, 11 fans, and 2 refrigerators.[115]

The broader supply side ecosystem of off-grid appliance funders, donors, and sector intermediaries has also evolved rapidly in the past few years.

The energy access ecosystem—including policymakers, regulators, investors, development actors—is gradually placing more emphasis on off-grid appliances. The off-grid appliance space has been supported proactively in recent years by development partners and philanthropies that participate in the Efficiency for Access Coalition and other multi-donor programs.

In the meantime, impact investors looking to harness off-grid solar and mini-grid penetration are channeling growing volumes of patient equity capital and concessional debt to drive off-grid appliance sector growth. Civil society organizations such as CLASP and industry associations like

109. Data in this paragraph are from the CLASP retail database.
110. CLASP and Dalberg analysis, 2019.
111. All sales data are from GOGLA's proprietary sales database.
112. Using the example of Bangladesh, the world's leading household solar home system market, SHS household surveys suggest that almost none of the SHS households are using off-grid refrigerators today.
113. Dalberg proprietary research, 2019.
114. See Global Leap Awards Global Buying Guides, 2016-2017. See, e.g., https://clasp.ngo/publications/global-leap-awards-2017-buyers-guide-for-off-grid-fans-televisions.
115. CLASP, *Appliance Data Trends*, Efficiency for Access Coalition, 2018, https://efficiencyforaccess.org/publications/appliance-data-trends.

GOGLA that play a role in market governance are furthering quality assurance and standards in an attempt to create a more transparent, competitive environment—and ultimately better choices for consumers. Growing grant funding is also supporting R&D for advancements in off-grid appliances, as exemplified by Efficiency for Access R&D rounds, and the 2019 launch of a new specialized intermediary focused on global off-grid appliance innovation, the Access to Energy Institute (A2EI).

The growth of off-grid appliance ecosystem funders and intermediaries is expected to accelerate in the coming years as technologies improve, financing and distribution models are refined, and new appliance categories are introduced in the off-grid market.

Who are the key actors in the off-grid appliance value chain?

Business models around off-grid appliance manufacturing and distribution are rapidly becoming more specialized as more players enter the space and the sector matures. Off-grid solar companies, the fastest growing segment of the off-grid appliance market, primarily focus on establishing long-term relationships with customers and upselling them appliances, since selling durable, high-quality appliances is a great way to ensure sustained demand for solar system sales. Outside of this off-grid solar specialist segment, large, branded original equipment manufacturers (OEMs) are increasingly important as direct sellers to small retail outlets and as overall drivers of off-grid appliance market growth. Manufacturers of generic appliances (both AC and DC) are also growing, though due to a lack of publicly available data their pace of growth is difficult to quantify relative to other company segments. Their products are typically less energy efficient but are more affordable than branded off-grid appliances, and are widely distributed in markets where there are few established off-grid solar home system players.

Beyond the off-grid sector, there is also increased interest from the mini-grid developers in facilitating sales of appliances on-site to drive energy demand and generate value for their customers.[116] Many mini-grid deployments are focused on selling conventional rather than efficient appliances because their primary objective is to maximize energy consumption and thus 'pay for what you use' tariff revenues. This is particularly true for AC mini-grids which are not optimized for off-grid appliances. Using a typical off-grid DC appliance with an AC mini-grid connection requires the use of a rectifier which adds to system costs and lowers appliance efficiency. An increasing number of mini-grid actors, however, particularly those in Africa which are focused on household energy access via DC micro-grids, are starting to focus on the efficient appliance opportunity as a lever for extending the impact and viability of their business models. Several have now entered into or are exploring partnerships with efficient off-grid and weak-grid appliance manufacturers, a trend that will accelerate substantially in coming years.

There is not a single 'value chain' for the diverse variety of off-grid appliances, ranging from fans at the low end, through televisions and to a range of refrigeration solutions at the higher end of cost and energy demand. We have not yet seen one dominant supply chain structure across the growing off-grid appliances space because of the variety of appliance categories, widely differing levels of maturity amongst technologies, the range of market types, and overall nascency of certain aspects of the market. Instead, a range of actors are working alongside one another, all learning how best to serve this growing market, and more time is needed to determine which are most successful and under which circumstances. Stakeholders along the various off-grid appliance value chains vary significantly in terms of maturity, level of integration, and diversity of service offering. In addition, the early stage of development of this market means that there are not yet clear leading business models. Figure 22 illustrates the main typologies of actors currently operating in the off-grid appliances space. However, there is an expectation that the landscape of actors will evolve as the sector matures.

Another defining feature of markets ready for commercial scale-up is that there are two distinct groups of actors gaining ground evolving both from the conventional appliance ecosystem and the off-grid energy ecosystem. Distributed Energy Service Companies (DESCOs) have leading market shares using well-tested business models in the off-grid solar space and are expanding into appliances. These companies see appliance offerings as a way to increase uptake and add value to their core product: solar home systems. They are leveraging their existing customer base, relationships and infrastructure to distribute off-grid appliances and are often able to provide consumer financing as part of their product offering. Some DESCOs are more vertically integrated, with in-house product design and production, while others focus more on the downstream market. Actors operating upstream – including OEMs and branded manufacturers – focus on product design and manufacturing. Many have traditionally produced or sold conventional on-grid appliances and are now moving onto off-grid appliances. Downstream actors, including importers, distributors, and specialist financiers, focus on sales, distribution, financing, and after-care. As this market is still nascent, the supply chain is continuing to evolve, with new players expected to enter the market as more information becomes available and government and donor support continues.

116. McCall, M. & Santana, S., *Closing the Circuit: Stimulating End-Use Demand For Rural Electrification,* Rocky Mountain Institute (RMI), 2019, https://rmi.org/insight/closing-the-circuit/.

Figure 22: Primary actors in the off-grid appliances value chain

Source: CLASP and Dalberg analysis

There are early indications of emerging trends in the supply chain structure of off-grid appliances, reflecting varying levels of market maturity and opportunity. In some countries, DESCOs lead the market across off-grid appliance categories. This is often true in markets with sizeable market potential, more established players, and sufficient prevalence of mobile money or microfinance. For example, in Kenya, larger players such as M-KOPA and d.light are driving distribution and sales of off-grid appliances, in particular, televisions. In India, branded manufacturers are more prevalent and often work in partnership with MFIs to drive market growth. Another category includes countries with a large potential market size but less developed distribution networks. Here, distribution-focused DESCOs have taken the lead in establishing a presence and introducing a more limited range of off-grid appliances. And finally, in nascent markets with small potential market size, local distributors and importers/wholesalers tend to drive the market, bringing in lower-priced generic off-grid appliances. These trends are evolving as the off-grid appliance space matures, and are expected to change as off-grid appliances become more affordable, policies adapt to include off-grid appliances more pro-actively, and mini-grids gain in distribution.

ORIGINAL EQUIPMENT MANUFACTURERS (OEMS)

OEMs produce both component parts and complete off-grid appliances, including generic and branded products. There are over 10,000 OEMs in China manufacturing solar products and off-grid appliances with factories located mostly in Shenzhen, Guangzhou, and Ningbo.[117] Most OEMs sell to other businesses and have limited insight into customer preferences since they do not interface directly with end-users. These companies manufacture both component parts and complete appliances, resulting in a disaggregated supply chain that is challenging to map in its entirety. These businesses play a critical role in the supply chains of all established appliance markets and operate predominantly in the commercial domain, aiming for high-volume orders that are needed to sustain manufacturing enterprises without access to the grants and various forms of support enjoyed by vertically integrated or downstream companies working in markets ready for commercial scale-up of off-grid appliances. For international off-grid appliance manufacturers, the keys to success are low manufacturing costs, a highly technical skill base, and manufacturing in a country with high ease of doing business. For these reasons, the majority of internationally competitive manufacturing takes place in China, Taiwan, and Japan; they are the key drivers of the global market for OEMs and vertically integrated product design, testing and manufacturing of these appliances. There is an opportunity to manufacture more off-grid solar appliance products and components in-country in markets with more sophisticated manufacturing sectors; for example, in India, Bangladesh, and Pakistan. Manufacturing closer to the intended customer could result in improvements in fit-for-purpose product design.

Many OEMs specialize in one type of appliance, such as fans or refrigerators, often producing both conventional on-grid and off-grid appliances. A few OEMs have specialized in off-grid appliances only; these players are at the forefront of driving off-grid solar appliance product design. Metropolitan Electrical Appliance Mfg. Co Ltd. is one such example. The company has been operating since 1982, and since 2016 it has won multiple Global LEAP Awards for energy-efficient table and ceiling fans. If the market for off-grid appliances continues to be perceived as niche, the incentives for OEMs to move into the off-grid space will remain limited. There is hope that more opportunities to engage with the ecosystem, with incentives such as Global LEAP Awards, can bring to light the critical role of OEMs in the supply chain.

117. Made in China, 2019, Product Directory, see https://www.made-in-china.com/.

The geographical and cultural distance between OEMs and the off-grid appliance customer base means that product design and development tend to be based on conventional on-grid appliances. The OEM business model relies on price, volume and speed. OEMs, therefore, tend to take conventional on-grid appliances and adapt the components to suit off-grid use, for example, by substituting in a DC motor along with other required design changes. OEMs typically produce to local distributors' specifications and as such, rely on their market and customer knowledge. To make appliances that are more aligned with real-life circumstances, companies would need to invest more in understanding local customer design preferences or develop strong partnerships with specialized distributors to ensure that they manufacture appliances that better meet consumer needs.

While the majority of international manufacturers are based in China, many governments are trying to incentivize local production of electronics, including off-grid appliances. A good example is the Indian government, who recently increased customs duties on refrigerators and air-cooling appliances by 20% to curb non-essential imports, while also increasing duties on compressors for air-conditioners and refrigerators from 7.5% to 10% to incentivize local production of these components.[118] These duties led to a 10% increase in the price of imported appliances. In Bangladesh, another market with a growing appetite for local electronics manufacturing, LG recently opened a television manufacturing plant and plans to open a refrigerator manufacturing facility.[119] However, protectionist interventions are not always effective, especially when markets are not equipped to manufacture products domestically at a near competitive cost and quality standards, or when a country's overall business climate discourages needed investments in the sector. Ethiopia has encouraged local assembly and production, and Fosera has established a facility for local assembly of solar home systems; however, this remains at a very small scale. The nature of local production, especially in sub-Saharan Africa, may change with the rollout of China's Belt and Road initiative;[120] however, this is yet to be seen. In markets where domestic manufacturing is not viable in the near term, governments should encourage imports to ensure greater access to appliances.

BRANDED MANUFACTURERS

Branded manufacturers – whether conventional or specialized in the off-grid space – offer a suite of products that they source from generic manufacturers and/or OEMs. These actors typically rely on OEMs and generic manufacturers to provide them with parts or products manufactured according to their specifications. There are two kinds of branded manufacturers: off-grid appliance brands like Niwa and Fosera, and conventional appliance leaders like Panasonic, Hisense, and Samsung. These larger appliance brands have more sophisticated technical capabilities, manufacturing factory capacity at scale, and capital. However, they tend to focus on selling existing product lines in developed and larger markets. They have traditionally shown less interest and risk appetite to enter less proven markets.

Specialist branded manufacturers, who focus on the off-grid market, are limited by their lack of scale. Specialist players are much smaller in size than conventional manufacturers, and they typically have less reach and capital. In the off-grid industry, these players tend to be global with local distributors in country markets. To drive sales, branded manufacturers require in-market distribution partners that understand their products and know how to sell their brand to consumers. In some cases, they have a country-based business development representative or team responsible for building their brand in-market and developing partnerships with local retail outlets or third-party distributors. Some specialist players may also employ local technical teams to assemble products and assist distributors with any required after-sales support—especially for larger appliances such as refrigerators, which are often exported without full assembly. In addition to these distribution partnerships, branded manufacturers try to build strong feedback loops and ways of working with OEMs so that they can translate customer needs and customer feedback into product design.

As the market becomes more competitive, research and development (R&D) is becoming a means to differentiate products and yield higher margins. This focus on the value proposition of lowest possible cost while providing key functionalities is increasingly important as customers move from accessing fans and televisions to higher-value appliances such as refrigerators and take on longer-term financing (usually two to three years). Products must not only be affordable but also have a lifespan that, at the very least, last the duration of the customer's repayment period and provide a level of performance and service that keeps customers satisfied

118. Writankar, M., "White Goods Makers to Turn Champions of Made in India," *Economic Times,* November 2018, https://economictimes.indiatimes.com/industry/cons-products/durables/white-goods-makers-to-turn-champions-of-make-in-india/articleshow/66743569.cms

119. Hossain Ovi, I., "LG, Butterfly set up first ever TV manufacturing facility in Mymensingh", *Dhaka Tribune,* March 2018, https://www.dhakatribune.com/business/2018/03/15/lg-butterfly-set-up-first-ever-tv-manufacturing-facility-in-mymensingh

120. China's Belt and Road Initiative is a global development strategy adopted by the Chinese government to develop infrastructure and make investments in 152 countries.

throughout the product's lifetime. This makes product innovation for durability and energy efficiency critically important. However, in the short term, until manufacturers can reach scale, a focus on efficiency and durability leads to a more expensive product. Fosera, for example, recently invested heavily in the design and manufacture of their Cool Sun refrigerator. It improves on the energy efficiency of earlier generations and uses a better-quality thermostat to increase durability for target customers who need the product to work for at least as long as it takes them to pay off the loan they borrowed to buy the item.[121] In the long run, this R&D investment is likely to lead to higher margins as customers demand higher quality products. In the short term, however, with so many uncertified, low-quality products accessible in the market, manufacturers are hard-pressed to reap the rewards of their innovation.

Lack of funding is a serious constraint to R&D. A few manufacturers able to use their own capital largely drive product development and innovation. Manufacturers today feel obliged to reinvest savings from optimizing on production costs into R&D, rather than lowering retail prices.[122] The lack of scale in the industry continues to be a challenge to lowering the cost of manufacturing, and consequently the cost to the consumer.

VERTICALLY INTEGRATED DESCOS

Vertically integrated DESCOs have built up capacity to own the end-to-end delivery of solar home systems, and in recent years have included off-grid appliances in their business models. Today's leading DESCOs were established between 2010 and 2015 when the off-grid solar market took off with a few manufacturers supplying off-grid products into markets ready for commercial scale-up of off-grid appliances. Examples include M-KOPA, BBOXX, and d.light, which all started out providing pico-solar lanterns and lights-only solar home systems for rural customers. To succeed in their nascent market, these businesses established capabilities across the supply chain, including product manufacturing, sales, and distribution. Vertically integrated DESCOs have largely also adopted 'pay as you go' (PAYGO) models to sell appliances on credit to off-grid consumers and have developed software to control customers' access if they do not make payments. This access to credit has enabled customers in weak- and off-grid areas to afford more expensive systems beyond lighting and mobile phone charging. While DESCOs have helped drive uptake of off-grid solar appliances, they have faced challenges in achieving profitability due to the high cost-to-serve driven by the high cost of distribution and low volumes.[123]

As markets mature, there is both opportunity and pressure for vertically integrated DESCOs to adjust their business models. These players' original, vertically integrated approach emerged due to a lack of reliable suppliers to manufacture the technology, as well as a lack of reliable distributors to reach their target customers. However, as specialized product development, distribution, financing, and other business-to-business players enter the market, vertical integration may be less necessary.[124] For DESCOs responding to this trend, appliances represent opportunities to cross-sell to existing customers and to attract new customers. In Asia, most providers have offered fans for years, while the TV offering is relatively new, and the refrigerator offering is nascent. In sub-Saharan Africa, where vertically integrated DESCOs have seen success with their solar home system offerings, the addition of appliances to their product offerings helps increase demand for solar home systems.

Despite the changing market, opportunities exist for vertically integrated DESCOs to continue creating long-term customer value. As the market matures, it is likely that vertically integrated manufacturers will need to select a new competitive advantage beyond their product and distribution network. They will need to shift their focus to, for example, the software components they can offer the supply ecosystem (e.g., software to soft lock products, TV content, etc.). The data collected on these platforms can also be used to understand customers as the bottom of the pyramid, potentially enabling financial service providers (FSPs) to provide financing to people that lack a traditional credit history.

DISTRIBUTION FOCUSED DESCOS

Distribution focused DESCOs rely on upstream and downstream partnerships to offer end-to-end value chain capabilities. Distribution focused DESCOs are typically newer market entrants than traditional DESCO businesses, having stepped into the market since 2015. They coordinate activities across the supply chain but have opted for strategic partnerships rather than offering end-to-end capabilities in-house. This 'unbundling' of the DESCO model allows for more agility in technology and business models. Companies are now looking to specialize in one or two pieces of the supply chain, such as hardware, software, distribution, consumer financing, and/or value-added services. Examples of these businesses include PEG Africa and Baobab+, which buy products from manufacturers, having provided some product specifications, and then partner downstream with telecommunications companies and MFIs to offer financing options (e.g., PAYGO or microcredit) to consumers. They focus on distribution and financing tools, rather than the product itself, to drive product sales.

121. Dalberg stakeholder interviews, 2019.

122. Ibid.

123. Persistent Energy & Shell Foundation, *Bridging the Gap to Commercial Success for Energy Access Businesses,* Shell Foundation, 2018, https://persistent.energy/wp-content/uploads/2018/11/Bridging-the-Gap-to-Commercial-Success-for-Energy-Access-Businesses.pdf. Cost to serve refers to the cost per customer DESCOs must spend to be able to provide their customers with the service.

124. Sotiriou, A. et al., *Strange Beasts: Making Sense of PAYGO Solar Business Models,* CGAP, 2018, https://www.cgap.org/sites/default/files/publications/Forum-Strange-Beasts-Jan-2018.pdf.

CASE STUDY
Baobab+ Partnerships

Baobab+ partners with upstream and downstream actors to build end-to-end value chain capabilities and drive product sales in Senegal, Côte d'Ivoire, Mali, and Madagascar. Baobab+ typically targets rural and peri-urban customers providing off-grid appropriate TVs bundled with SHS. Upstream, Baobab+ partners with Greenlight Planet's Sun King and Niwa to supply TVs and Biolite to supply branded solar home systems. Downstream, Baobab+ has developed a sales and distribution network to reach its customer base, and partners with Baobab Bank to improve financial inclusion after a solar loan. With the PAYGO option, a client pays a deposit fee—usually 10% of the total product price—followed by regular weekly or monthly payments until the client fully owns the system.

Launching PAYGO in 2017 has enabled Baobab+ to grow its consumer base, remove the affordability barrier for its products in Côte d'Ivoire, and record its largest annual sales revenue in 2018. Partnering along the value chain allows Baobab+ to effectively share the risks and costs of providing off-grid products to hard-to-reach customers while ensuring that it can specialize in product sales and distribution. The company has enriched its model by partnering with another downstream actor, Canal+, to offer TV channels and sports entertainment as separate payment packages that continue to produce revenue even after the consumer fully owns the system.

Distribution focused DESCOs are newer to the market and are driving innovation as they launch, in particular in West Africa. They have made significant investments in offering better consumer financing (via PAYGO) offerings and after-care services. Their model is built on strong partnerships, allowing them to remove some of the more cumbersome distribution and product design costs from their balance sheets. These businesses are more likely to work in weak-grid peri-urban areas, where there are existing distributors or financing providers with whom they can partner.

IMPORTERS AND WHOLESALERS

Importers and wholesalers have historically brought conventional appliances into markets in sub-Saharan Africa and Asia, and some are beginning to add off-grid appliances to their portfolios. These players operate existing commercially viable enterprises, import products at high volumes from OEMs or branded manufacturers, and sell to local distributors or retail outlets. Importers and wholesalers are often constrained by their cash flows, needing to recover costs before placing new orders and typically waiting to import full shipping containers to limit transportation costs per unit. These players face particular challenges importing and wholesaling off-grid appliances because they are more expensive and market demand is less certain than for lower cost off-grid products, consumer electronics, etc. Because of these dual constraints – the constraint of cash flow on the supply side and the demand side market constraint – importers and wholesalers tend to focus on cheaper generic off-grid appliances.

Importers and wholesalers play a stronger role in the off-grid solar supply chain in more nascent off-grid appliance markets such as Ethiopia and Sierra Leone, where they have been the first movers driving products into the market. As awareness grows, the expectation is that off-grid appliances will become a more important segment for importers and wholesalers even in high potential markets. These actors can be important distribution partners for larger manufacturers, given their expertise in the conventional appliance markets, established distribution networks, and familiarity with local regulations and business practices. They may potentially have easier access to conventional sources of finance from local banks in comparison to the other value chain actors featured here.

Local distributors and retailers

Local distributors and retailers may purchase appliances either from local wholesalers/importers or import appliances directly from branded or generic manufacturers for resale in the local market. Local distributors and retailers develop a strong network of sales agents or retail outlets that they use to sell appliances on behalf of a manufacturer. These local distributors and retailers are the closest to the customer. While some focus on off-grid appliances, many also sell other appliances or other

categories of goods. Many seek partnerships with third-party organizations such as MFIs, NGOs, or telecommunications companies to expand their reach to local consumers. Smarter Grid International, for example, received a grant from the GSMA to partner with Nigerian telecommunications companies so it can expand its distribution range and retail outlets. It also has a partnership with an MFI to provide financing to consumers.[125] In India, MFIs have been critical partners because they offer financing and distributors have been able to tap into their established customer bases.

The distribution of off-grid appliances must also come with trained specialists able to provide sufficient after-sales service. Given the more specialized nature of televisions and refrigerators in particular, providers are working to improve how they can provide the right level of after-care service to customers. Appropriate technical education is needed to ensure that there are enough qualified technicians available to serve a growing customer base of off-grid appliances. This challenge is already faced for solar-home systems, but becomes more pronounced with the advent of off-grid appliances. Some governments and schools have prioritized Information and Communications Technology (ICT) in their higher education policies, working to ensure that there is a workforce that can support the growing industry. Businesses are also developing approaches to train technicians for the off-grid solar industry, including appliances.

CASE STUDY
The Global Distributors Collective

The Global Distributors Collective works with last mile distribution companies to help them reach underserved customers with a variety of life-changing products – including off-grid appliances. It provides centralized resources such as training, innovation pilots, and learning events. It is also working to develop a centralized purchasing platform for its members that could help reduce costs of procuring products by helping create scale and centralizing logistics. This initiative has the potential to kick-start last mile distribution and provide incentives for more off-grid appliance manufacturers to think about how to distribute most effectively.

Financing is usually a constraint for local distributors. Distributors typically run micro-enterprises and have limited assets or liquidity to serve as collateral for conventional bank loans or to convince suppliers to provide goods on credit. They also need to lay out considerable up-front capital to stock off-grid appliances, but many customers can only pay in installments. This method of payment creates a challenging cash flow imbalance, especially for more expensive appliances like televisions and refrigerators. Organizations such as EnVenture Enterprises in Uganda have been critical in empowering these smaller distributors. They have devised a financing model that provides below-market rate business loans to community-based organizations that become distributors in their communities. Using community-based local organizations de-risks the investment, making the community accountable for repayment, and it also improves trust in the products sold.

SPECIALIST FINANCIERS

Specialist financiers provide access to finance to off- and weak-grid households, allowing potential customers to overcome affordability barriers. These actors include MFIs, mobile money providers, and other technology-enabled companies. They are using the increasing demand for off-grid appliances to grow their businesses and offer various forms of PAYGO and asset financing. Their unique selling point is their existing presence and client base in off- and weak-grid areas, where their services tend to be focused. They have expertise serving lower-income populations and have developed approaches to assess credit risk for customers who lack traditional credit data. Specialist financiers typically work in partnership either with DESCOs or with local distributors. In South Asia, in partnership with product suppliers such as Greenlight Planet, microfinance institutions such as BRAC and the Self Employed Women's Association (SEWA) are offering consumer loans to customers for the purchase of off-grid appliances.

Specialist financiers are critical because they target off- and weak-grid customers who are typically not served by traditional financial institutions. Banks often do not serve off-grid solar customers because of the high cost to serve and reach them, as well as the perceived higher risk profile of their loans. Off-grid customers tend to be in more remote areas, and therefore the cost of reaching them geographically – typically via motorcycle – is high both in logistical costs and in the time demands on loan officers. Even for customers in urban and peri-urban areas, the time required to assess a loan application for an appliance is high relative to the loan value. Moreover, financial institutions often lack the expertise to assess risk effectively for low-income customers, who often lack formal credit history, and especially farmers, whose applications can face a particular set of challenges such as a lack of land title. Specialist financiers fill this gap by designing business models tailored to the needs of base-of-the-pyramid customers.

125. Dalberg stakeholder interviews, 2019.

In countries with mobile money, new technology-driven business models have accelerated specialist financing. Mobile money providers have been at the forefront of expanding access to consumer finance and scaling PAYGO for sub-Saharan African markets. For example, in Kenya, Equity Bank's "Eco Moto" loan product has financed the purchase of approximately 40,000 off-grid solar products in past three years in partnership with six business, including Greenlight Planet's Sun King, d.light, and BioLite. While it initially focused on clean energy cookstoves and solar lighting products, Equity Bank is currently expanding its product offerings to include the financing of off-grid TVs and refrigerators.[126] Flexible repayments are allowed over a 12-month maximum loan term, with customers taking an average of three to six months to repay. Equity sells appliances to customers through its 30,000 agents, who facilitate end-user financing assessments through the bank's digital platform, Equitel.

What is the role of consumer financing?

The challenge of affordability makes consumer financing a critical enabler of off-grid appliance business models. There are two prevalent models of financing for off-grid appliances: traditional PAYGO financing or a micro-loan through an MFI.

Consumer financing is increasingly enabling customers to purchase more off-grid appliances, especially TVs and fans. After observing that access to finance was one of the biggest drivers of SHS sales in the last ten years, several businesses have invested significantly in expanding the base of the pyramid access to finance for off-grid appliances. In the case of SHSs, consumer finance enabled customers to purchase systems retailing between USD 125 and USD 800—prices that customers would not otherwise have been able to afford.[127]

Vertically integrated DESCOs and distribution-focused DESCOs have historically provided PAYGO financing for their appliance bundles—although other options are gaining traction. PAYGO is the leading financing model for DESCOs in most of sub-Saharan Africa. A few major operators, such as Barefoot Power, d.light, and BioLite, are experimenting with other consumer financing models, such as MFI-based product loans or micro-loans accessed through mobile money. In India, MFIs are experiencing increased uptake and have substantial demand for clean energy finance. In 2015, the estimated demand for micro-finance products stood at INR 1.33 billion (US 18.8 million) for the poorest segment (USD 7 million people) and INR 2.67 billion (USD 38 million) for the low-income segment (2.2 million).[128]

Consumer financing for expensive products such as off-grid appliances does come at a price to the customer. Consumer financing increases the total amount paid for an appliance by 40 to 70% above the upfront retail price because providers pass their high cost of debt onto consumers.[129] Consumers are starting to recognize this and are increasingly conscious of the risk of taking on more debt. The arrangement is particularly precarious for rural customers, who have seasonal incomes but sign up for monthly repayment schemes. Many financing offerings also demand high down payments (between 5% and 30% of the total package price), which may require prospective customers to save for several months before they can purchase a package.

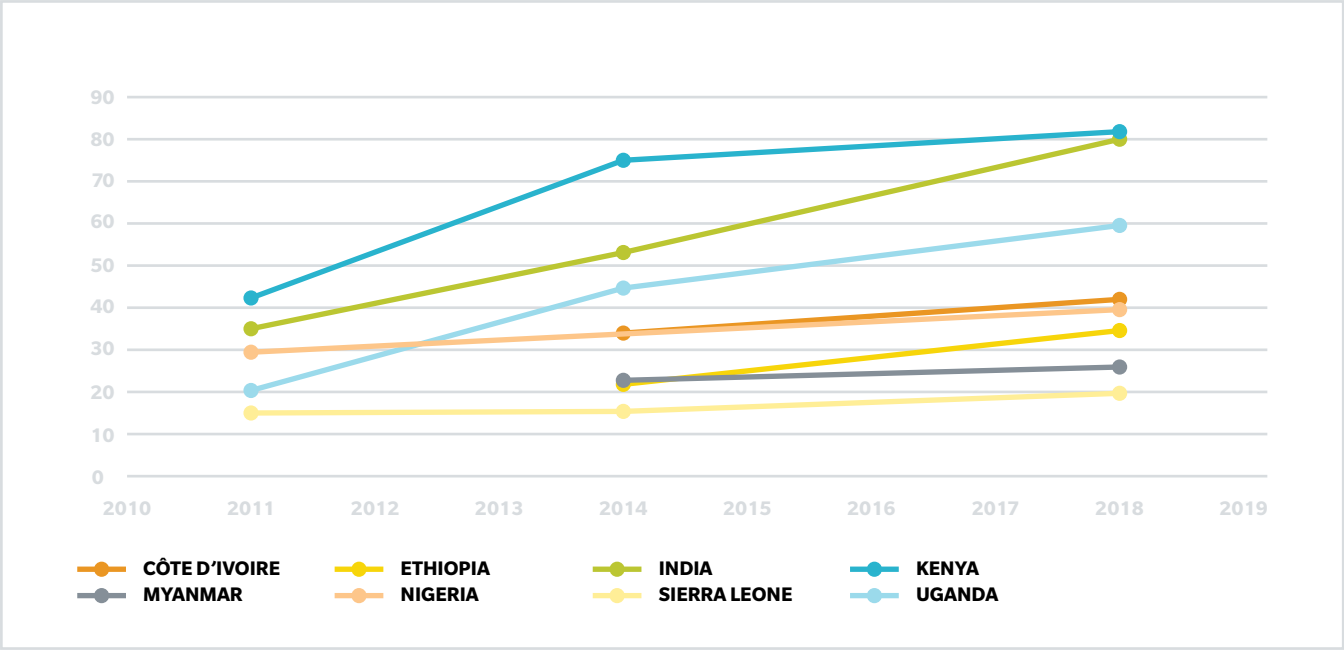
Digital financing and mobile money are critical in making consumer financing of off-grid appliances viable.

Digital financing has been a critical enabler of consumer financing, and continues to be the biggest potential enabler of increased off-grid appliance sales. Mobile payments can lower the cost of providing financial services by 80 – 90%, enabling providers to serve lower-income customers profitably.[130] In a growing number of countries in sub-Saharan Africa, a traditional stronghold of mobile money, over 60% of the adult population has a mobile money account—and of the six African countries in our study, Kenya (82%) and Uganda (59%) have the highest penetration rates.[131] However, there is still a tremendous opportunity to increase financial inclusion and stimulate growth in the continent's mobile money sleeping giants: Nigeria, Egypt, and Ethiopia.[132]

As customers benefit from access to finance, mobile money providers in turn benefit from increased sales of off-grid appliances. Some studies suggest that mobile money transaction values increase as the level of solar energy access increases, and this trend appears to be growing over time.[133] As vertically integrated distributors continue to increase their distribution networks, they may be able to attract more mobile money partners to support off-grid appliance sales. Over time, mobile money partners may also be able to expand credit to customers who have established a track record through PAYGO payments for solar products. However, there is no clear, proven causal relationship between purchasing solar products through PAYGO and improvements in financial inclusion.[134]

126. Ibid.
127. World Bank & Dalberg Advisors, *Off-grid Solar Market Trends Report,* World Bank Lighting Global Program, 2018, https://www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report/.
128. MicroSave & WWF India, *Role of Finance with a Special Focus on Microfinance in Enhancing Clean Energy Access,* WWF, 2015, https://d2391rlyg4hwoh.cloudfront.net/downloads/role_of_finance_in_enhancing_clean_energy_access.pdf. Poor households are defined as those with an income of INR 120 – 200 per day; Low income households are those with incomes above INR 200.
129. World Bank & Dalberg Advisors, *Off-grid Solar Market Trends Report,* World Bank Lighting Global Program, 2018, https://www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report/.
130. McKinsey Global Institute (MGI), *Digital Finance for All: Powering Inclusive Growth in Emerging Economies,* McKinsey, 2016.
131. World Bank, "Account Ownership at a Financial Institution or Mobile Money Service Provider," 2018.
132. GSMA, *State of the Industry Report on Mobile Money,* GSMA, 2018.
133. UNCDF website materials on "Clean Start", UNCDF, 2018.
134. Goyal, R. & Jacobson, A., *Energy Access and Off-grid Solar Use in Uganda,* Schatz Energy Research Center (SERC) and UNCDF, 2019.

Figure 23: Account ownership at a financial institution or with a mobile-money service provider (% of population ages 15+)



Source: World Bank 2017, Global Findex Database

PAY-AS-YOU-GO (PAYGO)

PAYGO is most prominent in East Africa, where the model helps drive solar home system and off-grid appliance sales. In 2017 M-KOPA, Fenix, Zola Electric, d.light, and Azuri accounted for more than 90% of all SHS sales.[135] Customers in four East African markets - Kenya, Tanzania, Uganda, and Rwanda - purchased 83% of these units.[136] Using the same financing model, these companies are now expanding their product portfolios to sell off-grid TVs, fans, and refrigerators, as appliance sales allow them to bundle the price of the solar home system with an appliance.

While most providers are sanguine about the potential of PAYGO to drive appliance sales, especially for televisions, the model does present some challenges. Default rates on appliance portfolios have been high for some businesses, with reported rates ranging from 20% to 50%.[137] However, these numbers are based on self-reporting, fall within a specific time and geographical area and are often based on pilots or small volumes of sales. A lack of concrete industry data also makes it difficult to determine clear causality. Other businesses report relatively better repayment on SHSs that are large enough to power televisions because, unlike for smaller systems that power solar lights and can be substituted with kerosene, customers have no available alternative. In addition, unlike lights-only solar home systems which companies can control remotely, televisions and fans have no software for remote switch-off. Providers must instead rely on switching off the entire SHS if customers do not pay their installments. This measure is appropriate for customers who are first-time buyers of an SHS bundled with an appliance. However, for future customers who might own an SHS and purchase an appliance outside of the bundle, enforcement of this penalty is challenging, and the alternative of repossessing the asset is costly for both providers and distributors.

MICROCREDIT

Across South Asia, microfinance institutions (MFIs) are driving the uptake of off-grid appliances through microcredit. This is also occurring in sub-Saharan Africa, particularly in East Africa, albeit on a much smaller scale. In these geographies, it plays a highly significant role that has the potential of growing substantially as markets mature and MFIs become more comfortable with the asset class and approach. Microcredit is the extension of very small loans to impoverished borrowers who typically lack collateral, steady employment, or a verifiable credit history. The structure of microcredit arrangements differs from that of traditional banking, where collateral may be required or other terms established to guarantee repayment. There are no upfront costs to most micro-loans, and there might not be a written agreement at all. In some instances, the microcredit is guaranteed by an agreement with the members of the borrower's community, who can compel the borrower to work toward repaying the debt. As borrowers successfully pay off their microcredits, they may become eligible for larger loans.

135. Climatescope, "2Q 2017 Off-grid and Mini-grid Market Outlook," 2017.
136. Akanksha, S., "Going Greenfield with Utility Pay-as-you-go Models: enabling access to water, sanitation, and energy in and beyond East Africa," GSMA, 2017.
137. Dalberg stakeholder interviews, 2019.

MFIs are well positioned to drive off-grid appliance sales, because they have an established customer base with whom they have developed trust, and they can provide products at the right price point through partnership with solar service companies and appliance suppliers. Off-grid appliances are at the ideal price point for microcredit lending. Loan amounts for pico-solar lights and basic off-grid lighting products are too small to justify the transaction costs borne by MFIs, while larger solar home systems would require a loan more costly than what the consumer could afford and too long-term for MFIs to take the risk. Greenlight Planet's fan, for example, retails for USD 85—too much for most customers to pay for in cash, but affordable with financing. The company estimates a demand of roughly 10,000 – 15,000 units per month based on customers' willingness to purchase via a loan with an MFI.[138] Figure 24 illustrates the typical structure of an MFI's direct-to-customer loan.

The need for consumer finance is greater for higher-value appliances. We anticipate two main trends, which may happen in parallel as providers evolve to take advantage of new product opportunities.

Major vertically integrated DESCOs that offer PAYGO are raising capital to expand their role as financiers—essentially becoming banks to off- and weak-grid customers. Under this model, DESCOs directly qualify borrowers and service loans. They can draw on their own equity or raise debt capital to finance loans. DESCOs are poised to expand further into the financing space due to their unique understanding of their customers and proprietary approaches to risk assessment which leverages their unique access to customer repayment and product use profiles. Indeed, these businesses already have a strong track record raising capital to finance their PAYGO offerings. Eight of the top ten deals for energy access investments since 2016 have been to PAYGO providers, and PAYGO providers have absorbed about 90% of the USD 1.7 billion in investment capital flowing to energy access companies to date.[139]

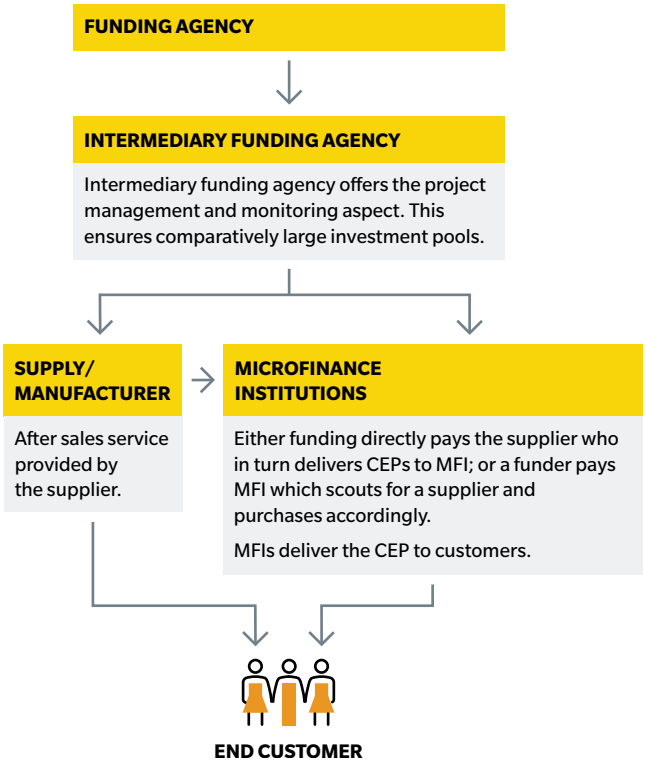
Over time, the off-grid solar financing space may disaggregate, with distribution focused DESCOs partnering with specialist financiers. Specialist financiers' focus and expertise in off-grid consumer financing could bring down financing costs over time. This could reduce the role of vertically integrated DESCOs as financiers, leading them to focus more on product technology and distribution. Partnerships will be critical for this advancement to occur in the market, and efforts should be taken to facilitate and coordinate these partnerships.

Figure 24: Direct-to-customer intermediation microcredit model

DIRECT-TO-CUSTOMER INTERMEDIATION MODEL
In the microfinance intermediation model, funding agencies provide the funds for lending to an intermediary funding agency. This intermediary funding agency is then responsible to identify suppliers and microfinance institutions, conduct due diligence, distribute and manage funds, and ensure repayments from microfinance institutions. The microfinance institution in turn is responsible for building awareness of the financing, client acquisition, collection and post sales services. The collaboration between the funding agency, intermediary funding agency, microfinance institution, and supplier allows for a more cost effective service for customers.

PURPOSE
- This model is generally adopted for individual small ticket size solar loans ranging from INR 400 to INR 25,000 for products.

EXAMPLES
- SEWA Bank - Friends of Women's World Banking – India
- Envirofit



Source: Dalberg analysis

138. Ibid.
139. Wood Mackenzie, *Strategic Investments in Off-grid Energy Access: Scaling the Utility of the Future at the Last Mile,* 2018, https://www.woodmac.com/news/editorial/growing-offgrid-energy-access-sector/

What is the current state of off-grid appliance features and performance?

The range of high quality, efficient off-grid appliances available in the market has expanded in recent years. In its early stages, the solar off-grid market largely focused on lighting systems and basic, low-cost appliances like mobile phone chargers and radios. A new wave of off-grid appliances has reached, or are close to reaching, commercial readiness for household use. These appliances include fans, televisions, refrigerators, and, as covered in a companion Efficiency for Access Coalition report on solar water pumps. In terms of technology, off-grid fans and televisions are most mature. Off-grid refrigerators have seen a recent surge in the number of products under development, with many currently undergoing market testing.

TELEVISIONS

Technology improvements are rapidly enabling off-grid customers to enjoy higher-performance and larger televisions at similar prices to those of much smaller TVs just a few years ago.

Off-grid televisions have developed beyond the anticipated 19-inch size we predicted for 2020 in the earlier sector report – 24-32 inch televisions are starting to dominate today's market.[140] The market for off-grid televisions has evolved rapidly in the past four years, responding to growing consumer demand. Many solar off-grid system distributors sell over 25% of solar home systems with a television.[141] Manufacturers and distributors report a clear trend in demand for larger TV screen sizes, with consumers increasingly demanding screen that are 24 inches and larger.

This market trend is supported by data reported by GOGLA-affiliated businesses. In the second half of 2018, 64% of all off-grid televisions sold by GOGLA members had a screen size of at least 24 inches, with 8% having 30 or more inches.[142] In East Africa, where the off-grid television market is most developed, more than 75% of off-grid televisions sold are at least 24 inches.[143] In West Africa's more nascent market, customers demand smaller screen sizes on average, though demand for large televisions at the high-end of the market is as strong as in East Africa. There is insufficient data on South Asia's off-grid television sales to generalize about technology trends. However, anecdotal evidence from our interviews suggests a move to larger television screens in India, Bangladesh, and Myanmar.

Figure 25: The current state of play – TVs, Fans, and Refrigerators

	TELEVISIONS	FANS	REFRIGERATORS
TYPICAL PRODUCT SIZES	Small: 15" – 24" Large: 24" – 32"	Pedestal: 320 – 650 mm Ceiling: 1040 – 1380 mm Table: 100 – 380 mm	Small: <100 L Large: 100 – 250 L
AVERAGE RETAIL PRICE*	Small: $56 - $195 (avg. $115) Large: $110 - $257 (avg. $181)	Pedestal: $9 – $127 (avg. $38) Ceiling: $14 – $135 (avg. $48) Table: $7 – $76 (avg. $27)	Small: $160 - $600 (avg. $310) Large: $245 - $1350 (avg. $550)
RATED POWER CONSUMPTION	Small: 15 W – 39 W Large: 40 W – 130 W	Pedestal: 10 W – 230 W Ceiling: 24 W – 80 W Table: 8 W – 25 W	Small: 43 W – 65 W Large: 55 W – 90 W
EFFICIENCY METRICS	**Luminance (cd/m²)** Small: 51 – 387 cd/m² Large: 133 – 230 cd/m² **Average EEI (sq. in/W)** Small: 10.01 sq. in/W Large: 11.39 sq. in/W	**Energy Efficiency Value (m³/min/W)** Pedestal: 0.7 – 3.4 m³/min/W Ceiling: 3.9 – 7.6 m³/min/W Table: 1.0 – 4.3 m³/min/W	**Daily Energy Consumption (kW/24h)** Small: 0.5 – 0.7 kWh/24h Large: 1 – 2.5 kWh/24h
TECHNOLOGY INNOVATIONS	• LED technology • Variable voltage • Efficient optical films • Compatibility with relevant signal type	• Brushless DC motors • Permanent magnet technology • Increase in blade size and power • Higher efficiency of motor for improved cooling	• Brushless and variable speed DC compressors • High efficiency gasket materials

*Not inclusive of supporting energy source. The refrigerator size classification is informed by the 2017 LEIA Technologies Summaries report that classifies any fridge under 100L to be small.

Source: CLASP and Dalberg Analysis, 2019

140. For earlier projections of off-grid TV technology trends see CLASP & Dalberg Advisors, *The State of the Off-grid Appliance Sector Report*, 2017, https://efficiencyforaccess.org/publications/the-state-of-the-global-off-grid-appliance-market-2017. See the "Supply market status and business model trends" (Chapter 3) of this report for more information on off-grid appliance sales based on GOGLA data.
141. Dalberg stakeholder interviews suggest a range of 25%-50% depending on solar distributor consulted, 2019.
142. All sales data are from GOGLA's proprietary sales database based on an early 2019 GOGLA affiliate survey.
143. Ibid.

The market is moving to screens that are above 24 inches in comparison to the smaller TVs that were common just a few years earlier (e.g., the 22 inch screen-size solar TV distributed by BRAC in Bangladesh and the 20 inch "Magic" TV launched by Simpa Networks in 2017).

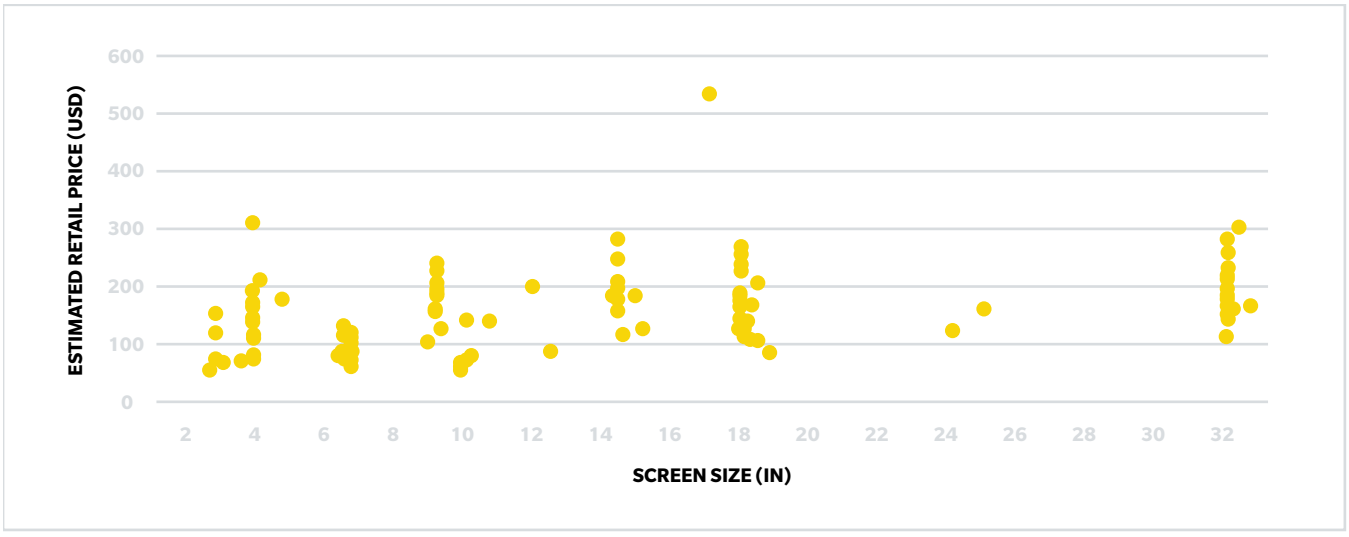
Retail prices for off-grid televisions have decreased on average from USD 150 in 2015 to approximately USD 115 in 2018, a decline of 23%.[144] The current trend suggests that the market will likely exceed the 30% price drop we predicted by 2020 in the 2016-2017 appliance sector report. This cost reduction can be attributed in part to greater economies of scale in production as the off-grid television market becomes more established. The market has benefitted from centralized manufacturing in China, South Korea, Japan, and Taiwan, which has lowered overall production costs. In 2015, the average cost per screen size of a Global LEAP Award TV was USD 1.57 per square inch; this dropped to USD 1.06 per square inch in 2017 and even further at USD 0.65 per square inch for baseline products.[145]

While prices per inch have dropped, average prices for off-grid televisions in the market have stayed constant, or even increased, since—as noted above—consumer have embraced larger television screen sizes. Televisions with screen sizes of 24-inch now retail at on average USD 150 and premium products of up to 32 inches are in the USD 150-250 range (see Figure 26).

CASE STUDY
Cello Solar

Cello Solar is an associate company of one of the leading LED television brands, Cello Electronics. Their solar products incorporate the charge controller, battery, satellite tuner, and USB for device charging, all built into one television set. The available product specifications are 22-inch and 32-inch televisions retailing at USD 240 and USD 420, respectively, with a 43-inch product set to be released soon. Cello Solar televisions are the first fully incorporated solar products. Its 22-inch model works with a 30W panel, and the 32-inch model works with a 40W solar panel. The product is currently being rolled out through third party distributors, with the expectation that high quality design will drive sales.

Figure 26: Overview of off-grid TVs currently in the market, by price and screen size



Source: Equip Data (n=123)

144. Dalberg stakeholder interviews, 2019; CLASP pricing data, 2018.
145. "Appliance Data Trends," Efficiency for Access, 2018.

FANS

Table fans continue to dominate the off-grid fan market, while pedestal fans are increasingly in-demand as consumers seek higher cooling capacity. Table fans are low-cost, portable, and have modest energy consumption compared to larger fan types.[146] Pedestal or standing fans offer better airflow and are often not significantly more energy-intensive or expensive than table fans (see Figure 27).

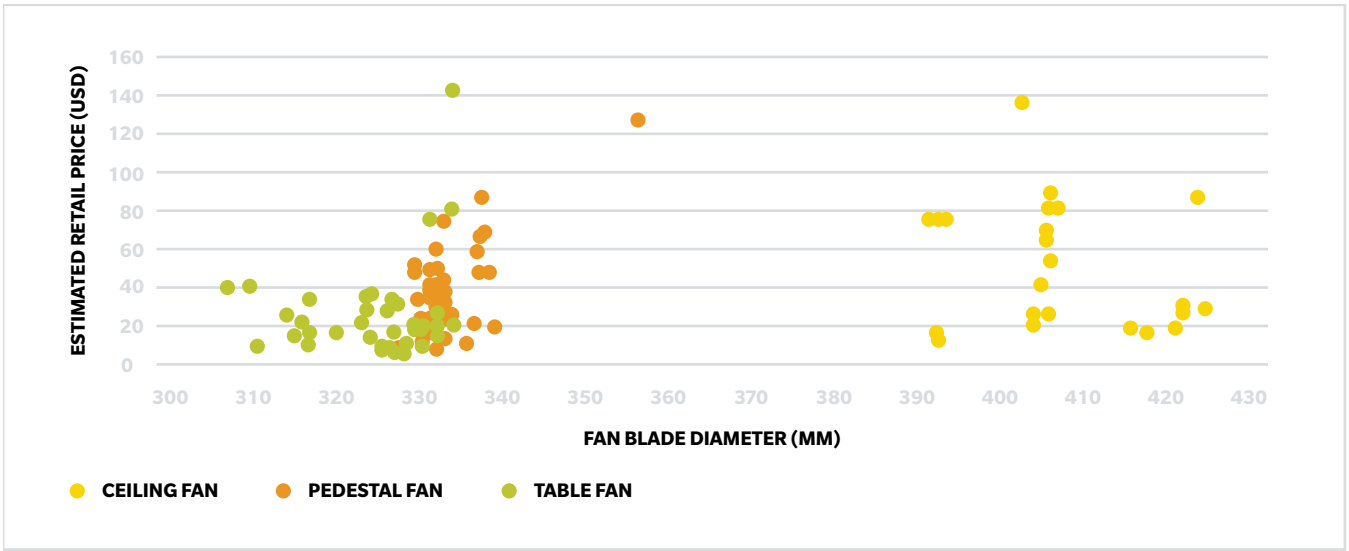
Based on GOGLA sales data, which as noted in Chapter 2 of this report may not be fully representative of the broader off-grid fan market, GOGLA affiliates sold roughly as many table fans as pedestal fans.[147] From 2017, ceiling fans have also started to find a market, sales of which are likely to increase as more affordable ceiling products are developed. Generic products currently dominate the off-grid fan market.

Fan specifications and pricing vary by market, potentially due to use case differences. In Myanmar and India, smaller table fans dominate the market and prices range from USD 20 to USD 22 per unit. Larger pedestal or ceiling fans are more common in West Africa, with prices ranging from USD 47 to USD 57 per unit.[148] This variation may be due to the use case, as some industry players report that table fans are typically used in households, while pedestal and ceiling fans are more likely to be used in commercial settings. Fans are increasingly being bundled with solar home system packages or offered with micro-credit to improve affordability for consumers.

CASE STUDY
Sun King

Greenlight Planet, under its flagship Sun King product line, has released a 16-inch fan that retails at USD 85. It incorporates a brushless motor, which increases the lifespan of the fan to five years and makes it less susceptible to defects. The product also offers a built-in LED light switch, timer, and battery indicator. These innovations demonstrate the potential to innovate on fan technology.

Figure 27: Overview of off-grid fans currently in the market



Source: Equip Data (n=108)

146. CLASP & Dalberg Advisors, *The State of the Off-grid Appliance Market*, Global LEAP, 2017.
147. All sales data are from GOGLA's proprietary sales database.
148. CLASP, *Off-Grid Appliance Market Survey*, Efficiency for Access Coalition, 2018.

REFRIGERATORS

Off-grid refrigerators for household use are only now starting to hit the market and their uptake remains very low.

There are an increasing number of manufacturers developing refrigerators for the off-grid market. These products typically have a capacity of between 50 and 250 liters, however most refrigerators sold by GOGLA affiliates are small to medium in size (between 50 and 100 liters).

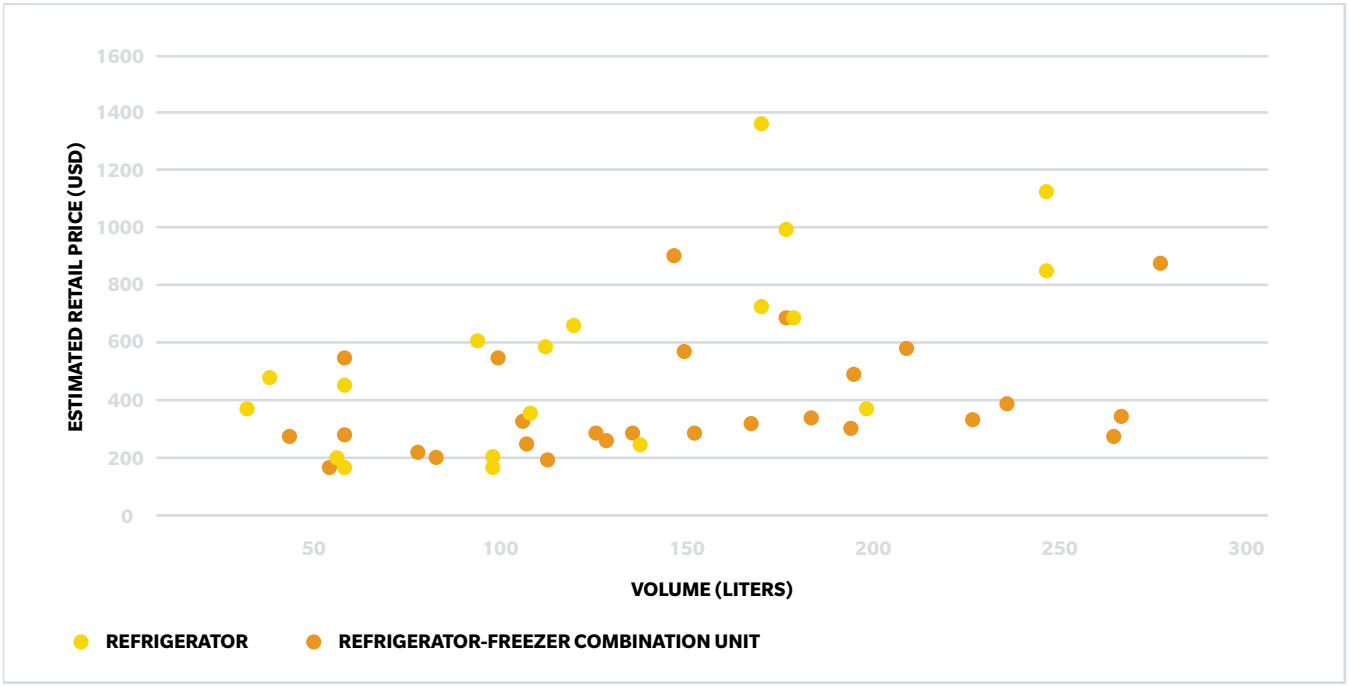
Refrigerator prices remain high and largely unaffordable for off-grid households.[149] The price for a 100-liter refrigerator ranges from approximately USD 300 to USD 600 (see Figure 28), not including the solar panel. Based on insights from supplier interviews, the price of off-grid refrigerators needs to decrease to between USD 200 and USD 300 to be considered affordable for the off-grid market.[150]

Technological improvements can drive improved efficiency. The compressor and insulation are the most significant drivers of refrigerator energy efficiency, and new, more energy-efficient and cost-effective compressors are being introduced to the market. However, these technology improvements are expected to come at an incremental cost, potentially further increasing the sales price of refrigerators.

CASE STUDY
Youmma

Youmma is an early stage venture of the multinational compressor manufacturer Embraco, known for pioneering eco-friendly innovations such as the use of alternative refrigerants to improve refrigerator cooling capacity and efficiency. Youmma is developing a range of energy efficient off-grid refrigerators based on Embraco's core compressor technology. Youmma's refrigerators will be available in 50-liter and 100 liter-units and work on an 80W system. The company plans to offer pay-as-you-go financing and is targeting a price point of under 1.50 USD per day.[151] The refrigerators will have efficient compressors, and built-in software that automatically manages refrigerator settings. For example, the software will automatically adjust performance according to internal temperature conditions and monitor battery load.

Figure 28: Overview of off-grid refrigerators currently in the market



Source: Equip Data (n=52)

149. CLASP, *Off-Grid Appliance Market Survey*, Efficiency for Access Coalition, 2018.
150. CLASP & Dalberg Advisors, *The State of the Off-grid Appliance Market*, Global LEAP, 2017; Dalberg stakeholder interviews, 2019.
151. Assuming PAYGO financing

What trends are defining off-grid appliance technology?

Manufacturers of off-grid appropriate appliances are trying to strike a balance between ensuring products are affordable while maintaining performance and efficiency. These products must also compete with generic off-grid appliance manufacturers often willing to sacrifice durability, quality, and efficiency for the cheapest possible price point.

TELEVISIONS

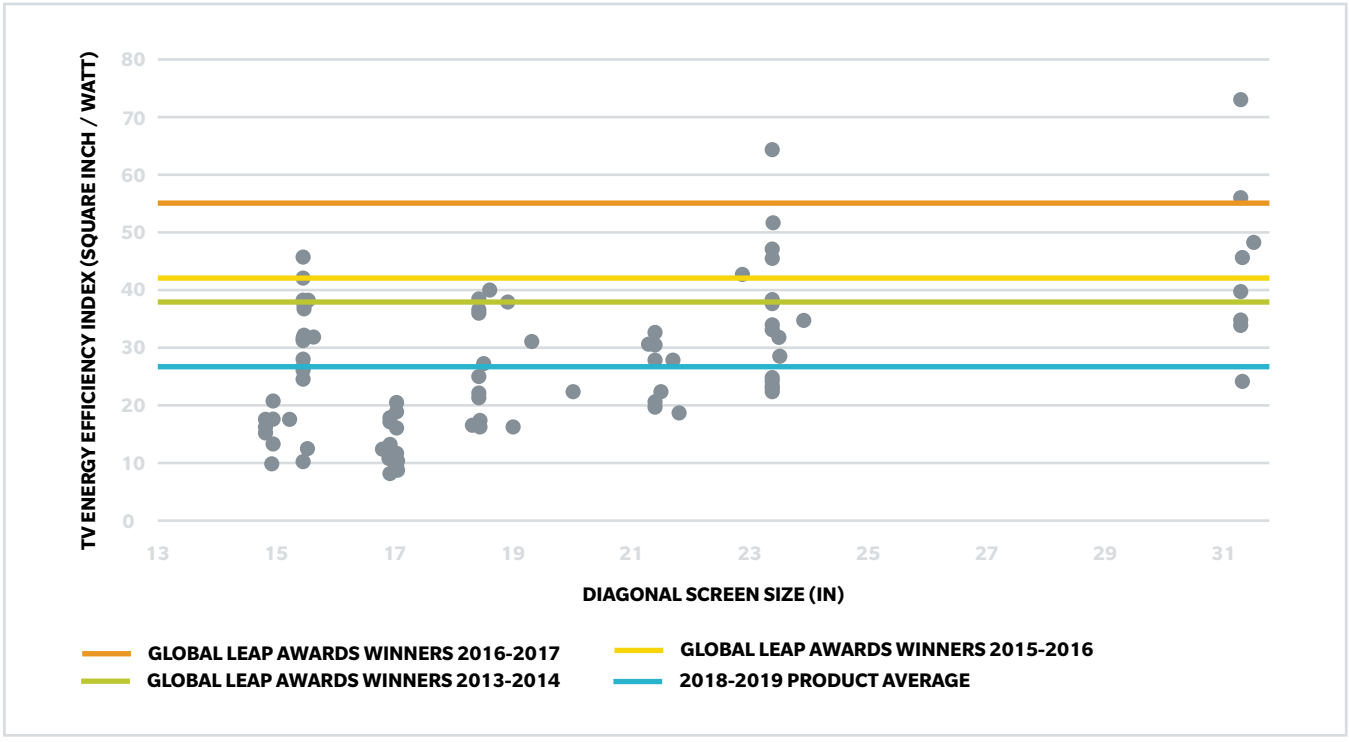
Manufacturers are balancing the trade-off between screen brightness and efficiency, with recent televisions being launched with dimmer screens to save energy. Manufacturers have been investing heavily in optimizing the LED backlit panels to increase television lighting efficiency. Early research has shown that this could decrease energy consumption by more than 20%.[152] Furthermore, manufacturers have started to design televisions to be dimmer as a way to make the television more efficient. Early evidence suggest that customers are satisfied with lower luminance. A survey of 142 customers of four off-grid television firms showed that almost 90% of customers assessed the brightness of their televisions as good or very good, even with dimmer models.[153]

Over the past five years, technology and design improvements have made televisions more efficient. In a sample of 90 different off-grid televisions that have been tested on performance and energy efficiency since 2014, the average energy efficiency index of all baseline products is around 27.7 square inches per watt.[154] Best in class televisions have substantially higher efficiencies, which have been increasingly steadily.

Using the Global LEAP Award winners as an overall market proxy, in 2013-2014 the efficiency of Global LEAP award winners was below 40 square inches per watt, by the 2015-2016 Award round efficiency was approximately 41.5 square inches per watt, and jumped further to 55.4 square inches per watt in the 2016-2017 round. The television with the highest energy efficiency index in the 2016-2017 round had an index of 72.7 square inches per watt, which was more than 2.5 times higher than the average off-grid television in the market.

Manufacturers of off-grid televisions are now increasingly prioritizing longer viewing hours in response to their customers' access to more content. On average, customers in off-grid communities watch three hours of television per day.[155] As televisions gain wider distribution and access to content increases, demand for longer

Figure 29: Off-grid TV energy efficiency trends



Source: CLASP, Global LEAP product testing data

152. Park, W.Y., et al., "Efficiency improvement opportunities in TVs: Implications for market transformation programs", *Energy Policy,* 2013, https://www.sciencedirect.com/science/article/pii/S0301421513002267.

153. CLASP analysis, 2019.

154. The TV energy efficiency index is defined as is defined as the area of screen size in square inch per Watt of input power. The higher the EEI, the more efficient the TV. The analysis in this paragraph based on proprietary retail and product testing data gathered by CLASP.

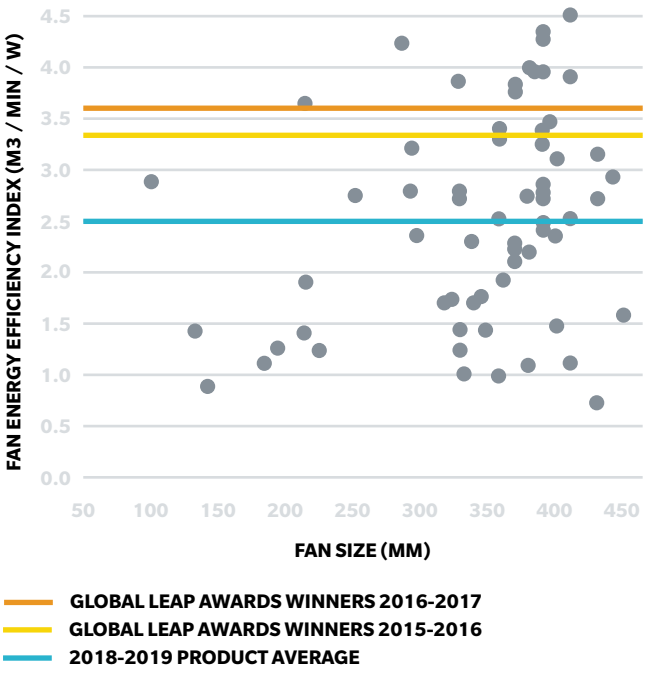
155. GOGLA, Powering Opportunity: The Economic Impact of Off-Grid Solar, Global Offgrid Lighting Association, 2018, https://www.gogla.org/sites/default/files/resource_docs/gogla_powering_opportunity_report.pdf.

operating hours grows.[156] Innovations are beginning to address this demand. Cello's stand-alone solar powered television allow it to run from its own battery source, rather than share with other household appliances. As consumers demand longer television-watching times, companies are also driving innovation in content development. Azuri has partnered with Zuku, a Kenyan television service provider, to launch a pay-as-you-go satellite television package which offers customers a suite of Zuku-branded channels. Once customers own the equipment, they pay only for the content subscription service.[157]

FANS

Improvements in brushless DC motors and blade design continues to improve fan efficiency. A number of companies have incorporated brushless DC motors into their fans, increasing durability and reducing energy consumption.[158] The motor is a significant driver of a fan's energy consumption, with brushless DC motors able to increase energy efficiency by up to 50%.[159] As a result, the average energy efficiency of a pedestal fan with a DC motor is about 3.2 meters-cubed per minute of air delivered per watt of input power (m3/min/W), which is 1.8 times better than a fan with an AC motor. Increasing the efficiency of the motor is only one way to make fans more efficient. For example, twisted and tapered blade designs can provide higher airflow at the same speed and increase the efficiency of fans by 15%.[160]

Figure 30: Off-grid Fan (Table and Pedestal) Energy Efficiency Trends



Source: CLASP Product Database, 2019

Fans are becoming more efficient on average, but there are still many inefficient products in the market. The energy efficiency of fans continues to increase, with a considerable uptick of fans in the market with a higher energy efficiency index (EEI) than that of the 2016 – 2017 Global LEAP Award-winning products (see Figure 30).

REFRIGERATORS

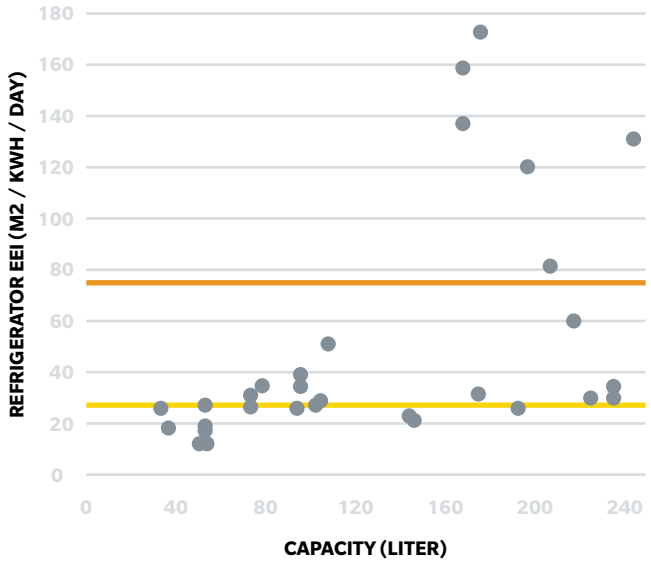
Products in the market vary greatly in terms of efficiency and performance, and there is limited correlation to size or price; this indicates the market has not yet converged around a standard product range. Refrigerators in the market typically have an EEI[161] between 10 and 40. Recent Global LEAP Award winners significantly improved energy efficiency with indexes of up to 150 to 178. The five most efficient refrigerator types currently in the market consume only 0.24 kWh per day, compared to an average of 0.69 kWh/day for all refrigerators in the sample of products available in the market gathered by CLASP.[162]

Early off-grid refrigerators largely focused on commercial and health segments but are now being developed for household use. Off-grid refrigerators were initially developed with non-household uses in mind. They were mainly used in niche markets that required highly reliable and specialized cooling devices (e.g. cold storage for vaccines) for less price-sensitive customer segments. Some donor-funded programs, including the Efficiency for Access R&D Fund,[163] are supporting the development of more affordable refrigerator products for household use.

Improvements in cooling system and insulation technology can make off-grid refrigerators more efficient in the coming years.[164] Promising innovations include brushless DC motors and variable speed compressors, which improve both energy efficiency and durability. The insulation of a refrigerator (determined by thickness and type of insulation materials) is also critical to its energy efficiency–especially in hot climates. Weak insulation causes the compressor to work harder to cool the compartment, reducing efficiency. Research suggests that improved compressor efficiency paired with increased insulation thickness (or vacuum insulation) can decrease energy consumption by more than 50%.[165] Magnetic cooling systems also promise to improve energy efficiency by up to 50% but are currently still too costly for use in off-grid products.[166]

156. CLASP, Off-Grid Appliance Market Survey 2018, Efficiency for Access Coaltion, 2018.
157. Nahigyan. P., "Solar Power Will Bring Off-Grid Kenyans Satellite TV," Planet Experts, 2016, http://www.planetexperts.com/solar-power-will-bring-off-grid-kenyans-satellite-tv/.
158. Stakeholder interview with Greenlight Planet, 2019.
159. CLASP, *Appliance Data Trends*, Efficiency for Access Coalition, 2018.
160. Sathaye, N. et al., *Potential Global Benefits of Improved Ceiling fan energy efficiency,* Lawrence Berkeley National Laboratory, 2012, https://eta.lbl.gov/sites/all/files/publications/lbnl.5980e.pdf.
161. The refrigerator energy efficiency index is defined as units of surface area (meter square) per daily energy consumed (kWh per day) – m2/kWh/day. The higher the EEI, the more efficient the refrigerator.
162. The analysis in this paragraph based on proprietary retail and product testing data gathered by CLASP.
163. See https://efficiencyforaccess.org/grants
164. CLASP, *Appliance Data Trends*, Efficiency for Access Coalition, 2018, https://efficiencyforaccess.org/publications/appliance-data-trends.
165. CLASP, *Low-Energy Inclusive Appliance Technologies Summaries,* Energy for Access Coalition, 2017, https://efficiencyforaccess.org/publications/low-energy-inclusive-appliance-technology-summaries.
166. Ibid.

Figure 31: Off-grid refrigerator energy efficiency trends



Source: CLASP, Global LEAP data on product energy efficiency

Manufacturers are focusing on direct-drive technology for off-grid refrigerators, reducing the need for additional energy storage. Direct-drive technology stores thermal energy in a phase-changing material, which can maintain cool internal temperatures for up to five to six days when compartments are sealed.[167] This significantly reduces or even eliminates the need for electrical battery storage, typically the component in a solar home system with the shortest lifetime. SunDazer, SureChill, Palfridge are among the companies already offering household refrigerators with phase-changing material, though its mainly featured in vaccine refrigeration.

Overall, manufacturers are still searching for the optimal way to develop off-grid appropriate DC refrigerators. Manufacturers need to find the right trade-off between developing a highly efficient product that can be powered by standalone solar systems and offering products at a price that consumers are able and willing to pay. Beyond the manufacturing costs, off-grid refrigerators have relatively high distribution and servicing costs as compared to conventional AC refrigerators or other off-grid appliances. Unlike conventional refrigerators, which for the most part can be installed without the need for additional hardware or a specialized technician, off-grid refrigerators require technical expertise for installation.[168] Due to the larger size and weight, distribution into rural areas also poses a challenge. The technical maintenance, due to the complexity of the cooling system, requires that there is sufficient local knowledge to provide repairs.

The high costs of purchasing and powering refrigerators makes them unaffordable to average off-grid customers. An off-grid refrigerator requires on average around 0.74 kWh per day to operate in an ambient temperature of 32°C. Under optimal conditions, this would require a solar home system used with at least a 200 Wp solar panel and a 160 Ah battery used exclusively to power the refrigerator.[169] The majority of existing solar home system consumers cannot currently afford a system of this size, regardless of the price of the off-grid refrigerator itself. To be supported by a 100 Wp solar system, off-grid refrigerators' consumption would need to closer to 0.4 kWh per day. Several businesses are developing products to meet these consumption requirements. The Fosera Cool Sun 54-liter refrigerator, to be released later this year, aims to consume 0.165 kWh per day and is one of the first models to be designed specifically for the off-grid market.[170] Another model, Sundanzer's Global LEAP Award-winning 50-liter DCR50 refrigerator, consumes just 0.118 kWh per day.[171]

Which products are on the horizon?

Electric cookstoves are becoming more market-ready but commercialization will depend on behavioral change and continued improvements in energy efficiency and product design. Induction cookstoves have high thermal efficiency levels (60-90%), but require 1-2kW per hub, far more than most off-grid and weak-grid systems can support.[172] Off-grid electric hotplates require less energy—highly efficient DC hotplate can require 300-700W, AC versions require 800-2300W. However, when combined with right-sized solar panels and batteries, the costs of such systems are also far in excess of what households can afford.[173] Electric slow cookers require much less energy (100-300W) but are only suitable for a very narrow range of cooking needs. Across all potential off-grid cooking technologies today, electric pressure cookers (EPCs) are likely the solution that has the best balance for cooking performance and affordability.[174] EPCs combine advanced sensors, insulation and pressure to greatly reduce the amount of electricity needed to cook many dishes commonly consumed in off-grid households; models on the market are in the 500-1000W range, but DC EPCs can be much more efficient (200-400W) and further efficiency improvements are possible.[175]

167. CLASP and Dalberg Advisors, *The State of the off-grid Appliance Market*, Global LEAP, 2017, https://efficiencyforaccess.org/publications/the-state-of-the-global-off-grid-appliance-market-2017.
168. Abagi. N., et al., "State of Play and Innovations in Off-grid Refrigeration Technology: Lessons Learned from Current Initiatives", *Energy Efficiency,* 2019, https://efficiencyforaccess.org/publications/state-of-play-and-innovations-in-off-grid-refrigeration-technology-lessons-learned-from-current-initiatives.
169. CLASP, *Appliance Data Trends*, Efficiency for Access Coalition, 2018, https://efficiencyforaccess.org/publications/appliance-data-trends.
170. Dalberg stakeholder interviews, 2019.
171. CLASP, *2017 Buyer's Guide for Outstanding Off-Grid Refrigerators,* Global LEAP, 2017, https://efficiencyforaccess.org/publications/global-leap-buyers-guide-refrigerators.
172. CLASP, *Low-Energy Inclusive Appliance Technologies Summaries,* Efficiency for Access Coalition, 2017, https://efficiencyforaccess.org/publications/low-energy-inclusive-appliance-technology-summaries. See also, Batchelor, S. et al., *The viability of cooking with electricity in Sub-Saharan Africa and South/Southeast Asia – a cost perspective,* LEIA Programme, University of Loughborough, 2019 (forthcoming);
173. Couture, T., and Jacobs, D., Beyond Fire: How to Achieve Electric Cooking, HIVOS, 2019, https://greeninclusiveenergy.org/publication/beyond-fire-how-to-achieve-electric-cooking/; see also Batchelor, S. et al, 2019 (forthcoming).
174. Avila, E., et al., *The Desirability of Clean Cooking in Off-Grid Households,* Access to Energy Institute, 2019, https://a2ei.org/resources/uploads/2019/06/A2EI_The_Desirability_of_Clean-Cooking_in_Off_Grid_Households.pdf; see also Batchelor, S., et al, 2019 (forthcoming).
175. See Couture & Jacobs, 2019 for current wattage of appliances and Batchelor, S. et al., 2019 (forthcoming) re potential efficiency improvements for DC-optimized EPCs.

Although less versatile than electric hotplates and induction stoves (e.g., not suitable for deep-frying), electric pressure cookers are well suited to preparing long-cooking meals in Africa and parts of Asia such as beans, rice, and meat stews. Additionally, electric pressure cookers are highly energy efficient in comparison with other electric cooking technologies, meaning they face the lowest barrier to adoption in terms of cost. In early pilots, EPCs have proven to be cheaper, faster, and more convenient means of cooking in comparison to costly urban fuel alternatives like charcoal and kerosene.[176] In a recent Tanzania pilot conducted by the Access to Energy Institute, EPCs received high grades for cooking convenience from end-users and were sufficiently faster—roughly 50 minutes per meal versus 124 to 132 minutes with typical charcoal and wood cookstoves, respectively.[177] From a cost perspective, EPCs are already competitive with charcoal stoves in geographies with high charcoal costs (>USD 0.30/kg) and will continue to become even more cost-competitive in relative terms as charcoal and kerosene costs rise and solar system costs decline over the next decade.[178] From an upfront cost perspective, EPC costs are currently in the USD 20-100 range, not counting the costs of the battery and solar panel, which add hundreds of dollars in the case of off-grid EPC usage, but total system costs become manageable on a PAYGO basic and will continue to decline.[179]

It is critically important to note, however, that EPCs are not a universal cooking solution and, more broadly, a **one-size-fits all off-grid electric cooking solution is not currently tenable due to high costs and usage barriers.** While EPCs are highly efficient and well adapted for some cooking tasks like the cooking of beans, rice, and stews, pressure cookers are an inferior solution or unsuitable for other purposes. This has meant that when users were given a free EPC in some field trials, these stoves were only used for a subset of dishes and many households continued to use wood and charcoal to cook their staple meals despite clear financial, time, and labor savings.[180]

Realistically, this means that EPCs will be used only 20-80% of the time (perhaps for 50% of cooking tasks on average based on Kenya and Tanzania data) and will thus not be a "magic bullet" for household clean cooking energy transition.[181] Support for off-grid EPCs is still warranted, however, as the reality of cooking solution 'stacking' in no way diminishes the viability of the EPC solution in comparison to alternatives. Support for EPCs will mean incremental R&D investments—despite a range of models developed for pilots, EPCs have not yet been optimized for energy constrained off-grid households. With further design modifications and investments into household behavior change EPCs could become an attractive appliance with relatively wide appeal.

CASE STUDY Electric Pressure Cooking Testing

The University of Loughborough conducted a bean boiling challenge in Kenyan homes using EPCs. Each household was asked to cook 1 cup of beans while monitoring energy consumption. On the lower end, household used only 94W, while the most energy intensive performing households used 2000W. The low consumption exhibited by the challenge winner demonstrate the technology's potential, while the broad range of energy consumption results indicates the importance of consumer behavior in realizing efficiency gains. The World Bank's and Loughborough's Modern Energy Cooking Services (MECS) program is collaborating with EforA and others to conduct more research to further understanding of both consumer behavior and technology. Additionally, a Global LEAP competition in collaboration with the MECS program will soon be taking place for EPCs.

Various other appliances carry high potential for the off-grid market but are currently too expensive and require further innovation. There is high potential demand for sewing machines and irons (an appliance that consistently rates high in consumer demand surveys), but prices are still too high both for the appliances themselves and for the energy they use for most off-grid households. Although there may already be potential for application on mini grids, efficiency gains are needed to scale irons for domestic off-grid use. For more energy-intensive appliances, such as washing machines, the outlook for off-grid appropriate technology is more long-term. For example, washing machines today require around 500 watts of power and on average consume 0.8 – 0.9 kWh per day.[182]

176. Ibid.
177. Avila, E., et al., 2019.
178. Couture, T., and Jacobs, D., 2019 and Batchelor, S., et al., 2019 (forthcoming).
179. Ibid.
180. Avila, E., et al, 2019.
181. Ibid. and Batchelor, S., et al, 2019 (forthcoming).
182. An average energy star rated washing machine consumes 316kWh per year on annual usage. See energystar.gov.

Smart inverters and rectifiers, which allow appliances to switch between DC and AC power sources, are being tested and have the potential to enable broader reach of appliances especially for weak-grid households. Inverters make it possible for customers to purchase AC appliances to operate on DC off-grid solar systems. Conversely, rectifiers allow customers to use DC appliances with grid electricity or with mini-grids that have AC power distribution. For weak-grid customers, inverters and rectifiers create the option to use appliances with both AC grid electricity when power is on and with a solar home system or mini-grid during power cuts. Samsung is launching a refrigerator with an in-built smart inverter that could be used in this manner.[183] However, inverters have clear drawbacks, making them less attractive especially for off-grid customers. The upfront purchase cost of inverters is high, and using an inverter or rectifier reduces appliance efficiency due to energy lost in the conversion process. LEIA is in the process of developing additional research on inverters and conducting testing to quantify inverters' impacts on appliance performance and efficiency.

183. Samsung, "Samsung India Launches Solar-Powered Refrigerators, ACs That Cool 43% Faster", 2017.

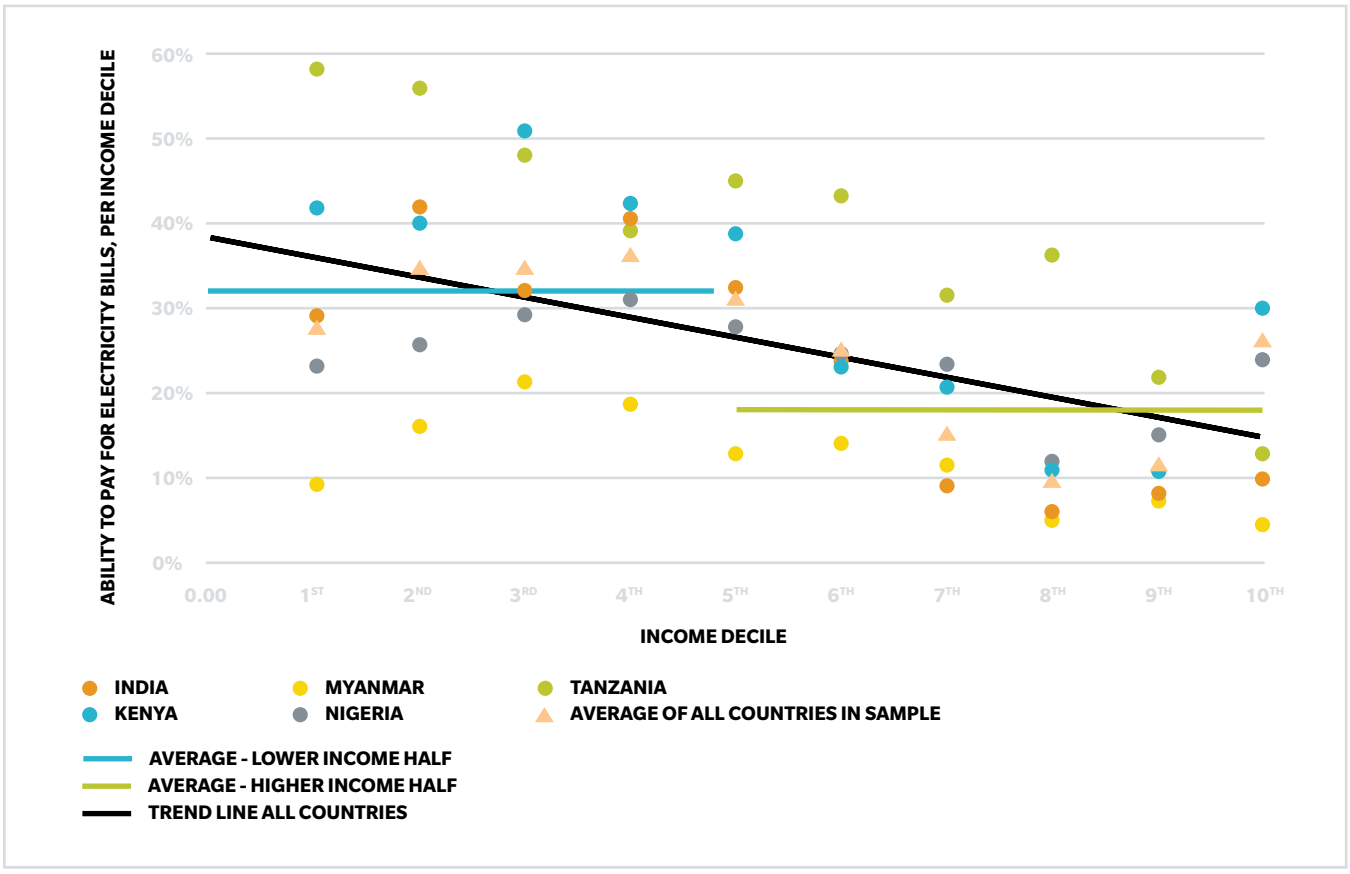
Who are the consumers of off-grid appliances, and what are their needs?

Communities in rural areas with no access to grid electricity have lower average incomes than the general population, and spend disproportionately more on energy. Household survey data suggests that off-grid households have on average 10% lower incomes than the national average, and many people living in off- and weak-grid areas are in the lowest income quintile.[184] In both urban and rural settings, poorer households tend to be grouped in communities with weak electricity infrastructure. Households in this category spend approximately 10% of their income on energy—roughly the same amount that they spend on education and health combined.[185] This expenditure covers only essential energy needs, typically fossil fuels such as kerosene or wood biomass to power basic, inefficient lighting and cooking solutions.

Despite spending on only the most basic energy needs, as shown in Figure 32, more than 30% of poor households have had difficulty paying for electricity and household fuels in the past.[186] The same survey data suggest that even richer households (those in the top half of the income distribution) struggle to pay for electricity in many developing countries. While they may aspire to own appliances, most of these households currently spend little, if any, of their income on household appliances. If they could access off-grid appliances, these households could take advantage of the benefits of higher levels of electrification without access to a central grid infrastructure, but affordability remains a key barrier.

For households in urban and peri-urban areas, solar home systems and mini-grids bundled with appliances can provide an alternative to or supplement for unreliable and expensive grid electricity. The off-grid appliance opportunity is not limited to off-grid households. Urban households often live in densely populated areas where grid electricity is highly unreliable, in particular during peak hours in the early afternoon and evening. In a recent survey in

Figure 32: Share of households that have had difficulties paying for electricity or household fuel in the past



Source: Dalberg, The Human Account, https://www.thehumanaccount.com/

184. Dalberg analysis based on Dalberg The Human Account database of sample of households in Kenya, Myanmar, Nigeria and Tanzania (N=4731), 2018. See http://www.thehumanaccount.com.

185. Dalberg analysis. The countries informing the market sizing are India, Myanmar, Ethiopia, Côte d'Ivoire, Sierra Leone, Kenya, Nigeria, and Uganda. Energy consumption data from World Bank, Global Consumption Database, 2010. While these data are from 2010, the average expenditure on energy by low-income household has been triangulated with more recent studies.

186. Dalberg analysis of the Human Account database, 2018, http://www.thehumanaccount.com.

Nigeria, for instance, almost two-thirds of the respondents living in urban areas and connected to the national grid reported that they only had power supply occasionally.[187] Weak-grid settings limit the hours when customers can use conventional appliances – and in the case of refrigerators, prolonged outages can lead to food spoilage, limiting the overall benefit to a household of owning such a costly appliance. Given added fuel costs, running conventional, inefficient appliances on back-up diesel generators quickly becomes very costly. Urban and peri-urban communities are thus looking for appliances that can work more consistently and cost-effectively in weak-grid environments.

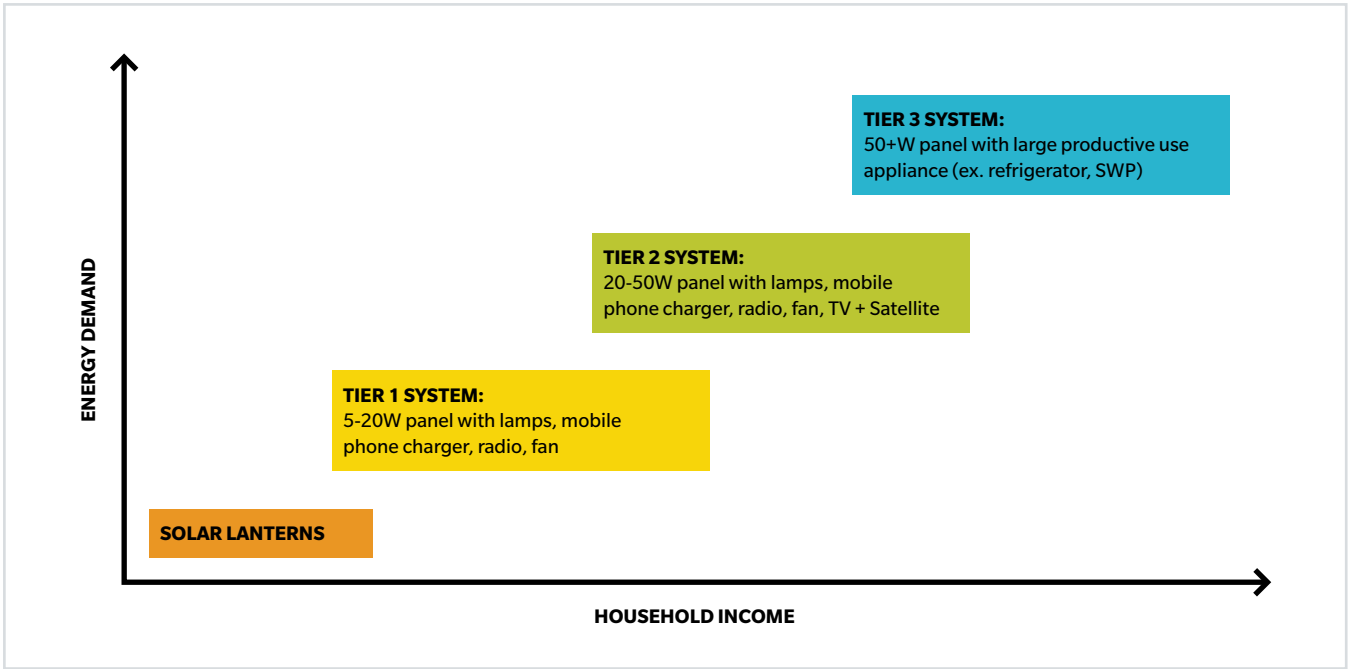
What is shaping consumer demand for off-grid appliances?

From "the energy ladder" to "energy stacking", there has been a shift in understanding off-grid consumer demand.

In the past few years, there has been a change in the sector's collective understanding of consumer decision-making, from a progression "up the energy ladder" to a scenario of "energy stacking", in which consumer choice plays a bigger role. Earlier on, it was widely believed that with increasing levels of access to better energy technologies, consumers would abandon their previously used energy sources and replace them with these newer options—moving incrementally from a candle to a pico-solar light to a solar home system. New findings are instead pointing toward the importance of the customer's ability to choose from a range of options. This is supported by recent research, which shows that most customers that bought a solar home system for the first time had never bought a pico-solar light previously, and that their need for multiple lights drove their purchase.[188] Anecdotal evidence suggests that these findings also apply to off-grid appliances. Many stakeholders have found that their appliance customers are first-time solar buyers, not existing pico-solar or Tier 1 solar home systems owners.

In a recent study by an off-grid solar company, the top three brand attributes for solar home systems most valued by consumers—both current and potential users—were choice, clarity, and flexibility.[189] Quality and affordability were important but ranked fourth and fifth respectively.[190] This suggests that while financing is often a prerequisite for consumers, they do not purchase or upgrade to solar products solely based on affordability. Consumer financing solutions such as microfinance credit, pay-as-you-go (PAYGO) models, and other forms of financing, as well as donor support and subsidies, enable buying decisions that prioritize other attributes over price. When financing is available, consumers can buy the products they need and want, not just the products they can immediately afford. This trend is particularly important for the off-grid appliance industry, as the threshold for convincing financially vulnerable customers of quality and value for money becomes critical.

Figure 33: Energy stacking of off-grid solar home systems and appliances



Source: Dalberg analysis, Goyal, R. & Jacobson, A., *Energy Access and Off-grid Solar Use in Uganda,* Schatz Energy Research Center (SERC) and UNCDF, 2019.

187. Afrobarometer data on Nigeria, Electric connection from mains, 2018.
188. This is a common refrain in solar home system distributor interviews. See also, Goyal, R. & Jacobson, A., *Energy Access and Off-grid Solar Use in Uganda,* Schatz Energy Research Center (SERC) and UNCDF, 2019.
189. Choice was defined as a range of items to choose from, clarity was defined as the quality of being clear about the business's rules and policies and flexibility was defined as the willingness to compromise or change when the customer wants to grow with the business or leave. See BBOXX, *Brand Attributes Research in Rwanda,* 2018.
190. Ibid.

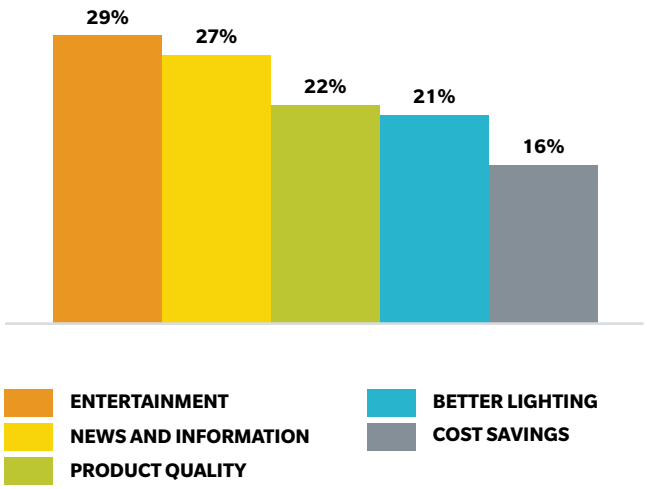
Consumers buy off-grid appliances primarily to improve their quality of life, in addition to saving on energy expenditures. Off-grid appliances are designed for use with non-grid sources of power and allow households to reduce energy costs over time if they switch from kerosene lamps or generators. However, this does not appear to be the primary reason that households purchase off-grid appliances, in part because relatively few consumers in off-grid areas use generators to power appliances due to the high price of diesel fuel. According to a recent study by the Schatz Energy Research Center (SERC) and UNCDF in Uganda, while households using smaller off-grid systems may save on their total energy costs, households with larger-sized systems pay more than what they save on fuel.[191] In a survey conducted by Acumen on consumer perspectives on light systems, customers ranked having brighter light and more reliable electricity supply as more important than the ability to reduce energy expenditure.[192] These preferences are supported by televisions being the most in-demand household appliance after LED lights. For smaller, less expensive appliances such as fans, other demand drivers become even more important. In Bangladesh, customers cite comfort as being the most important purchase driver for fans.[193]

Televisions, in particular, are purchased primarily for entertainment and information access. In a survey with the aim to understand consumer behavior in the off-grid TV market, around three-quarters of off-grid TV owners stated they had never owned a TV or another off-grid appliance before. Their main motivations for purchasing an off-grid TV were entertainment and information rather than savings on energy expenditure.[194] Content is particularly important for television owners, with distributors noticing a sales uptick around major sporting events. Emerging research from India points towards similar trends, with the majority of television users citing entertainment and news as the most watched TV channels.

Community relationships drive both product awareness and purchasing behavior

Awareness of a household appliance's benefits, especially when recommended directly by friends, is an important purchase driver for off-grid appliances. Consumers seek to purchase off-grid appliances when they have heard about their merits through friends or family members, have seen others in the community using the product, or had the opportunity to test them in person.[195] In Global LEAP's off-grid solar baseline surveys, almost 50% of respondents said that they had first heard about solar home systems through their friends. For solar refrigerators, the share of households that had heard about the product through friends was as high as 60%. In the SERC and UNCDF study conducted in Uganda, community-based awareness and referrals were a factor in 19-26% of purchases of off-grid energy products. Customers also cited buying products not just to follow a neighbor's recommendation, but also to demonstrate and signal their social and economic status to their communities.

Figure 34: Motivation of households to purchase an off-grid television (or TV/SHS bundle)



Source: 60 Decibels and CLASP, Global LEAP RBF Surveys, 2019

Early adopters and innovators form the largest segment of the current customer base of off-grid appliances, allowing for specific sales targeting and marketing strategies.[196] In Global LEAP's off-grid solar baseline surveys, 46% of off-grid refrigerator users and 33% of off-grid TV users described themselves as innovators or early adopters, meaning that they usually seek out and use new products as soon as they become available.[197] Given the relatively low penetration of appliances in these markets and the high prevalence of friend recommendations leading to purchase, it could be concluded that there is a clear segment of influential early innovators in communities.

Men are more likely to be the decision-maker in an off-grid appliance purchase. A study in Rwanda indicates that male household heads decide alone to purchase an off-grid solar solution in 78% of cases. Male household heads typically also decide alone whether to purchase appliances, with less than half of decisions made either jointly or by the woman alone.[198] In Global LEAP's off-grid solar TV baseline survey,

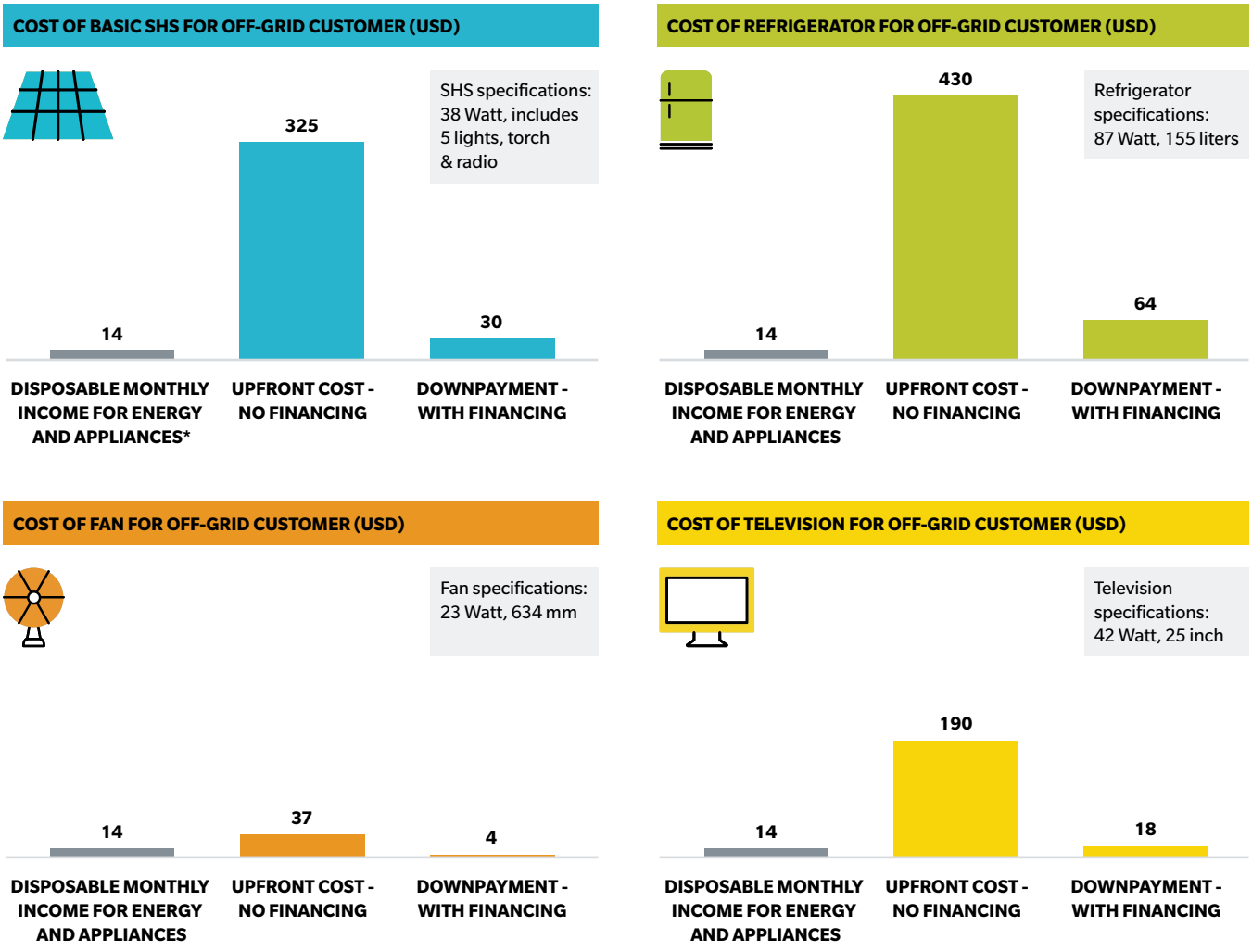
191. Goyal, R. & Jacobson, A., *Energy Access and Off-grid Solar Use in Uganda,* Schatz Energy Research Center and UNCDF, 2019.
192. Harrison, K. and Adams, T., *An evidence review: How affordable is off-grid energy access in Africa?,* Acumen, 2016.
193. Dalberg stakeholder interviews, 2019.
194. CLASP, Global LEAP Solar TV RBF: Baseline in East Africa, Lean Data, 2018.
195. Goyal, R. & Jacobson, A., *Energy Access and Off-grid Solar Use in Uganda,* Schatz Energy Research Center / UNCDF, 2019.
196. Diffusion of technology is a theory how, why and at what rate innovation and new technologies get adopted. According to Rogers, innovators and early adopters represent around 2.5% – 13.5% of the total market share. See Rogers, E., *Diffusion of Innovations,* Free Press of Glencoe, 1962.
197. CLASP, Global LEAP Solar TV RBF: Baseline in East Africa, Lean Data, 2018; CLASP, Global LEAP Solar Refrigerator RBF: Baseline in East Africa, Lean Data, 2018
198. Koo, B. et al, *Rwanda Beyond Connections: Energy Access Diagnostic Report Based on the Multi-Tier Framework,* World Bank Group, 2018, http://documents.worldbank.org/curated/en/406341533065364544/pdf/Rwanda-Beyond-connections-energy-access-diagnostic-report-based-on-the-multi-tier-framework.pdf

in 70% of households, the male head of household heard about the solar TV first.[199] In the SERC and UNCDF study conducted in Uganda, 56% of households that bought a solar television stated that the male head of household made the decision alone.[200] This has implications both in developing awareness-building campaigns that are more gender-neutral, and ensuring that purchase decisions are accessible for both men and women.

Early evidence suggests that retailer affinity seems particularly important for customers of mid- to larger-sized solar home systems that have appliances included in the bundle. These customers show higher "distributor stickiness" than customers of smaller-sized systems. In Uganda, customers of smaller-sized and lower-cost solar systems were less likely to buy again from the same distributor than customers for mid-sized and larger-sized systems. 70% of the customers of mid-sized and larger-sized systems wanted to purchase subsequent products from the same company, compared to a little more than 30% of smaller-scale systems.[201] What exactly drives customer loyalty still needs to be explored further, but after-sales service support may play a significant role. In the Uganda study, small-sized systems comprised lanterns with no after-sales service support, which likely reduced the importance of the retailer for small system sales and, in turn, impacted retailer stickiness.

The penetration of retail points, and therefore exposure to local distributors, is also important. In recent off-grid appliance customer surveys in Kenya, Uganda and Tanzania, 16% of solar television customers, and only 3% of solar refrigerator customers, were certain that they could have found a good alternative to the product they had bought.[202] Even where there is fair competition among distributors, product bundles are similar and do not at this stage have distinctive features that offset them from the rest of the market.

Figure 35: Cost of appliances compared to monthly disposable income of lowest income half



Source: Dalberg analysis

199. CLASP, Global LEAP Solar TV RBF: Baseline in East Africa, Lean data, 2018
200. CLASP, Global LEAP Solar TV RBF: Baseline in East Africa, Lean data, 2018
201. Goyal, R. & Jacobson, A., *Energy Access and Off-grid Solar Use in Uganda,* Schatz Energy Research Center / UNCDF, 2019.
202. CLASP, Global LEAP Solar TV and Refrigerator RBF: Baseline in East Africa, Lean Data, 2018.

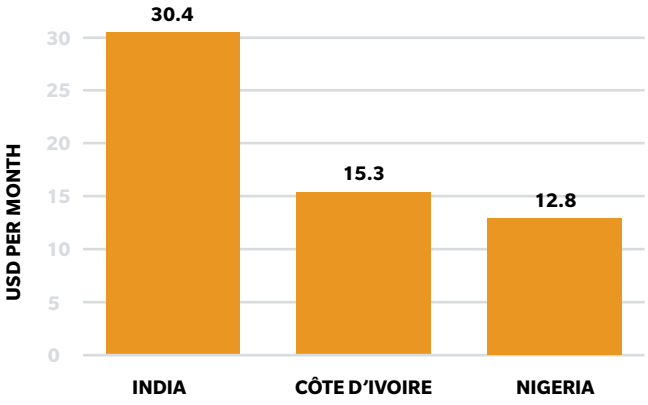
Access to financing helps mitigate affordability challenges for the majority of off-grid customers.

Affordability remains a key constraint to sales growth for fans, TVs, and refrigerators. While consumer choice, awareness, and access are increasingly acknowledged as drivers of consumer demand, affordability is ultimately the most important constraint. Most customers are only able to buy an off-grid appliance when they can access financing.

While off-grid appliances can help users reduce energy costs in the long run, the up-front expense often remains beyond what most households can afford, especially without adequate financing mechanisms. When sold with the requisite solar home system, off-grid appliances have price tags that significantly exceed the disposable income of a typical target household. In Nigeria, for example, the price of an average television and solar home system bundle is approximately USD 800.[203] This price is more than twice as much as the average monthly income (USD 200-300) for households in the lower half of the income distribution, the segment that represents most rural off-grid consumers.[204] The portion of income that is realistically disposable to purchase a television is around 10% of that monthly income. Even if households manage to save a few months' worth of income to purchase a system with off-grid appliances specifically designed to reduce energy costs, high upfront costs put these systems out of reach of most consumers. Without consumer financing, only about 2.2 million households in Nigeria (10%) would be able to afford an off-grid TV, compared to 7.7 million (40%) if financing was included.[205]

Access to finance is crucial to make off-grid appliances more affordable. In East Africa in particular, many off-grid appliances are offered with PAYGO financing models provided by the distributor, while in Asian markets they tend to be sold in conjunction with consumer finance products offered by third-party finance institutions. With required deposits of 10-30% of the full product cost, consumer financing brings off-grid appliances within reach of consumers. By reducing the need to save for a large lump-sum payment, appliances no longer have to compete with other important expenditures, such as school fees.[206] For some customers, the off-grid appliance loan also represents their first-ever experience accessing formal credit, and can have further financial benefits for the household.

Figure 36: Monthly disposable income for energy related expenditure for households in the lower 50% of the income spread (in USD)

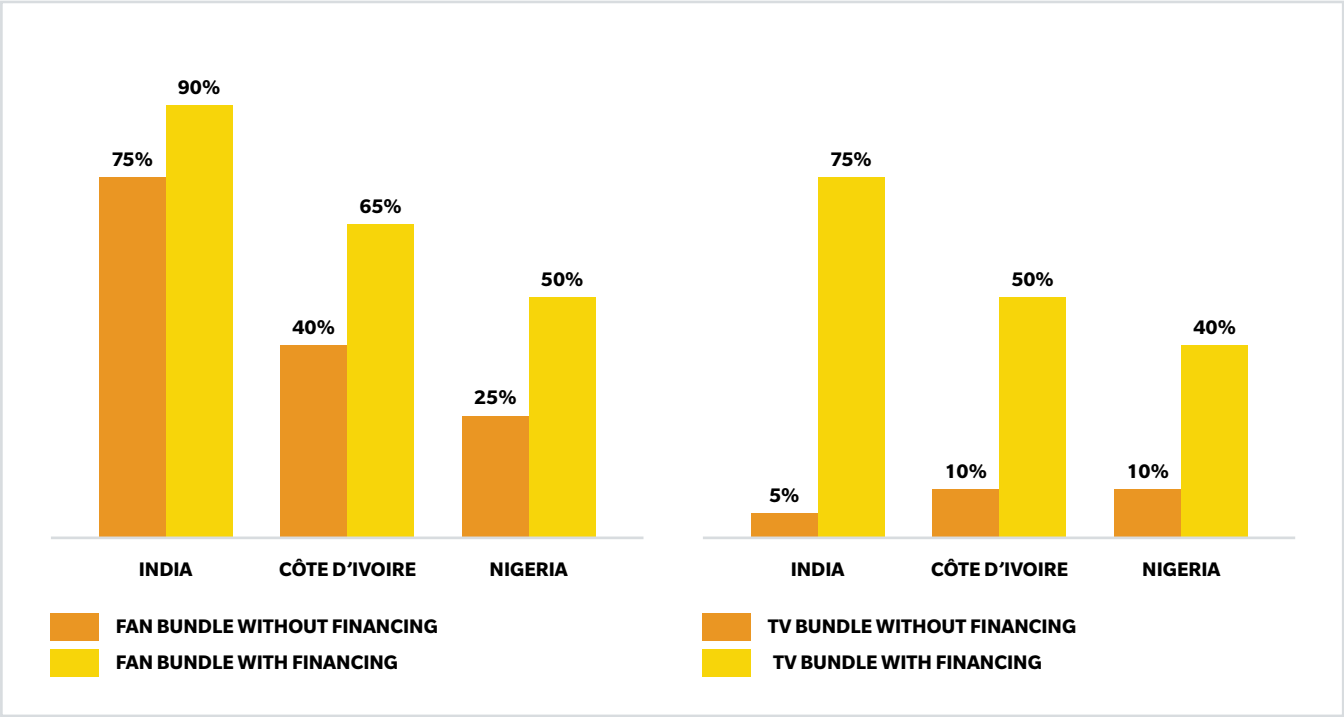


Source: Dalberg analysis, World Bank Income Data

While consumer financing models have managed somewhat to mitigate affordability constraints, customers are mindful of the high cost of ownership. Acumen research shows a wide range of repayment challenges reported by companies, from 8% of failed repayments for one company in East Africa to 28% for another in India.[207] A separate study in Rwanda found that as many as 52% of consumers faced difficulties servicing their repayments regularly.[208] There is some indication that customers can find PAYGO financing contracts confusing. According to data collected by Acumen for one company, 27% of customers felt that the agent did not explain the contract to them adequately, and 13% said that parts of the payment plan were unclear.[209] In the SERC and UNCDF study in Uganda, all PAYGO users indicated that they would prefer not to use PAYGO-based financing for subsequent purchases.[210] More research is needed to understand why customers would prefer alternatives to PAYGO financing, but it is likely that customers are aware of the high premium they are paying for such financing over cash sales or more moderately priced consumer financing loans.

203. Product information provided by Smarter Grid International, 2019
204. Dalberg calculations based on World Bank data on income distribution.
205. Dalberg analysis. Affordability analysis is based on income data and income distribution data by the World Bank. Regarding the affordability of the upfront costs, it is assumed that households already have recurrent monthly payments for a solar home system and add a TV or fan to the system.
206. Zollman, J., et al., *Escaping Darkness: Understanding Consumer Value in PAYGO Solar,* CGAP, 2017.
207. Harrison, K. & Adams, T., *An Evidence Review: How affordable is off-grid energy access in Africa?,* Acumen, 2017.
208. Ibid.
209. Ibid.
210. Goyal, R. & Jacobson, A., Energy Access and Off-grid Solar Use in Uganda, Schatz Energy Research Center and UNCDF, 2019.

Figure 37: Share of off-grid and weak-grid households able to afford appliances, with and without financing



Source: Dalberg analysis and World Bank Income Data

Note: we define a household's ability to afford a product if the monthly disposable income is enough to pay for the upfront or monthly financing costs of an appliance, taking into account a household's ability to save 2-3 months of disposable income for larger expenditures.

Given the affordability constraints for larger appliances, productive use represents an important demand driver for the future of off-grid appliances.

While there is not always a clear line between household and business use of off-grid appliances, consumers tend to use some products more for income-generating activities. Entrepreneurs sometimes live at their business premises, and they may use the same appliance for both personal and business use. Appliances such as phone chargers have in the past been used primarily for entrepreneurial efforts but are shifting to household use as solar home systems become more accessible. Appliances such as televisions and fans can have productive use benefits, typically to draw customers to a business, for example, by making a shop more comfortable, or providing entertainment. This appears to be less common with televisions, as only 8% of off-grid television customers surveyed in four countries in East Africa use the appliance in their business.[211]

Larger products such as refrigerators appear to be considered by consumers primarily as income-generating appliances. In the same survey conducted with owners of off-grid refrigerators, almost 60% of the respondents bought a refrigerator to improve their business and attract more customers, while only 2% use them merely for convenience.[212] Due to the high price point, most customers can invest in purchasing a refrigerator only if it produces additional revenue to help pay off the financing. 90% of respondents in the same survey purchased their refrigerator to use it at their place of work, and almost 80% hoped to use the refrigerator to generate additional income.[213] Other dual use appliances (i.e. both applicable for households and businesses) such as sewing machines and hair clippers also fall into this productive use category.

211. CLASP, Global LEAP solar TV RBF: Baseline in East Africa, 2018. The reported figure of 8% may understate the use of off-grid appliances in businesses because the figure is self-reported, and customers may not consider home based economy activity to be business use.
212. CLASP, Global LEAP solar refrigerator RBF: Baseline in East Africa, 2018
213. Ibid.

In Kenya, an off-grid refrigeration market of USD 20 million is reachable in the next few years

- A 200-liter off-grid refrigerator currently costs between USD 300-400 in most markets—excluding the costs for the solar panel, the battery, or installation. With the system costs included, a refrigerator costs at least USD 1000.[214] For most households, this is not affordable. However, the refrigerator's affordability increases if its use generates income. Data from a small field trial in Uganda conducted by conducted by CLASP and E4I indicate that daily income for some micro-enterprises, such as small shops and restaurants, could double through the use of off-grid refrigerators.[215]

- Off-grid solar refrigerators are particularly useful in small shops, restaurants, and bars. In Kenya, these sectors provide economic activity to around 570,000 micro and small enterprises that report electricity constraints. Market penetration of solar refrigerators in Kenya is currently close to zero, but as prices drop and awareness rises, those businesses are likely to present an important market. Assuming that only one in ten of those MSMEs needs a refrigerator, this still represents a cumulative Kenya market of USD 20 million. As a comparison, off-grid solar energy systems reached a market penetration of ten percent within the first nine years.[216]

- As retail prices drop and enable buyers of off-grid refrigerators to reach break-even sooner, off-grid refrigerators could scale as quickly as - or even faster than - devices less commonly used for income-generating activities.

Consumers and businesses have started to explore the potential of off-grid appliances in healthcare, agriculture, and semi-productive use settings. While the demand for off-grid refrigerators by households and small businesses is just starting to take shape, there are other use cases for cooling technologies, especially in agricultural and medical cold chains. Solar water pumps allow farmers to reduce the fuel and labor costs of irrigation—and have already seen strong uptake in India and growing interest in Africa.[217] Furthermore, off-grid appliances have a high potential to support agricultural processing, for example with flour mills. Other product categories that have not yet advanced far beyond the pilot phase, but which could drive the market in the future, include larger-scale solar-powered banks that are capable of charging laptops, tablets, phones, and other devices simultaneously. And while cooking appliances have long been thought to consume too much energy for what SHSs can provide, this is also changing. Electric pressure cookers and rice cookers could potentially be useful in a wide range of settings, for semi-productive use at home or productive use in small restaurants. As of yet, there are no commercially proven business models for selling productive use off-grid appliances at scale. For the lower-income target group, trials and programs funded by philanthropic actors currently dominate this market. These productive use products are not the focus of this report and will be covered in subsequent Efficiency for Access reports.

What is holding back customer demand beyond the ability to pay, and how can we unlock this latent demand?

Limited awareness and lack of trust are the most critical challenges holding back consumer demand, after ability to pay.

Potential consumers may not trust the quality of off-grid solar appliances especially in less mature markets or when they have had negative experiences with inferior off-grid solar products. In Nigeria, for instance, off-grid technology can be seen as unreliable because it was previously introduced in street lamps that did not work consistently. Similarly, in Myanmar, many of the off-grid products currently available on the market are generic and of lower quality. These products can break while customers are still paying for them in monthly installments or shortly thereafter, eroding trust in the sector. There is a risk that this pattern will repeat in other, more nascent markets. For example, our interviews suggest that in markets such as Sierra Leone, brand recognition and appreciation for more expensive but higher quality off-grid appliances is low, and many households are opting for generic low-cost devices and counterfeits. Over time, this could damage consumer perceptions of off-grid products overall, including appliances.

214. Proprietary retail database for off-grid fans, TVs, and refrigerators, CLASP, 2019.
215. Insights from a field trial conducted by CLASP in Uganda in 2019.
216. World Bank & Dalberg Advisors, *The 2018 Off-grid Solar Market Trends Report*, World Bank Lighting Global Program, 2018.
217. Efficiency for Access Coalition, *Solar Water Pump Outlook 2019: Global Trends and Market Opportunities*. https://efficiencyforaccess.org/publications/solar-water-pump-outlook-2019-global-trends-and-market-opportunities

In addition, consumers may not fully understand the personal finance implications of purchasing an off-grid solar appliance. Distributors and manufacturers report that customers often are not aware of the longer-term energy savings that solar home systems can offer. On the other hand, they also may not understand the financial conditions and implications of financing bundles and often perceive interest rates and repayment terms as unfair. Trust in the sector can further weaken if consumers face personal finance challenges after purchasing an off-grid appliance.

Businesses, industry associations, and governments can all play a role in building consumer trust.

Building consumer recognition of high-quality products can in turn help to build trust. In more nascent markets, there are many low-quality and cheaper off-grid products that, while more affordable, often break quickly. As markets mature, for example, in Kenya, consumers demand increasingly high-quality products—including more premium product features and more durable products. Consumer education campaigns can help to build awareness and trust in these higher quality products. For example, in Kenya, the introduction of off-grid appliances has been supported by awareness campaigns about off-grid electrification. Since the campaign began, customer trust and acceptance, as well as market penetration of solar home systems and off-grid appliances, have gone up.[218]

Strengthened after-sales support can also improve the consumer experience. As markets develop, and as consumers purchase higher value appliances such as refrigerators, they increasingly value the service that comes along with the product. Providing after sales services also makes business sense: as the markets for off-grid appliances develop, competition between distributors and retailers increases. There is often little differentiation between the offerings of various distributors for many of the bundled products. The point of competition becomes the service package each distributor offers. In markets such as Côte d'Ivoire, distributors like Baobab+ are putting increasing emphasis on customer service. The company now offers aftersales support within 72 hours of a customer's outreach.[219] Surveys show that distributors still have room for improvement when it comes to meeting customers' expectations for service quality. In Uganda, Tanzania, and Kenya, 83% of customers who encountered challenges indicated that the challenges had not been resolved.[220]

Looking ahead, regulation can improve national product quality standards and better protect consumers. As the off-grid appliance sector is still nascent, quality assurance – a means of consumer protection – has not been a priority for regulatory bodies. This is changing, however, as more actors recognize the need to protect consumers by ensuring product quality. Lighting Global has launched the solar lighting quality assurance framework[221], and there is hope that such work can help inform progress in the quality assurance of more off-grid appliances as the sector grows. The African Union Commission, in collaboration with the European Union Technical Assistance Facility, kicked off efforts in 2018 to establish national roadmaps for the implementation of Minimum Energy Performance Standards (MEPS) and Labelling Programs. There is hope that this will also extend to cover off-grid appliances.

DESIGN CONSIDERATIONS FOR OFF-GRID APPLIANCES

The design of off-grid appliances should include an understanding of the large investment they represent for the consumer, and the conditions under which appliances will be used. As the off-grid appliance market matures, and customers demand higher quality appliances, there are implications for product design. A deep understanding of consumer needs is key to designing off-grid appliances. These should continue to be refined as the off-grid appliance sector grows, in particular accounting for regional differences.

Figure 38 shows examples of design considerations commonly informed by customer preferences.

218. World Bank, *Kenya - A Thriving Off-Grid Market – With a New Focus on Underserved Areas,* Lighting Africa Program, 2018.
219. Stakeholder interview with Baobab+, 2019.
220. CLASP, Global LEAP Solar TV RBF: Baseline in East Africa, Lean Data, 2018.
221. See https://www.lightingglobal.org/quality-assurance-program/

Figure 38: Off-grid Appliance Design Considerations

PRODUCT-SPECIFIC DESIGN CONSIDERATIONS	
TELEVISIONS	• Consumers have preferences for TVs that feature a wide viewing angle and large screen size (as the TVs are often viewed by numerous people at a time) • Similar to screen quality, consumers require TVs with strong and clear audio output in order to produce clear sound for a number of viewers • Remote control, clear menu selection, brightness control, audio quality, water protection, and signal receiver efficiency and safety increase the TV's ease of use and the buyer's comfort level
FANS	• As fans are often set up in larger bars and restaurants, operate in hot and humid environments, and run for long periods of time, they should provide sufficient air flow and have high durability and low maintenance costs • For household use, fans should make minimum noise and efficiency should enable them to run through the night
REFRIGERATORS	• The energy consumption of a refrigerator is a key factor in the total cost a household or business needs to pay for a refrigerator bundle. The compressor is the part of the refrigerator that consumes the most energy, and must be designed to be as energy efficient as possible while providing the same cooling capacity • In most settings such as restaurants and shops, doors are opened frequently but drinks and food should still remain cold. This requires durable door sealings and isolations as well as compartments to allow separate storage of products
FINANCING DESIGN CONSIDERATIONS	
ALL HIGH-PERFORMING APPLIANCES	• Many consumers have limited financial education and face other financial constraints. Financing terms should be developed with the consumer in mind and informed particularly by the financial behavior of the target population • Income in the target population is often seasonal, with disposable income often not a given depending on farming cycles and seasonal expenses such as school fees. Payment structure should therefore allow for flexibility in repayments, and include options to prepay whenever surplus income is available

What impact can off-grid appliances have on consumers?

The potential impact of off-grid appliances on Sustainable Development Goals has been explored briefly in Chapter 1 of this report. Here we expand on that discussion with a focus on consumer impacts.

Off-grid appliances increase access to information and education and help households save time and costs.

Off-grid televisions provide access to modern communication channels and increase access to education and information in regions that have previously been un- or underserved. Although televisions are primarily entertainment appliances, there is evidence that they can also have a positive developmental impact. Customers surveyed as part of the Global LEAP RBF, for instance, report that they use their televisions in equal measure for entertainment and to access local and national news. Televisions can contribute to national cohesion and democratization by helping to ensure that rural communities are better informed and thus more likely to be civically engaged.[222] Televisions also provide the opportunity for educational programs that focus on building explicit skills—e.g., shows on farming best practices, financial education, or language learning. Azuri, an off-grid solar television distributor, for example, notes that 60% of their customers reported that their children improved reading, writing and speaking skills after the installation of an Azuri Solar TV.[223]

The educational impact of televisions can be particularly high for marginalized communities. For marginalized groups such as women and people with disabilities, or household members with limited access to education, televisions can be an important complement to, or even substitute for, formal education. Off-grid televisions can help to close education gaps by providing non-formal education through local or national language educational programming and edutainment. For example, Shamba Shape Up is a "farm make-over" show that has aired across East Africa, and while providing entertainment value, also provides tips for better farm management. Soap operas and dramas can be used to educate the community as a whole about family planning and highlight social issues such as domestic violence, alcohol and drug abuse, or gambling. In India, studies have found a positive correlation between the introduction of TVs and the status of women and minorities, and in Mexico telenovelas have had positive impacts on the financial literacy of female viewers.[224] This impact relies on educational and appropriate content, and it is also important to note that there are potential negative impacts such as time spent by children on TV viewing at the cost of reading or other beneficial active pursuits.

222. Abagi, N., *Getting to know off- and weak-grid consumers: The unforeseen impacts of energy efficient off-grid appliances,* CLASP, 2019.

223. Azuri website (https://www.azuri-technologies.com/).

224. Jensen and Oster, "The Power of TV: Cable Television and Women's Status in India", *NBER Working Paper,* 2007. See also, World Bank, "Mucho Corazón: Using a soap opera as a vehicle for financial education in Mexico", World Bank Group, 2014, https://www.worldbank.org/en/results/2014/09/04/using-a-soap-opera-as-a-vehicle-for-financial-education-in-mexico..

Refrigerators and cookstoves help households save time and income, and help people live healthier lives. Households owning a refrigerator can store food—in particular, meat, fish and dairy products—safely for longer periods. This entails a behavior change, which, if achieved means refrigerator owners no longer need to go to the market daily, freeing up time for other activities. As food stays fresh longer, there is a reduced risk of food-related infections and diseases. Moreover, less food loss also means less lost income for households. Electric cookstoves also have the potential to allow households to save more time while improving health outcomes. Low-income households spend significant time collecting fuel and firewood. The Clean Cooking Alliance estimates that in India, women spend 374 hours annually collecting fuel and firewood, much of which can be saved by household transition to electric cookstoves.[225] More importantly, the World Health Organization estimates that more than 4 million people per year die prematurely due to illnesses attributable to indoor air pollution caused by traditional biomass cookstoves and cooking fuels, an annual public health crisis more deadly than HIV/AIDS, tuberculosis, and malaria combined.[226] Electric off-grid cookstoves—including both thermal pressure cookers and induction stoves—eliminate household exposure to toxic particulate matter and carcinogen emissions and have the potential to significantly reduce the mortality and morbidity burden of biomass cooking, but only in those cases where electric cooking technologies can fully or largely displace traditional biomass and kerosene cooking techniques.[227]

Fans provide comfort and can save lives through cooling. Particularly in hot and humid environments such as the South Asian and West African markets, indoor fans—as a relatively low-cost cooling solution—have the potential to mitigate heat-related health conditions and can reduce mortality for vulnerable people such as the elderly and children during heat waves.[228]

Off-grid appliances have a strong impact on women if they help reduce the burden of domestic work.

Off-grid appliances, particularly those designed to help with traditionally "female" household tasks, can have a strong impact on the empowerment of women. Women overwhelmingly shoulder the burden of the majority of household tasks: globally, women do more than three times as much domestic work as men. In some countries, this statistic is as high as ten times more.[229] Women spend up to two hours per day collecting firewood in rural areas, and another few hours daily on cooking and related household cleaning chores.[230] In the US, between 1900 and 1970, the introduction of modern appliances reduced the time spent by women on household work by an estimated 70%.[231] Bringing this scale of time savings to women in South Asia and Sub Saharan Africa could be transformative, both in terms of the quality of life and empowerment of individual women, and at the level of economies once the time saved from chores is at least partly translated into higher value paid work, education, and child rearing activities. Off-grid appliances such as electric cookstoves and refrigerators could enable this shift in the near to medium term. To confirm such impacts, more research is needed to understand how women use off-grid appliances and to quantify the impact on their day to day lives.

Off-grid appliances allow households to save energy-related costs and generate additional income.

Off-grid appliances can lower their household energy expenditure if they replace conventional appliances powered by expensive fuels with efficient, high-performing ones. While the investment costs for systems with off-grid appliances are higher than conventional systems, these devices can reduce household expenditure on energy in the long run. The extent to which this benefit is realized depends on the size of the solar system as well as whether or not it replaces conventional, fuel-based systems with high running costs. In a recent Global LEAP survey of solar TV customers in Kenya, Tanzania, and Uganda, half of the respondents used a solar home system with a television to replace kerosene lamps, or generator- or grid-powered lighting sources.[232] In cases in which a smaller, solar-powered system replaces a fuel-based system, a recent UNCDF report suggests that the customer will break even in less than a year.[233] If the purchase price (and/or financing cost) is measured only against fuel savings, larger systems—including multiple light systems or systems including a TV—usually do not recover the upfront cost within the average lifetime of the appliance. Some research suggests that those systems will create a net positive lifetime value for households with higher energy expenditure than the average bottom-of-the pyramid household.[234] The appeal of off-grid appliances can lead people to buy solar home systems, which reduces overall energy spend while increasing the range of services they can access.

225. Practical Action, Gender and Livelihoods Impacts of Clean Cookstoves in South Asia, Global Alliance for Clean Cookstoves, 2014.
226. WHO, Household Air Pollution and Health Fact Sheet, 2018.
227. World Bank & Dalberg Advisors, *Clean and Improved Cooking Landscape Report*, 2015.
228. Ravanelli, N. M., "Electric fan use in heat waves: Turn on or turn off?", Temperature 2016; 3(3): 358–360, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5079223/..
229. Dalberg Advisors, "Time Poverty: Why It Matters and What to Do about It", 2018.
230. Clean Cooking Alliance (CCA), *Impact on Cookstoves on Women and Gender,* retrieved in April 2019; "Gender and Clean Cooking Factsheet," Clean Cooking Alliance, retrieved 02/05/2019.
231. Greenwood, J. et al., "Engines of Liberation", *Review of Economic Studies,* 2005.
232. CLASP, Global LEAP Solar TV RBF: Baseline in East Africa," LEAN Data, 2018.
233. Goyal, R. & Jacobson, A., *Energy Access and Off-grid Solar Use in Uganda,* Schatz Energy Research Center and UNCDF, 2019.
234. Gubbins, P. & Zollmann, J., "Beyond the price tag: The real benefits of off-grid solar," FSK Kenya, 2016.

A WINDOW TO THE WORLD
SAMBURU, KENYA

The ramshackle, wind-swept town of Merille is home to the Samburu, a semi-nomadic people who roam the arid expanses of northern Kenya. Here, Teresa Lekuraki lives with her four children on what she can earn running a small shop.

But despite her difficult circumstances, Lekuraki has ambitions for her children. Denied an education of her own, she nonetheless harbors an abiding passion for learning. "If I had been educated back then I would not be living here now. The world is now ruled by education," she insists. "I will make sure all my children go to school."

Her children were at the front of her mind when Lekuraki first learned about Azuri Technology's solar TV systems. The kids had begun gathering at a neighbor's house every night to watch movies; she was lonely without them. She did the math and decided she could just about afford a TV of her own.

Azuri's solar TV, which comes with a phone charger and four bulbs, required a 5,000 shilling (around USD 50) down payment and weekly payments of 693 shillings (USD 7).

This wasn't her first experience with solar lights, but never before had she owned a TV, and as a grown woman she had always felt too ashamed to watch at the neighbor's house.

Now, with a TV under her own roof, Lekuraki says she has been impressed at how much both she and her children can learn from it. Lekuraki finds that the TV also gives her a taste of the education she never received. She says, "It has taught me more Swahili," a language she would have mastered had she gone to school. She is also fascinated by local and international politics, and she never misses a speech about Kenya's history.

The most wonderful thing about having a TV in the house, says Lekuraki, is that it keeps the family together. "My children have started staying indoors, and we all eat together," she says. "They have all their friends around, filling up the seats and sitting on the floor."

NO MAN IS AN ISLAND
KISUMU, KENYA

Simon Otieno is the first to admit that in his village, perched on rocky Mageta Island in Lake Victoria, there isn't much to do. There are no cafés and very few shops, and the island has never been connected to the grid. While the rooftops are dotted with solar panels providing light to a few homes, until recently no one here owned a television.

But last year Otieno had an idea that would change things not just for his own family, but for his neighbors as well: he decided to buy a Mobisol solar TV, and used it to open a video hall. Now dozens of villagers crowd every day into the modest room he uses to screen the news, movies, and football games, jostling one another on long wooden benches, sweating under the corrugated metal roof. During big football tournaments up to 100 people squeeze in, cheering in support of their favorite teams.

Before the video hall opened, the nearest TV was five kilometers away. Villagers would make the trip on foot or motorbike just to watch the news, or catch the occasional movie. But Otieno's business has brought entertainment to their doorstep. "They feel it's great to have," he says. "Sometimes they wake me up so I can go open the place for them."

Otieno first heard about Mobisol TVs from a friend, prompting him to visit the company's office in the city of Kisumu. The package he opted for includes a 32" flat screen TV, four light bulbs, a radio, and a flashlight, and costs him 200 shillings (around USD 2) a day. Charging 10 shillings entry for movies and 30 for football matches, Otieno makes at least 800 shillings (USD 8) a day from his video hall, and sometimes much more. He also runs a small shop and a stall where he uses a solar-powered razor to cut men's hair, all lit by the bulbs included in his Mobisol package.

Like most islanders, Otieno used to make a living catching fish. But he doesn't miss life on the water. "Fishing is seasonal," he explains. "Sometimes they're there, and sometimes they're not." For years he, his wife and his two young children have been living in a room attached to the shop, unable to afford a place of their own. But not only is the video hall more reliable then fishing, it's also more profitable. Now he's saving his extra money for a new project: buying his own piece of land and building a house for his family.

On the eve of the FIFA World Cup, Otieno said he was expecting the tournament to help make those dreams a reality. "The video hall will be full I am sure, because the people here love watching football," he says with a grin. "I find this helps my whole family, and we feel good about it."

The use of off-grid appliances for income-generating activities can help small businesses enter virtuous cycles of economic surplus generation. Most small businesses and entrepreneurs have limited financial capacity to invest in more productive tools and appliances. This can result in businesses getting trapped in a low productivity state. Entrepreneurs may want to reach a higher level of productivity—and generate more income—but lack the necessary financial capital to do so. Off-grid appliances can help businesses bridge this gap. Most off-grid refrigerators used in productive settings are likely to be used in shops, followed by bars and restaurants.[235] Early evidence from case studies suggests that off-grid appliances like refrigerators could more than double a small business's revenue.[236] Businesses can use this increased income to repay the loan for the appliance faster, invest it to upgrade their solar home system, unlock other sources of income or productive assets, or increase health and education-related expenses. 15% of customers covered in a Global LEAP field survey in Uganda mentioned that accessing an off-grid refrigerator allowed them to start a business.[237] As the efficiency of refrigerators and other productive use appliances improves and costs fall, the economic impact is likely to increase as well.

Finally, the use of consumer finance and leasing arrangements for off-grid appliances can help consumers build a credit history and help them access other financial products in the long run. Lack of collateral and insufficient credit history are major factors holding back many households in lower-income segments from accessing financial services. They face high interest rates and unfavorable repayment terms. Even potentially solvent and creditworthy customers are thus locked out of the formal financial sector. Being part of an off-grid appliance repayment system can help consumers access better loan products in the long run. Consumer financing providers and microfinance institutions typically collect repayment data that cover more than three years and provide them with detailed insight into a customer's repayment behavior. When households successfully repay loans used to finance off-grid appliances, they can use this information to access further loans on similar or more favorable terms. This can be a significant enabler to take out future loans, either from the same provider or other financial service providers.

The example of Baobab+ in Côte d'Ivoire and Senegal illustrates this dynamic. The customers of Baobab+ are mostly people working in agriculture who typically have a limited credit history with which to access loans. Baobab+ offers them solar home systems and off-grid appliances with a two-year financing term. Once the full asset is repaid, customers may be eligible to access a loan through Baobab Bank. Baobab Bank uses the data collected to determine loan suitability of the individual households.[238]

235. In the 2018 LEAP baseline survey on refrigerator use, three-quarters of customers said they used off-grid refrigerators in their shops, one-quarter said the used them in a bar, and about 5% used them in restaurants or other settings.
236. Data from a field trial conducted by CLASP in Uganda in 2019, for instance, showed that small businesses that utilized off-grid refrigerators improved their incomes 2.5 fold.
237. CLASP, *Global LEAP Solar TV RBF: Baseline in East Africa,* Lean Data, 2018.
238. Stakeholder interviews with Baobab+, 2019.

What are the conditions for off-grid appliance market growth?

Beyond the market size and income dynamics in any given country, enabling environment factors can accelerate or hinder the growth of the off-grid appliance market. In particular, these factors determine how affordable and available appliances are to off- and weak-grid households—which will be critical for increased market growth, given how price-sensitive and hard to reach these consumers typically are. The off-grid appliance industry needs to reach scale in order to achieve efficiencies and bring costs down for all players along the value chain. Figure 39 provides an overview of these enabling factors. The off-grid appliance sector is still new and emerging. There are many ideas for new policies, channels and strategies for distributing products, and financing models —but there is less practical learning on which market constraints are most important and which market conditions and interventions needs to be prioritized. In many cases, the necessary conditions for off-grid solar uptake are the same as those for off-grid appliances though with some nuances.

FINANCING MECHANISMS

Affordability is the main factor limiting access to off-grid appliances, and therefore consumer financing is an essential tool, especially for higher value appliances. PAYGO, microfinance, and bank financing are all potential avenues for consumer financing.

Figure 39: Conditions for off-grid appliance market viability

PRIMARY CONDITIONS

POLICY	FINANCING
The supply of energy access has historically been a government led initiative, and their engagement is needed to enable demand of off-grid appliances.	Access to finance for consumers and suppliers is crucial for enabling the demand and supply of off-grid appliance market.

SECONDARY CONDITIONS

CONSUMER AWARENESS	DISTRIBUTION INFRASTRUCTURE
Customers themselves need to understand the market and product options available so they can make informed purchases.	The diversification of players in the market, and other innovative means of distribution, ensures locally relevant distribution

While some lower-cost appliances like fans are more accessible to consumers via cash sales, the next wave of off-grid appliances are higher value, and very few consumers can access them without financing. Most off-grid customers cannot rely on their income or savings alone to finance the purchase of appliances. Due to weak enabling environments, historically, many off-grid enterprises found their own solutions for consumer financing, either by offering PAYGO financing directly to consumers or through partnerships with an MFI or commercial bank. This has continued with the bundling of off-grid appliances with solar home systems, and consumer financing is now often a core part of the off-grid appliance distribution business model. However, even with robust consumer financing, many people living off-grid still cannot afford appliance payments. While this report discusses business models for consumer financing in more detail in the preceding Chapter, below we highlight key aspects of corporate finance that enable off-grid appliances players to operate and provide consumer financing.

Corporate finance—including equity, debt, and grant capital—underpins investment and growth in the off-grid appliances space. Among other challenges, two key capital constraints to market growth are access to working capital and local currency financing.

Working capital is essential in the capital-intensive off-grid appliance sector because it enables industry players to manage inventory and provide financing to consumers. Off-grid appliance players incur working capital costs from the time they purchase stock until they recover funds from the customer. Working capital challenges are especially acute for vertically integrated players and downstream players – businesses that need to hold inventory before selling it to end-consumers. In some geographies, banks are beginning to offer trade financing to allow appliance importers to procure and re-sell their stock. Such financing makes the import business model more viable and has the potential to unlock growth in underpenetrated markets. Beyond traditional trade financing, businesses need additional working capital to provide consumer financing. This is especially true under the PAYGO model. Businesses can use their equity to lend onto consumers, but this limits the number of loans they can issue. Debt capital for appliance distributors, or financial products that allow consumers to take appliance loans from banks at the time of purchase, are essential for expanding consumers' access to financing.

Local currency financing is critical because the off-grid appliance market in most countries relies on importing products. Off-grid appliance importers need to purchase products in foreign currency but sell products in local currency, exposing them to currency risks. In markets with less developed financial systems, importers struggle to access local currency lines of credit. In addition, when DESCOs and other players provide PAYGO loans to consumers, these are denominated in the local currency. Underwriting these loans using capital borrowed in another currency is risky because it exposes the business to exchange rate fluctuations. Local currency financing, when it is available on reasonable terms, has the potential to eliminate such risks.

Private capital alone is not sufficient to unlock access to off-grid appliances; tools such as grants, results based financing, and concessional financing are also important for making the market viable.

Grant subsidies, results-based financing, and concessional financing are all tools to crowd in additional investment and improve access. To avoid distorting markets, supply-side approaches, such as targeted subsidies to reduce distribution and financing costs, should be a priority. One promising approach to unlock the business opportunity in off-grid appliances is results-based financing (RBF). The key objective of RBF is to overcome market failures constraining private sector delivery of distributed renewable energy systems

CASE STUDY
Global LEAP+RBF

This results-based financing (RBF) project aims to accelerate the development of a market for off-grid appropriate appliances such as fans, televisions, and refrigerators. To do so, the RBF provides incentives for off-grid solar firms to market pre-qualified off-grid appliances to their customers.

2016

In February 2016, with a USD 4.5 million investment from Energising Development (EnDev) and additional financial support from US Department of Energy, CLASP launched the first round of incentives in Bangladesh in close partnership with Infrastructure Development Company Limited's (IDCOL) solar home system program and in-kind partnership with the International Finance Corporation (IFC). This led to the procurement of 12,000 quality-assured off-grid televisions by Bangladeshi companies.

GLOBAL LEAP

2017

In October 2017, activities expanded to Kenya, Rwanda, Tanzania, and Uganda with additional support from the US Power Africa initiative, which committed USD 1.5 million for the administration of the program.

2019

In August 2019, with support from EnDev and Powering Agriculture, a new round of RBF opened which will provide over USD 2 million in incentive funds to support procurement of best-in-class solar water pumps and off-grid refrigerators expanding activities to Senegal and Zambia.

This initiative represents one of the most successful applications of results-based financing in the global off-grid market. To date, the initiative has catalyzed procurement of over 270,000 best-in-class off-grid TVs, fans, and refrigerators across Bangladesh, Kenya, Rwanda, Tanzania, and Uganda, providing new or enhanced energy access to more than 1 million people.

to the poor. Financial incentives are a temporary measure aimed at transforming the market to a self-sustaining level through mitigation of market barriers. For example, RBF is being used to incentivize importers and last-mile distributors to supply off-grid appliances. These importers and distributors receive payments based on pre-specified results achieved in delivery of clean and modern energy products and/or services – such as an off-grid appropriate appliance or connection to a mini-grid.[239] RBF for downstream actors like distributors is important to catalyze investment—it incentivizes players to enter markets that are unproven or are perceived to be overly risky. If successful, this can attract more conservative investors over time. CLASP has been at the forefront of promoting results-based financing for off-grid appliances in partnership with USAID and GIZ, as described below. Energizing Development (EnDev), in partnership with seven other donors, has supported 17 results-based financing projects globally since 2013, with CLASP and GIZ implementing the current RBF program for off-grid appliances since 2016.

Tax policy is also a form of financial incentives that can be used to overcome affordability barriers and accelerate market growth.

Several countries have introduced favorable tax policies related to the off-grid sector more broadly. However, for off-grid appliances specifically, few countries have provided tax incentives because they are expensive and can be politically controversial; where tax/tariff policies are in place, they often have been inconsistently applied.

Multiple countries have introduced tax exemptions for solar home systems, but the application of these benefits has been inconsistent and, when they exist, these policies often do not cover appliances. Countries such as Kenya, Ethiopia, and Sierra Leone have waived import duties and/or VAT on solar home systems and solar appliances. These countries are ahead of the market in extending their exemptions to off-grid appliances more broadly. However, even where such policies exist, the application of tax/tariff exemptions is often inconsistent in practice. Regulators also often face a fundamental challenge in differentiating between appliances intended for on- and off-grid use. This is an especially ambiguous question for appliances intended to run on mini-grids since they often run on AC current.

On the other end of the spectrum, countries such as Uganda, Côte d'Ivoire, and Nigeria have maintained relatively high duties on solar products. Some policymakers have expressed views that televisions, fans, and refrigerators are luxury products and should not benefit from tax exemptions. India has lowered its goods and services tax for off-grid television and fan components by 5% to encourage business-to-business imports and local assembly and manufacturing.

CASE STUDY
World Bank Grant Facility to Reduce Foreign Exchange Risk in Ethiopia

In 2017, the Ministry of Energy in Ethiopia approached the World Bank to support its agenda to increase access to renewable energy products in Ethiopia, initially with a focus on lighting and solar home systems. In Ethiopia, for example, restrictions on exchanging the Ethiopian Birr for foreign currency make it very difficult to import foreign goods, yet local manufacturing of off-grid appliances is still nascent. The World Bank provided a USD 20 million grant facility for the Development Bank of Ethiopia (DBE) to sub-grant foreign exchange credit lines to local private sector importers and distributors of solar products and/or appliances.

To identify organizations that would meet its qualifying criteria, DBE worked alongside the Solar Energy Development Association of Ethiopia to identify specific products that should be imported at higher volumes and members who were already importing globally certified, high-quality products to benefit from the scheme. In addition to this channel, microfinance institutions could also access this fund to provide consumer loans to households that were purchasing a Lighting Global Quality-Verified product. In the future, this type of intervention could be used to promote the import of off-grid appliances in addition to solar home systems.

The project led to the importation of over 300,000 quality-verified products, which provided lighting and energy to roughly one million Ethiopians. The fund was subsequently granted an additional USD 20 million in financing after 18 months of successfully lending to importers and consumers.

239. EnDev, Results-based Financing, 2019.

Where tax regulations have been adjusted to incentivize off-grid appliance market growth, local customs authorities require support in implementing the exemptions and clearing products. Consistent with the challenges in standards and testing, most tax and border agents are not able to easily differentiate between on-grid and off-grid appliances or have few incentives to invest their time into identifying and applying duty exemptions, resulting in the poor implementation of these tax/duty exemption rules.

While tax exemptions can be effective in removing barriers to entry, they are not a silver bullet to grow the market, and can carry a significant cost in terms of foregone tax revenues. In 2016, for instance, Sierra Leone implemented an intervention to jump-start the off-grid solar market through a duty waiver (now an exemption) on import taxes and a VAT removal for solar home systems, both of which effectively lowered prices by 40%.[240] While this had a positive impact on the market—and it is likely that similar interventions for off-grid appliances could yield positive results—the government still fell far short of its target of 250,000 SHSs. This suggests that government exemptions need to be supported by other incentives to promote overall market growth. Governments are also not incentivized to lower exemptions since there is no replacement in the short to medium term for the revenue lost. A recent study for Uganda revealed that if the government implemented full VAT and import duty exemptions on solar products, it would lose more than USD 18 million in tax revenue from 2019 to 2030.[241]

Beyond the lack of financial incentive for tax collectors, the lack of clear quality standards can make the implementation of tax exemptions impossible for local authorities. Tax exemptions can only be applied when standards are clear and when products are labeled clearly—without these prerequisites, customs officials may be unable to differentiate among products. This has been a challenge in both Kenya and Sierra Leone, where there have been reports that customs officials have misidentified products as conventional appliances rather than off-grid appliances. Furthermore, in Myanmar, the lack of clarity on standards has made it possible for more sub-standard products to enter the country.[242] Pre-verification of conformity is an important tool that can be used to overcome this barrier, but it only works when those issuing the certificates know how to differentiate among product types.

POLICY

National energy policies now increasingly emphasize rural electrification through access to distributed renewable energy, but governments have been slower to promote policies for off-grid appliances and related quality standards, tax incentive regimes, and end-of-life management.

Rural electrification agencies and regulators often lack the capabilities and resources to achieve their ambitious mandates, and many do not even consider off-grid appliances to be a part of their mandates. Across Sub-Saharan Africa, rural electrification agencies and other designated electrification policy and implementation bodies are exploring a variety of alternatives to grid extension—including the promotion of both standalone solar systems and mini-grids. Similarly, in Asia, in countries like India and Bangladesh there has been a focus by the government on electrification via grid extension and solar off-grid systems, respectively, without explicit attention to demand promotion via affordable appliances. Figure 40 provides an overview of targets set by electrification agencies and programs for targeting poor and hard-to-reach populations.

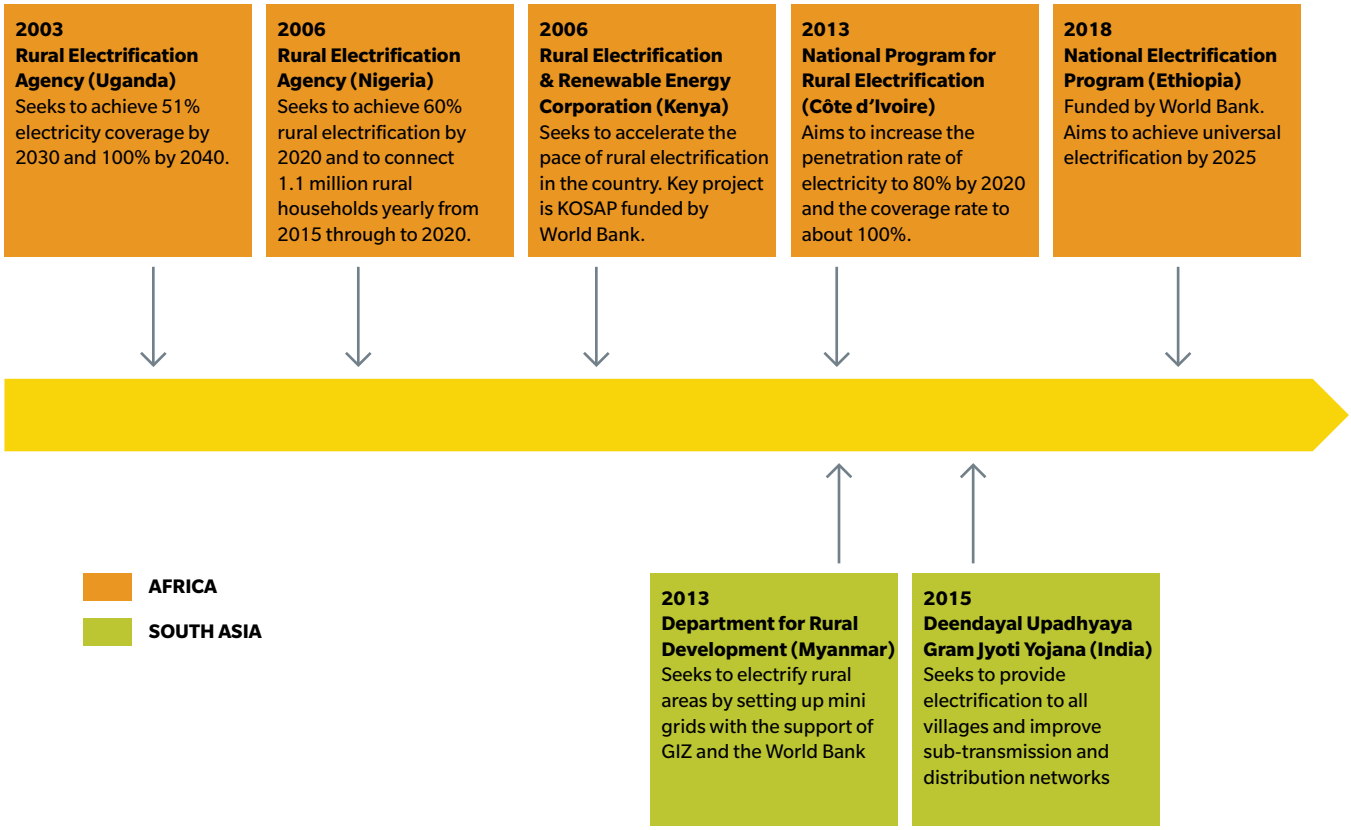
More concerted national efforts are needed to drive and coordinate policy reform. Ministries of Energy can lead these efforts and should draw in a range of other ministries, national agencies, and parastatals. Beyond the efforts of rural electrification agencies to execute mini- and off-grid initiatives, more high level and coordinated national efforts are needed to promote off-grid appliances. Ministries of Energy are often best placed to lead such efforts and can do so through dedicated programs or implementation units, such as the Kenya Off-grid Solar Access Project (KOSAP), which is financed by the World Bank. Other key government actors for a nationally coordinated appliance policy include standards bureaus to enforce standards; utility companies to integrate appliances into on-grid demand creation plans; and Ministries of Finance to collaborate on economic planning and tax policy decisions.

240. Dalberg stakeholder interviews, 2019.

241. Cardoso, D., et al., *Fiscal Policy Analysis: An Assessment of the Tax and Subsidy Options to Accelerate Solar Home Systems in Uganda*, Uganda Off-grid Market Accelerator (UOMA), 2018, https://uoma.ug/wp-content/uploads/2019/03/Fiscal-policy-analysis-report.pdf

242. Dalberg stakeholder interviews, 2019.

Figure 40: Overview of rural electrification agencies and programs across case study countries



Some countries do have policies and initiatives which recognize off-grid energy as critical to achieving universal electrification; however, few countries explicitly recognize the importance of off-grid appliances. For example, Sierra Leone developed its Energy Revolution Compact as a bold initiative to accelerate access to solar power to 250,000 homes by the end of 2018 and to provide universal electricity access by 2025; however, there was and is no tax exemption provision for standalone off-grid appliances under the compact.[243, 244] It is also not clear how such a program could distinguish appliances intended for on- versus off-grid solar use in order to apply exemptions. The new Nigeria Electrification Project, in contrast, offers one example of how countries can expand access to off-grid appliances. The program is intended to increase energy access through mini-grids and standalone solar systems, and as part of this effort requires implementers to make household and productive-use appliances available to end-beneficiaries.[245]

National energy policies related to mini-grid planning, investment, and regulation should also be aligned to better support the uptake of high-quality and energy efficient appliances. As mini-grid markets develop with potentially massive upcoming investments into the mini-grid sector over the next decade, support for policies that promote the uptake of energy efficient policies can help unlock appliance market scale. Mini grid developers do not have the same incentives to encourage the use of energy efficient appliances as solar home system providers because their business models depend on increasing energy consumption. However, it is more sustainable in the long term and in the best interest of customers to deploy high quality and energy efficient appliances on mini grids as it will improve the amount of energy services that customers receive for each watt paid for. Tariff structures and policies that incentivize mini grid developers to integrate and promote efficient appliances as part of their business models encourage further innovation and market scale.

243. The Energy Africa Campaign is a DFID-led initiative to accelerate the household solar market in Africa and help achieve universal energy access by 2030. Policy Compacts—voluntary bilateral agreements between the UK and over a dozen partner countries—are an essential part of the Campaign. Sierra Leone is the first such Compact to be completed, called the Sierra Leone Energy Revolution.

244. Tice. D., "Energy Africa Access Campaign: Policy Compact Sierra Leone," DFID, 2016.

245. World Bank, *Nigeria Electrification Project: Project Appraisal Document,* The World Bank International Development Association, 2018.

Today there is limited regulation around industry standards for off-grid appliances.

Standards and labelling initiatives are critical to promoting quality, improving energy efficiency, and protecting consumers – both at national and international levels. As we have seen in the introductory chapter of this report, high-quality appliances can have a large positive impact on end-users and societies. On the other hand, low quality products can be faulty and physically dangerous, can have higher total lifetime costs, and can result in market spoilage in the case of negative consumer experiences with inferior products. At the national level, governments can use a number of tools to support standards and labelling initiatives, including supporting testing labs, developing voluntary standards, and/or establishing mandatory standards for imported or manufactured products.[246] Testing methods and standards agreed at the international level and adopted by the International Electrotechnical Commission (IEC) can support governments that are unable to implement standalone initiatives due to a lack of expertise. These initiatives can be costly, and international support in this area is often needed.

Some national standards bureaus are starting to invest in product testing and developing mandatory standards specifically for off-grid appliances—costs, however, can outweigh benefits in nascent markets. There is an opportunity to further establish criteria in the local labelling of products to distinguish high-quality, efficient off-grid appliances from low quality versions. In Ethiopia, for example, the national standards bureau (Ethiopian Standards Agency) currently conducts local product testing for some off-grid appliances beyond lighting products such as TVs.[247] However, the organization is underfunded, which limits its effectiveness and efficiency. In such circumstances—common for most markets ready for commercial scale-up of off-grid appliances—there is an opportunity to develop relationships with third-party verification companies to ensure that market spoilage is prevented even when local testing capacity is constrained.

Another critical challenge for the regulation of off-grid appliances is uncertainty regarding regulations and limited ability to enforce them; significant investment into government capacity is therefore needed. Many markets ready for commercial scale-up of off-grid appliances import these appliances from overseas manufacturers. In these cases, customs officials are tasked with discerning among product types, enforcing tax rules, and ensuring that appliances meet required quality standards. Since on- and off-grid appliances of high and low quality can look alike, customs officials may not be able to discern a product's quality or intended power source. As a result, the enforcement of tax/tariff exemptions and quality requirements is often inconsistent.

CASE STUDY Quality Assurance Testing

Intertek is one of several companies active in the Testing, Inspection, and Certification (TIC) industry and authorized by governments to provide these services to importers. Globally, Intertek is assisting the national bureaus of standards in countries such as the Kingdom of Saudi Arabia, Nigeria, Kuwait, Uganda, Ethiopia, and Kenya in preventing the import of unsafe goods into their countries. Intertek is a global Total Quality Assurance provider that does testing and certification, as well as system assurance. Governments seeking to improve their processes typically instruct the National Bureau of Standards to enforce specific standards of quality and safety on imported electrical appliances and to define the list of products that must comply. The Bureau of Standards appoints Intertek to undertake testing at any one of its centers globally. Intertek provides test services to exporters and issues certificates of conformity, a mandatory document required by customs, for products that pass its tests.

Uncertainty regarding regulations creates the potential for low-quality products to enter the market in spite of quality regulations. It is also a challenge for manufacturers, who may not clearly understand which certificates are required for the products they are shipping. For example, some countries require certificates of conformity prior to import for conventional televisions but not for off-grid televisions—yet customs officials may not apply this rule consistently due to limited awareness. Education and training for customs officials, as well as labelling programs, are thus important for helping countries overcome these barriers.

246. The Efficiency for Access Policy Brief on Promoting High-Performing Off-grid Appliances provides more information and guidance to policymakers interested in developing policies that will support the growth of the off-grid appliance market. https://storage.googleapis.com/e4a-website-assets/Promoting_High-Performing_Off-Grid_Appliances.pdf

247. Dalberg Stakeholder Interviews, 2019.

Regulations on suitable management of electronic waste ('e-waste') are not yet directly linked to electrification; however, they have the potential to influence the off-grid appliance sector directly.

Sustainable management of e-waste is an emerging priority for the off-grid solar sector; however, this cannot be left solely to the private sector and requires government action to ensure responsible behavior. Today, the off-grid solar sector is only a small contributor to e-waste—the sector is responsible for just 0.5% of e-waste in Sub-Saharan Africa.[248] Even so, greater investment today will ensure that the industry's growth is sustainable over the long term and can enhance the sector's reputation as a leader in environmental responsibility. Off-grid appliance e-waste is similar to e-waste in general and can be addressed in that broader context. One of the most significant environmental impacts occurs when e-waste reaches high temperatures, resulting in the release of toxic chemicals into the air during combustion.[249] Discarded refrigerators in particular can have detrimental impacts because they contain considerable amounts of plastic, which is not biodegradable; and because they release toxins when burned at low temperatures, a common informal disposal practice.

Several organizations are beginning to find solutions and to develop commercial business models for appliance recycling.[249] There is also substantial commercial value to unlock in the recycling or repurposing of off-grid appliance e-waste. For example, televisions are 98% recyclable and contain materials such as zinc, nickel, and copper—all of which, through a careful recycling process, can be recovered and reused.[251] In Kenya, the Waste Electrical and Electronic Equipment (WEEE) Center has been handling e-waste from all sectors, including from televisions and fans, and has managed to recycle over 5,000 tons of e-waste that has been safely disposed of.[252] Global LEAP is currently running its first challenge in Sub-Saharan Africa to drive the development of an e-waste industry in the region and identify more businesses engaged in such activities.

In the absence of best practice policies for e-waste management, the growth of the off-grid appliance market will create additional burdens on e-waste disposal across economies ready for commercial scale-up of off-grid appliances. The off-grid appliance industry can pre-empt some of these challenges through further investments in sustainable product design, while governments and industry players can incorporate environmental considerations as they develop standards. There is also a need to strengthen the domestic or regional recycling industry and to create the right financial framework to support

CASE STUDY
Global LEAP Solar E-Waste Challenge

With support from USAID Scaling Off-Grid Energy (SOGE), the DFID Transforming Energy Access (TEA) programme, and in partnership with GOGLA, CLASP launched a USD 1.6 million Global LEAP Solar E-Waste Challenge for innovations in solar e-waste management in Sub-Saharan Africa. The program is supporting innovations in e-waste management for the off-grid sector, and in doing so, seeks to catalyze broader and longer-term action to address the e-waste challenge. Some of the key barriers the Challenge aims to address are take-back and collection, repair, and recycling. Grants have been awarded for the following:

i. Recycling and e-waste management companies seeking to expand business activities in support of the off-grid sector across Sub-Saharan Africa

ii. Solar home system distributors seeking to pilot and implement end-of-life program.

iii. Other specialized service providers with operations that are directly relevant to responsible solar e-waste management

Successful applicants[253] were awarded between USD 50,000-200,000 to support the implementation of their proposed projects over a 12-month period. A series of case studies about the projects will be developed at the end of the implementation period and disseminated among the off-grid energy community.

248. Magalini, F., et al., *Electronic waste (e-waste) impacts and mitigation options in the off-grid renewable energy sector,* DFID, 2016, https://assets.publishing.service.gov.uk/media/58482b3eed915d0b12000059/EoD_Report__20160825_E-Waste_Study_Final-31.08.16.pdf
249. MMC, "Five Shocking Environmental Effects of E-waste," Mayer Metals Corporation, 2018.
250. CLASP, "$1 Million Sub-Saharan Africa Solar E-Waste Innovation Program Launched," 2019.
251. E-Waste Australia, "Televisions Go to Landfill as Digital TV Arrives in Australia," 2018, https://www.ewaste.com.au/ewaste-articles/televisions-landfill-digital-tv-australia/.
252. WEEE Centre, 2019. Retrieved in April 2019
253. Profiles of awardees are available at https://storage.googleapis.com/leap-assets/Solar-E-Waste-Challenge-Company-Profiles.pdf

end-of-life management. End-of-life management policies need to be part of a broader range of cross-cutting enabling instruments that support the transition to sustainable PV life cycle policies. Governments should develop policy to address how business can ensure that they can recycle and/or reuse the components in solar PV panels, batteries, and other e-waste materials. The International Renewable Energy Agency (IRENA) recently highlighted three key policy interventions for e-waste management, summarized below.

CONSUMER AWARENESS

Given the early stage of the industry, many customers are not yet aware that they can benefit from appliances in an off-grid environment.

Surveys have shown that customers are likely to purchase from people they know and make purchase decisions primarily through word of mouth. Consumer understanding of off-grid appliances has been limited thus far by challenges in understanding product specifications and quality, but companies are exploring marketing channels beyond their proprietary sales channels. Vertically integrated businesses with strong agent sales forces have been most successful in driving product penetration through agent networks.[254] More distributors need to find appropriate promotional channels, as communications limited to word-of-mouth promotion takes time, and increases risks of misinformation. Greenlight Planet, for instance, has established partnerships with large social enterprises (e.g., Pollinate Energy) and/or rural retail organizations across several states in India that are trained to distribute their products.[255] These customer touchpoints enable Greenlight Planet to gain customer trust and loyalty as customers can go back to a trusted individual to inquire about product use and technological support. Companies can also partner with financial institutions to leverage communication channels and relationships of trust that those institutions have already built with their clients. Acumen found that one of the companies in its portfolio originated 70% of sales through the local microfinance institution it partnered with.[256]

DISTRIBUTION INFRASTRUCTURE

Cost effective and efficient last mile logistics, i.e., the distribution of appliances in rural areas, is one of the most challenging requirements for unlocking the off-grid appliance market.

A close-knit network of distribution points, as well as a sufficiently developed road infrastructure, is needed to ensure safe delivery of higher value appliances. As appliances grow in size, with 100L refrigerators and 32" televisions becoming common, distributors must find secure locations store these products and appropriate transport infrastructure for product installation sand after sales support. In Kenya, for example, there are 13.5 million rural residents not connected to an all-season road, reducing the likelihood of being able to access an off-grid appliance.[257] The World Bank's Rural Access Index has shown a link between transport connectivity and inclusive development. This includes both expanding road networks and improving road quality. The enabling environment of road infrastructure, in particular, is critical when transporting high-value goods such as off-grid appliances.

CASE STUDY
Solar Panel E-Waste Reduction

The International Renewable Energy Agency (IRENA) estimated that there were 250,000 metric tons of solar panel waste in the world at the end of 2016—a figure on track to reach 78 million metric tons of waste by 2050.

This calls for action across three recommended policy areas to address the growing challenge of solar e-waste:

- Placing a fee on solar panel purchases—to make sure that the cost of safely removing, recycling, or storing solar panel waste is built into the price of solar panels and not externalized onto future taxpayers
- Enforcing laws of decommission, storage, or recycling of solar panels to ensure that they do not end up in landfills
- Using UNEP's Global Partnership for Waste Management to strictly monitor e-waste shipments in order to encourage nations importing used solar panels into secondary markets to impose a fee that covers the cost of recycling or long-term management

254. Uganda Off-grid Market Accelerator (UOMA), "Mapping the Ugandan off-grid energy market," Shell Foundation, 2018, https://shellfoundation.org/app/uploads/2018/10/2018-UOMA-Market-Map.pdf
255. Dalberg stakeholder interviews, 2019.
256. Harrison, K. & Adams, T. "How Affordable Is Off-grid Energy Access in Africa?", Acumen, 2017, https://acumen.org/wp-content/uploads/2017/07/Evidence-Review-On-Affordability.pdf
257. Iimi, A. & Diehl, A., *A New Measure of Rural Access to Transport: Using GIS Data to Inform Decisions and Attainment of the SDGs,* World Bank, 2015, http://documents.worldbank.org/curated/en/767961468186548881/pdf/102767-BRI-Box394840B-PUBLIC-TransportICT-Newsletter-Note23-Oct-highres-00000002.pdf

Where will the off-grid appliance market be in 2030?

The market fundamentals for off-grid appliances are strong—the sector simply requires the right encouragement and support.

The off-grid appliance market is at an inflection point—our market projections show that the potential market for off-grid fans, refrigerators, and TVs alone could reach USD 25.3 billion by 2030. The growth in the obtainable market—roughly a doubling from the potential market size today—will be driven by an increase in the affordability of products, through a combination of better access to financing, higher consumer income levels, and product cost and price reductions. The market may grow even more quickly if product cost reductions translate into faster price declines as has been the pattern the past few years. For instance, the market will reach 10% more households by 2030 if appliance prices decline at 3% a year in line with historical trends for products like TVs.

While growth in the addressable and obtainable market is almost certain, the actual trends in market evolution could take very different trajectories or 'pathways' given the many open questions that remain on off-grid and mini-grid market trends, appliance technology evolution, financing availability, and the policy environment.

Taking these uncertainties into account and building on the conditions for growth described in Chapter 6—under all scenarios—current industry dynamics already suggest several clear directions for governments, donors, and development partners for improving appliance affordability and addressing other constraints to more accelerated off-grid appliance market development. Key required measure include:

1. Improving policies and developing associated guidelines to facilitate implementation of new and existing appliance policies (e.g., reduction in appliance taxes/tariffs, and consumer protection measures such as well-balanced off-grid appliance quality and efficiency standards);
2. Significantly increased financing made available at every level of the off-grid appliance ecosystem (e.g., consumer finance, working capital finance, results-based financing incentives);
3. Deeper insights into consumer behavior and market trends to inform appropriate product design and distribution strategies;
4. Ongoing investment into technology innovation and R&D; and
5. Partnerships with private sector actors, ranging from the small distribution entrepreneurs to the multi-national appliance manufacturers to de-risk market entry and support business model innovation.

As it continues to develop, the off-grid appliance market will also require **intensive sector coordination and best practice exchange,** a key area in which the Efficiency for Access Coalition intends to play a central role in the years to come.

What are the pathways to future off-grid appliance industry growth?

As the number of households with an off-grid energy source increases, there will be growing demand for appliances adapted to these off-grid power sources.

Grid extension is moving at a slower pace than population growth, and off-grid and mini-grid solutions are therefore critical to closing the energy access gap in the coming years. Traditional grid connections are not viable in or extend to many remote areas. They require large infrastructure investments and, even in those areas where the logistics of grid extension are viable, connections can cost more than USD 1,000 per household, making them financially unattainable for most households.[258] Moreover, national utilities, themselves constrained by financial considerations, often do not see sufficient demand for electricity in rural areas to justify the infrastructure investment. Off-grid solar and mini-grid solutions can drive electrification in rural areas and build up energy demand.

Efficient off-grid appliances are key to unlocking consumers' ability to benefit from improved energy access. Without appliances, access to energy cannot reach its full potential. By ensuring that off-grid electrification is provided in coordination with the distribution of appliances, efforts to increase energy access are more likely to succeed in meeting customers' needs. This link between appliances and energy access is being increasingly acknowledged in the sector and is now reflected in the World Bank's Multi-Tier Framework (MTF) which defines a number of attributes for energy supply which are based on levels of energy sufficient to power household appliances.[259]

258. For example, grid connection costs are USD 1400 per connection in Zambia, USD 880 to 2000 per connection in Rwanda, and USD 899. For Zambia and Rwanda, see *National Renewable Energy Laboratory (NREL),* Tariff Considerations for Micro-Grids In Africa, NREL and Power Africa, 2018. For Nigeria, see Ohiare, S., "Expanding electricity access to all in Nigeria: a spatial planning and cost analysis," *Energy, Sustainability and Society,* 2015. Even in countries where grid connections are lower cost, the cost is unaffordable to most households. In Kenya, for instance, grid connection costs are USD 400 per household, which is over four times the mean willingness to pay of surveyed Kenyans. Attia, B., and Shirley, R., "Living Under the Grid", GreenTechMedia, 2017.
259. World Bank, Beyond Connections: Energy Access Redefined, World Bank Energy Sector Management Assistance Program (ESMAP), 2015, https://openknowledge.worldbank.org/bitstream/handle/10986/24368/Beyond0connect0d000technical0report.pdf?sequence=1&isAllowed=y

As off-grid household incomes rise and demand for more sophisticated uses of energy increases, there will be strong demand for adapting conventional appliances for use with off-grid energy sources. The average on-grid liquid crystal display (LCD) television in the market requires around 50W, too much energy for a typical mid-sized solar home system.[260] As another case in point, powering an average conventional alternating current (AC) refrigerator requires a solar panel and battery that are 8-9 times bigger than those needed to power a best-in-class, efficient direct current (DC) off-grid refrigerator (see Figure 41).[261]

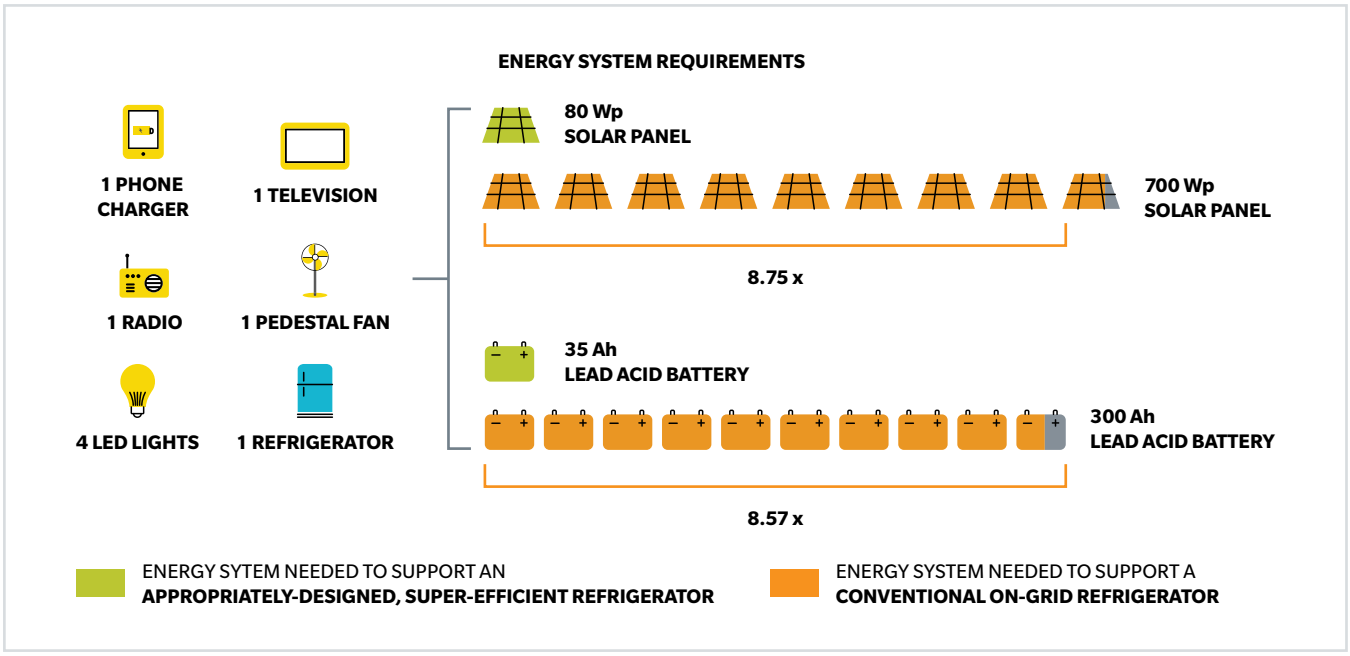
Solar home system sales will be the primary driver for off-grid appliance market growth in the near- to medium-term.

Off-grid appliance sales will be closely tied to solar home system sales in the next few years. Based on trends to date, over the next 3-5 years off-grid solar home system uptake will continue to be the primary engine for off-grid appliance market growth. While recent slow-downs in the solar off-grid sector suggests that annual sales growth forecasts of 80%+ from several years ago [262] may have been too aggressive, more recent data suggests that solar home system sales growth of over 60% annually, primarily driven by PAYGO solar sales, is still achievable for the off-grid sector overall.[263] Even if off-grid solar sales growth declines more rapidly than anticipated, the market will almost certainly reach tens of millions of new off-grid households by 2030. Given the high rates of appliance bundling with PAYGO solar system sales[264] and, as seen in Bangladesh, high rates of off-grid appliance purchasing and use by those who own stand-alone SHS units,[265] many of the households who will acquire an efficient off-grid appliance in the near future will likely do so as part of, or immediately consequent to, their SHS purchase.

Mini-grid customers also need access to appliances to benefit fully from electrification; in turn, efficient off-grid appliances can ensure the long-term sustainability of mini-grid business models.

Mini-grids can deliver power to communities without grid connectivity, yet their commercial viability remains mixed and the model likely requires long-term subsidies. Mini-grids are increasingly seen as an important part of the future of electrification. This is especially the case in sub-Saharan Africa, where, due to the sheer number of off-grid households, poor financial health of national utilities, large land area, and transmission costs of traditional grid infrastructure, extending the grid to all households is unrealistic.

Figure 41: Energy System Requirements to Power a Super-Efficient Off-grid vs. Conventional Refrigerator



260. CLASP test data, 2018.
261. The "Appropriately Designed Super-Efficient Refrigerator" consumes .1 kWh per day and has an 80L capacity. These figures are based on rated performance for the most efficient product nominated for the 2016-2017 Global LEAP Awards Off-Grid Refrigerator Competition. The "Conventional On-Grid Refrigerator" consumes 1.75 kWh per day and has a capacity of 691L. This level of energy consumption and size reflect the median of the range found in the Consortium for Energy Efficiency data which reflected typical developed world consumer preferences, and thus, typical product offerings.
262. World Bank Lighting Global & Dalberg Advisors, *Off-grid Solar Market Trends Report,* 2018.
263. In terms of installed capacity, the most recent (H2 2018) GOGLA's global off-grid solar home system sales data suggests an increase of 33% per each 6 month period, or a growth of roughly 80% annually. See GOGLA sales data, 2019 and Figure 21 in Chapter 3 of this report ("Supply Market Trends"). Proprietary 2019 Dalberg data for the PAYGO industry, suggest that sales growth over the next few years is likely to be 60% annually. A more precise estimate will be available in 2020 in the next edition of the World Bank Lighting Global & GOGLA Off-grid Solar Market Trends Report (forthcoming in mid-to-late 2020).
264. 25-85% of PAYGO SHS sales were bundled with appliances based on companies interviewed for this report (see Chapter 3).
265. See TV and Fan penetration rates among SHS households in Bangladesh in footnote 102, Chapter 3.

The International Energy Agency estimates that 140 million Africans (roughly 30 million households) will need to be served by mini-grids by 2040.[266] The World Bank has recently projected that to reach universal energy access by 2030, mini-grid connections globally would need to grow ten-fold from roughly 10-11 million households today (47 million people) to 100-120 million households (or 500 million people) by 2030.[267] Under the business-as-usual scenario, however, mini-grid penetration would fall far below this level. Extrapolating from historical mini-grid growth, the World Bank's ESMAP team has estimated that in the business as usual approach, by 2030, mini-grids would only serve 72 million people (i.e., 14-16 million households),[268] an increase of roughly 50% from current mini-grid connection levels.

Achieving commercial viability has been challenging for mini-grid developers. Today's mini-grids are almost exclusively privately-owned and do not benefit from any of the connection or tariff subsidies which national grid utilities can access. Mini-grids are installed with a certain power load in mind; if demand does not materialize, which is often the case, then the operator of such an "over-sized" mini-grid needs to raise tariffs to break even.[269] These tariffs then disincentivize customers to use mini-grid electricity—driving down demand in a negative feedback loop. Finding ways to increase demand for electricity on the mini-grid is thus a major factor for financial sustainability in many mini-grid deployments.

Efficient, high quality off-grid household and productive use appliances can improve mini-grid effectiveness by increasing demand and balancing loads. Off-grid appliances can help ensure appropriate mini-grid sizing and support sustained demand for energy from mini-grid users.[270] Inconsistent energy demand drives up the cost of the power, as more energy must be stored. Mini-grids are most cost-effective when used during periods of sunshine, as less battery storage is needed. Lights and televisions are currently the most sought-after appliance for household mini-grid users, but these appliances are all used primarily in the morning and evening.[271] Today the highest peak of energy consumption is during the evening; the advent of refrigeration and other productive use appliances that use the load effectively throughout the day has the potential to change this. Mini-grid providers should therefore be more attuned to a growing market for off-grid appliances used by micro and small businesses and in agricultural production, but also have an interest in growing the ecosystem of affordable household appliances.

The relationship between mini-grid sector development and off-grid appliance market development is complex and continues to evolve. While appliance use is of great interest to mini-grid developers as a potential driver of demand, not all mini-grid enterprises have historically been interested in efficient household appliances. Household energy access was an afterthought in many early mini-grid deployments which focused on serving business customers rather than household needs. More importantly, many mini-grid developers in the past have tended to rely on the distribution of inefficient AC appliances to maximize overall energy consumption or, at least, have not had the incentives to promote energy efficiency. In the long term, such models have not been financially sustainable for customers and thus have had the effect of constraining household uptake of mini-grid connections. In order for mini-grids to work at scale in the long term, providers must consider integrating appropriate appliances that can provide electrification benefits while being affordable both in the upfront purchase of the appliance and in terms of running costs.

Mini-grid developers are becoming more focused on improving household energy access and some now have stronger incentives to promote efficient appliances. Growing numbers of mini-grid developers now recognize the need to integrate off-grid appliances more fully into their product offerings. The World Bank has labeled the recent wave of solar mini-grid deployments as "third generation" models which are built around efficient appliance promotion.[272] Some developers of third-generation mini-grids encourage customers to use appliances, provide or facilitate access to appliance financing, and in a growing number of examples are getting directly involved in appliance distribution (e.g., renting out appliances using a PAYGO model and amortizing appliance costs into mini-grid tariffs). The efficient appliances promoted under such models require 60% less energy compared with the same appliances five years ago.[273] Developer interest in these models is just one of energy access impact and demand generation. By introducing efficient appliances from day one, the mini grid system can be designed significantly smaller, resulting in a reduction in capital expenditures (CAPEX) of more than 50% for the mini-grid developer compared with only three years ago, with equally significant improvements in mini-grid efficiency and costs possible in the future.[274]

266. See IEA estimate in Dubey, S., *A new chapter for Sub-Saharan Africa's mini grids industry,* World Bank, 2018, https://blogs.worldbank.org/nasikiliza/a-new-chapter-for-sub-saharan-africas-mini-grids-industry.
267. World Bank, *Mini-Grids for Half a Billion People: Market Outlook and Handbook for Decisionmakers,* 2019, https://openknowledge.worldbank.org/bitstream/handle/10986/31926/Mini-Grids-for-Half-a-Billion-People-Market-Outlook-and-Handbook-for-Decision-Makers-Executive-Summary.pdf?sequence=1&isAllowed=y.
268. See estimate in Knuckles, J., "State of the Mini-Grid Market Globally", World Bank, 2019, https://atainsights.com/wp-content/uploads/2019/06/2.B.James_.Knuckles.World-Bank-notes.pdf.
269. GMG, *Analysis of Barriers to Growth and the Potential Role of the African Development Bank in Supporting the Sector,* Green Mini-Grids Market Development Program, 2016, https://greenminigrid.se4all-africa.org/sites/default/files/GMG-MDP-Document-Series-N1.pdf
270. See, Kopec, G. et al., *The future of direct current electrical systems for the off-grid environment,* Smart Villages, 2016.
271. GIZ, What size shall it be? *A guide to mini-grid sizing and demand forecasting,* 2016, https://energypedia.info/images/0/0f/Mini-Grid_Sizing_Guidebook.pdf.
272. World Bank, *Mini-Grids for Half a Billion People,* 2019.
273. Ibid.
274. Ibid.

For instance, mini-grid enterprises like PowerGen and Devergy are testing appliance financing as a way to build household energy demand and Cyngi in India is distributing appliances. As another point of evidence, the Africa Mini-grid Developers Association (AMDA) now encourages the best practice of providing appliance financing appliances and machinery, especially for productive uses, to balance mini-grid load profiles and increase capacity utilization.[275] Early insights from CrossBoundary Innovation Lab found that offering appliances on credit increases overall mini grid revenues by 18% after 11 months.[276] Though the endorsement of efficient appliances (rather than appliances more generally) is not yet explicit in AMDA's official materials, a more formal focus on efficient appliances by the mini-grid sector appears likely in the next few years based on our interview consultations for this report.

While growing mini-grid developer interest in appliances is promising, it is unclear to what extent it will serve as a major impetus for the growth of the DC off-grid appliance market. An important point of complexity in the relationship between mini-grids and off-grid appliances is mini-grid compatibility with DC equipment. Off-grid appliances, such as those designed for off-grid solar systems, are typically adapted to DC power supply, which is required by or suitable for a range of low power household-level applications, such as LED lighting, consumer electronics products like TVs, radios, and mobile phones, as well as appliances with variable speed electric motor drives such as fans and solar water pumps.[277] Direct current is native to solar PV generation, while rotating generators such as wind, diesel, and hydropower generate alternating current. This means that mini-grids, which are predominantly solar or solar-diesel hybrids (80% of all planned mini-grid deployments as of 2019[278]), generate DC electricity. From an energy distribution perspective, however, the majority of mini-grids deployed today supply AC power.[279] In other words, most mini-grids convert DC electricity into AC electricity for final energy transmission to customers, and thus target AC appliances.

The path for mini-grid sector evolution is not yet clear. Some companies are exploring the DC mini-grid opportunity including Devergy, Mesh Power, and Black Star Energy in Africa, Mera Gao Power (MGP), Minda, and Cyngi in India, and Solaric in other parts of Asia. Some of these companies have already reached tens of thousands of households, and several bundle DC appliance sales as a core part of their business model.[280]

While the supply, transformation, distribution, and appliance technologies exist to make mini-grid DC systems feasible, the extent to which they will be adopted at scale in the next decade is unknown and is thus a significant open question for off-grid DC appliance demand. Efficient DC appliances can, of course, already be used with AC mini-grids or on-grid when combined with rectifiers or AC/DC power converters. Making full use of efficient appliances, however, likely requires concerted efforts to promote efficient appliances that can be easily adapted to both DC and AC settings.

Theoretically, the argument for more DC mini-grid investment across developing Africa and Asia is strong. Mini-grids that integrate DC-native electricity supplies with DC distribution and DC-native electrical appliances possess significant energy efficiency and cost advantages over AC distribution systems because of the lack of a need for energy conversion.[281] Furthermore, in the case of many rural communities where future grid interconnection is unlikely to be physically or financially feasible, DC mini-grid designs can be far more optimal due to lower capital costs and greater reliability, particularly in settings where settlements are more compact and long-distance energy transmission or higher energy business uses are not a factor.[282] It is entirely unclear, however, how the DC or AC/DC hybrid mini-grid ecosystem will evolve in the future relative to AC mini-grids. When combined with open questions about the overall pace of mini-grid sector growth, the prospects for this pathway to off-grid appliance scale-up require careful monitoring and study in the next few years.

In areas where grid access is unstable, off-grid appliances can act as an alternative or backup to conventional appliances, a potentially large and lucrative market.

Peri-urban and urban weak-grid customers can be a significant driver of off-grid appliance demand; however, they need more versatile appliances than off-grid customers. As noted in Chapter 2, the weak-grid population across the developing world is significant (225 million households) and, in many cases, still growing rapidly as population growth and rural-to-urban migration outpace the ability of utilities to improve the quality of urban and peri-urban grid-connections. Urban customers on weak grids tend to have a higher income than rural customers, and are less dependent

275. Dalberg stakeholder interview, 2019.
276. CrossBoundary and Energy 4 Impact, *"Innovation Insight: Appliance Financing"*, 2019, https://www.crossboundary.com/wp-content/uploads/2019/08/CrossBoundary-Innovation-Lab-Innovation-Insight-Appliance-Financing-Final-07-Aug-2019-1.pdf
277. Energypedia, "DC mini-grids", 2018, https://energypedia.info/wiki/DC_Mini-grids.
278. Knuckles, J., "State of the Mini-Grid Market Globally", World Bank, 2019.
279. This is a common observation in the literature. See, e.g., "most micro-grid power systems in the developing world are designed as alternating current (AC)", in Booth, S., et al. *Productive use of energy in African micro-grids,* NREL, 2018, https://www.nrel.gov/docs/fy18osti/71663.pdf. The precise proportion of DC (or AC/DC hybrid) versus AC mini-grids and their relative reach into the off-grid population are impossible to estimate at this moment. The most recent World Bank ESMAP study of global mini-grid penetration of households, estimated at 10 million, for example, does not indicate an AC vs. DC breakdown. See World Bank, *Mini-Grids for Half a Billion People,* 2019. Our industry interviews and desk research suggest that the proportion of DC to AC mini-grids is very low. For example, of the 100 mini-grid deployments tracked in Tanzania in 2017, only 14% were solar or solar-hybrid, and only a proportion of these distributed DC electricity. See Odarno, L., et al., *Accelerating Mini-grid Deployment in Sub-Saharan Africa: Lessons from Tanzania,* WRI, 2017, https://www.wri.org/publication/tanzania-mini-grids.
280. See, e.g., Cygni in India, which reaches over 20,000 households and offers a wide range of efficient DC appliances to its customers (http://www.cygni.com/).
281. Ibid. See also, Kopec, G. et al., *The future of direct current electrical systems for the off-grid environment,* Smart Villages, 2016, https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/TR8-The-future-of-direct-current-electrical-systems-for-the-off-grid-environment-web.pdf
282. Opiyo, N., "A comparison of DC- versus AC-based minigrids for cost-effective electrification of rural developing communities," Energy Reports, 2019, https://www.sciencedirect.com/science/article/pii/S2352484719300617.

on seasonal harvests. There is also a lower cost for companies to reach these customers given relatively higher densities in urban vis-à-vis rural areas. In Bangladesh, 23.5% of customers who purchased a solar powered fan through the Global LEAP RBF program were connected to a grid, more data is needed on other markets and products, but early evidence shows that there is a significant market for off-grid appropriate appliances that can operate in weak-grid environments.[283] In such urban weak-grid settings, off-grid appliances used as a back-up power source in addition to the grid can provide an overall more consistent—and in the case of generator users, cheaper—energy service.

Weak-grid customers should be the 'low-hanging fruit' for weak- and off-grid appliance distributors. Their needs, however, can be quite distinct from rural off-grid solar or mini-grid customers. Given their higher incomes, weak-grid households likely put a greater premium on product quality, performance, brand name and aesthetic appearance, not just affordability.[284] They seek a greater range of household appliances, and are interested in bigger models (e.g., bigger TV screens, larger refrigerator capacity) with broader functionality.[285] Notably, such households typically need appliances that can run on both AC and DC power and can do so seamlessly. Appliance components such as inverters and rectifiers, that enable appliances to run on both AC and DC power, exist, but can be costly and tend to make appliances less efficient due to conversion losses. Serving weak-grid households effectively thus requires ongoing product improvements, some of which are already in progress. There are initiatives, for instance, including LEIA's recent and forthcoming research,[286] to encourage the development of more affordable quality solutions that are compatible with hybrid DC and AC environment, such as appliances with built in power converters and appropriately optimized motors.

Implications for the path forward

Given the uncertainties around solar off-grid, mini-grid, and weak-grid pathways for off-grid appliance development, the appliance sector must prepare for a broad range of future scenarios.

Looking across off-grid, mini-grid, and weak-grid settings, we see several potential long-term scenarios for market development, many of which have significant implications for off-grid appliances. The three stylized scenarios that can help tease out the implications for the future state of the off-grid appliance market are:[287] AC domination, AC/DC hybrid environment, and DC domination (see Figure 42).

Scenario 1: AC domination: In this scenario the grid expands faster than expected, combined with very rapid AC mini-grid growth across Africa and Asia, driving tens of millions of off-grid households getting access to reliable, low cost AC mini-grid connections. At the same time, there is slower than expected development of the off-grid SHS market due to consumer finance and affordability challenges and competition from grids and mini-grids. In parallel, DC mini-grids do not take off. The technology fails to generate private sector interest or broad donor support. Aside from pockets of off-grid solar home system use, rural and peri-urban areas follow more traditional AC electricity pathways so that consumers, even in rural areas, show strong preference for AC appliances, in anticipation of connections to the grid or to AC mini-grids.

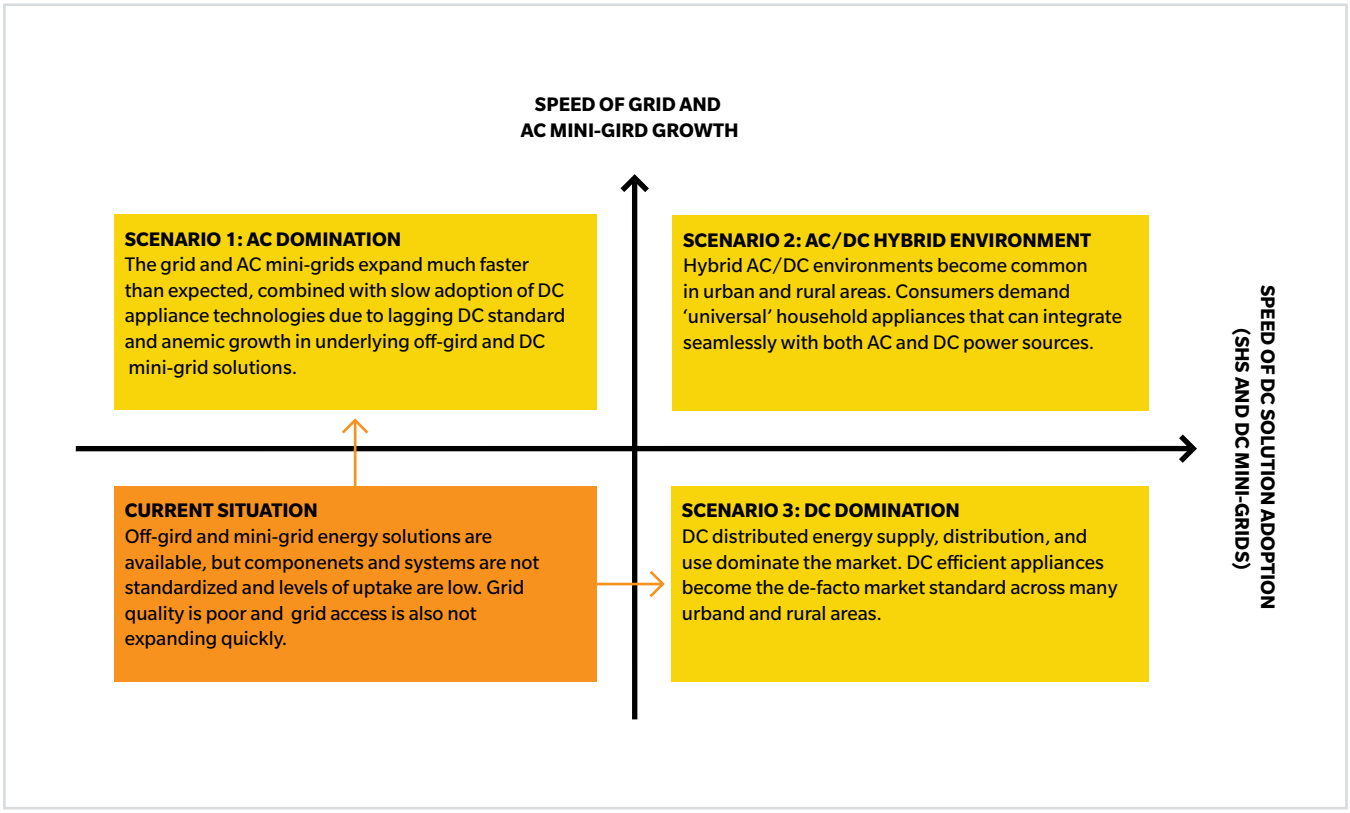
Appliance implications: This scenario would result in limited growth for off-grid DC appliances, which would remain a niche product category restricted to the off-grid SHS segment, and which would continue to have relatively high costs due to limited economies of scale. Appliance manufacturers would, however, invest in efficient AC appliance development, largely driven by fast growing 'third generation' AC mini-grid demand for efficient appliances and the continued challenges of intermittent grid energy supply, necessitating high quality, efficient appliances that can work with battery storage and grid back-up solutions.

Scenario 2: Hybrid AC/DC environment: In this scenario there is extensive AC/DC competition and cooperation. Because a new generation of AC mini-grids gains significant traction alongside continuing grid extension and improvement, AC standards would dominate in urban and peri-urban areas. Solar home system growth in this scenario, nonetheless, would also be very rapid and would lead to mass uptake of DC appliances in off-grid areas, but also extensive use of SHS power and DC appliances as back-ups in urban and peri-urban areas for unreliable grids. DC mini-grids would also achieve more significant market penetration relative to AC mini-grids, a major shift from today's focus on AC mini-grid development.

Appliance implications: Hybrid AC/DC configurations become commonplace in both rural and urban areas and the market shows extensive demand for "universal" efficient appliances which can switch seamlessly between AC and DC power (e.g., via external converters or more sophisticated engineering improvements including built-in power converters, smart circuitry, and motors optimized for both types of power supply). This scenario would mean significantly increased off-grid appliance demand relative to the status quo and also increasing focus on energy efficiency across all appliance types, since households will expect to use the same appliance for both on-grid (AC), mini-grid (AC or DC), and off-grid (DC) power sources.

283. The source for this data is Global LEAP RBF Verification Surveys conducted in 2018 and 2019. Before buying an appliance 23.5%% of customers had access to unreliable grid electricity, to ensure uninterrupted electricity supply they installed a solar home system kit, which included a fan.
284. Dalberg off-grid appliance distributor and manufacturer interviews, 2019.
285. Ibid.
286. See the Compatability and Interoperability Technology Roadmap. https://efficiencyforaccess.org/publications/compatibility-and-interoperability-technology- roadmap. Further research is planned to conduct research and potentially R&D into solutions that can allow appliances to switch seamlessly between different energy systems (e.g. SHS, mini grid, and grid).
287. The appliance sector scenarios provided here are based on a framework developed by Kopec, G. et al., *The future of direct current electrical systems for the off-grid environment,* Smart Villages, 2016, https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/TR8-The-future-of-direct-current-electrical-systems-for-the-off-grid-environment-web.pdf.

Figure 42: Scenarios for off-grid appliance market development



Scenario 3: DC domination: DC-distributed energy supply, distribution, and use dominate. The lack of grid growth, particularly into rural areas, is coupled with explosive growth of ever more powerful off-grid solar home systems and battery storage, such as solar generators that replace diesel generators, in both off-grid rural and urban (back-up power) settings. DC mini-grid distribution technologies become the dominant segment of a fast-growing mini-grid sector and, due to improved efficiency and lower costs, become the de-facto standard for off-grid energy access, deployed on common platforms (e.g., hub-and-spoke models) with off-grid solar home systems in peri-urban and rural areas where population density requires the blending of mini-grid and off-grid solutions.

Appliance implications: In this scenario off-grid efficient DC appliances would see the fastest growth. The range, quality, and pricing of DC appliances would reach parity with AC appliances and the potential off-grid appliance market would likely grow faster than our baseline projections for 2030.

We believe that the hybrid scenario, or some variant of such a scenario, is most likely to occur in most developing markets, but only time will tell. It is clear that **off-grid appliance enterprises, donors, and governments must be prepared for a broad range of market outcomes** irrespective of which of these pathways or appliance delivery channels come out on top.

One element of such preparedness is to support an efficient appliance ecosystem that is not siloed but flexible, and responsive simultaneously to AC, DC, and hybrid AC/DC settings. This means there is a need to support hybrid (AC/DC) appliance development and related improvements in power conversion (inverter/rectifier) technologies, to develop standards and market incentives that encourage appliance efficiency in both AC and DC settings without picking "winners", and to support underlying technology innovations (e.g., smart circuits, brushless motors, insulation in refrigerators) and business and financing model innovations (e.g., appliance PAYGO models, result-based financing models based on IoT-enabled appliance remote metering) that can be readily transferrable across both AC and DC contexts.

CUSTOMER DEMAND

Consumer awareness of - and demand for - quality, affordable off-grid appliances are expected to grow as incomes rise and the market becomes more competitive.

The off-grid appliance market will continue to grow with improved affordability and better last mile sales, distribution, and after-sales channels. Off-grid appliances that are relatively affordable and have a clear usage benefit such as TVs and fans should rapidly reach a level of penetration that approaches the projected penetration of SHSs and mini-grids, as long as consumer financing and distribution barriers are addressed. These appliances should act as drivers for the uptake of SHS and mini-grid connections, as customers continue to see the incremental value in bringing an off-grid system into their home. We expect that sales of higher cost products such as refrigerators will grow as awareness for their benefits grows among target customers, but sales growth will be less rapid than other segments due to high costs for at least the next 3-5 years. New household product segments, most notably electric cookstoves—starting with electric pressure cookers—will become an increasingly prominent market driver despite the complexities and current limitations of that cooking technology as discussed in Chapter 4. Other household products on the horizon are off-grid laptops, tablets and connectivity devices (e.g., Wi-Fi routers). Off-grid appropriate laptops and tablets are already being tested by some manufacturers, and as native DC products they can easily be connected to a solar home system.

While generic off-grid appliances will continue to feature heavily in the market, customers are expected to grow more discerning in their selection of off-grid appropriate appliances for use. Poor experiences with low-quality, generic household appliances and lack of good after-sales and repair services will likely become more significant concerns as the off-grid appliance market matures. Customers are expected to demand high-quality appliances, especially for larger investments such as refrigerators and for productive use appliances on which their livelihoods depend. These rising expectations have the potential to be particularly noticeable in high-potential markets such as Nigeria and Myanmar, where the current market is driven by generic off- and weak-grid appliances.

Demand for productive use cases, while not the focus of this report, should become an increasingly important driver of the off-grid appropriate appliances market, especially in rural areas. As PV panels and batteries become more affordable, larger-scale off-grid appliance technologies improve (e.g., energy efficient cooling, processing, irrigation), and as consumer financing becomes more accessible, productive use appliances will become more attractive to customers. Refrigerators are currently the most demanded household appliance for productive use,[288] and there is significant potential for this market to grow. There is already potential for smaller productive use products present in the market, such as hair clippers and sewing machines, to become more widespread. More energy-intensive productive appliances such as commercial scale electric stoves, washing machines, and irons will also begin to enter the market, particularly for micro- and small-business use in urban areas. Finally, a separate highly promising category of productive technologies focuses on agricultural use—these appliances, starting with solar water pumps, but also including less mature technologies such as egg incubators, off-grid cold chain equipment (e.g., dairy and horticulture coolers), and small-scale agri-processing equipment for niche uses (e.g., mills, solar off-grid dryers for fish and produce) represent a major area of future growth for the off-grid appliance industry given the overlap between household off-grid appliance customers and farmers.

Household and productive appliances should be seen as being part of the same sector. Household and off-grid appliance issues should not be seen as being siloed as there is great commonality across these product segments. The two markets are linked because the uptake of productive use appliances, indirectly, should serve as an engine for household appliance demand since productive appliances increase household incomes and thus generate more expendable income for the purchase of household appliances. We have seen no quantifiable evidence yet of such a virtuous loop between productive and household appliance demand, but interviews with appliance distributors—particularly a few PAYGO companies consulted for this report that already have both household and productive-use appliances in their product portfolios—suggests significant potential for mutually-reinforcing business model dynamics between productive use and household appliance markets. Furthermore, both from the perspective of market constraints and potential interventions, there are many parallels between household and productive use appliances. For instance, in both cases, product affordability and consumer financing, gaps in consumer awareness of new appliances, and innovations in distribution models are important considerations for future market development. There are also many parallels on the policy front, such as the need for well-balanced efficiency and quality standards for consumer protection and adjustments to tax/tariff policies that can make appliance uptake more viable. Funders and implementers should keep these parallels in mind when they program their investments.

288. Efficiency for Access. Off-grid Appliance Market Survey 2018. https://efficiencyforaccess.org/publications/off-grid-appliance-market-survey

PRODUCT DEVELOPMENT

We expect that off-grid appliance product design and manufacturing will be better informed by customer needs and will benefit from improved economies of scale.

More appliances will be developed intentionally for off-grid customer needs, rather than be adapted from on-grid counterparts. Refrigerators, in particular, are expected to be refined by the industry to be more affordable and better adapted for a rural home. Several donors are making investments and grants to support innovations in this area. The Efficiency for Access Coalition's R&D fund will provide over £1 million in grants, and as part of the Transforming Energy Access Program (TEA) DFID and Shell Foundation have provided over $4 million to create and scale companies developing innovative cooling solutions. Cooking appliances—such as electric pressure cookers (EPCs) and slow cookers—are likely be the next wave of product development specifically tailored to off-grid settings. The newly launched Modern Energy Cooking Services (MECS) program will invest in accelerating the process of off-grid electric cooking appliances becoming mainstream.

As the market for off-grid appliances grows, it is expected that the scale at which manufacturers produce units will increase, leading to more rapid price decreases. Thanks to efficiencies in large-scale production and technological improvements over time, off-grid appliance manufacturers are expected to reduce production costs and offer more affordable price tiers. Increased pressure from the entry of many new players, including some increasingly high-quality generic off-grid appliances manufactures, has the potential to make the market more competitive and to increase overall affordability. Demand for solar panels and batteries is expected to continue to grow globally, driving up the scale of production and hopefully leading to further cost savings in retail sales for off-grid appliances.

More breakthroughs are expected in finding environmentally sound ways to expand the market for off-grid appliances. Enhanced after-sale servicing and repairs, driven by manufacture support as well as customer demand, have the potential to lengthen product lifespans and reduce waste. Improved modularity and interoperability would help make it possible to add an appliance to an existing solar system without needing to replace the full system. For example, with a reliable battery, customers could upgrade their televisions without changing the full solar home system. Distributors should also be responsible for ensuring that resources are available for the correct disposal of appliances at the end of product lifecycles.

BUSINESS MODELS

The market is expected to become increasingly competitive and specialized.

As the off-grid appliance market becomes more firmly established, there will be greater business model specialization in product manufacturing, distribution, financing, and after-sales support. For market segments like PAYGO solar, where highly integrated models have been the norm, many previously vertically integrated companies are expected to move toward disaggregation, a trend that is already apparent in our interviews with sector actors about their plans for the future. Leading players will increasingly narrow their focus on high-end innovation and proprietary hardware and software, rather than growing market share on volume alone. Distribution-focused players, in particular, are expected to evolve quickly to meet demand for better after-sale services and improve operational logistics in order to sell larger appliances, such as refrigerators. More broadly, in emerging and high-potential markets, more home-grown businesses will emerge with both technology and distribution solutions.

Customer financing will likely be at the forefront of innovative business models in off-grid appropriate appliances across all segments of this sector. Off-grid appliance distributors, financiers, and investors, as well as other ecosystem actors are expected to use data more effectively to understand financing patterns—currently limited information is available on factors such as default rates and willingness to pay. New businesses and new partnerships within financial institutions will emerge to better serve the off-grid appropriate market—notably, loan repayment cycles that match income cycles for rural farming households and more effective and appropriate means of determining creditworthiness.

ENABLING ENVIRONMENT

Governments should start to more explicitly recognize the importance of off-grid appliances in achieving universal energy access and furthering other SDGs such as poverty reduction, health, livelihoods, and gender equity.

Governments will increasingly recognize the need for more holistic approaches to electrification, including distributed renewable energy and off-grid appliances. As electrification plans proceed apace, governments already see the need to plug gaps where the grid cannot reach. For areas where they plan to develop mini-grids, they need to provide a means for customers to use the electricity, ensuring a sustainable financial return for investors. Governments can develop and enforce quality standards and clear labeling practices to ensure the welfare of off-grid power customers.

Donor funding is expected to shift and focus more explicitly on the most remote off-grid customers. International and local distributors will naturally have picked the low-hanging fruit in terms of customers within reach in both peri-urban and rural areas. In 10 years, more effort will be provided to bring appliances (including productive appliances) to the hardest-to-reach, geographically and financially isolated households—who nonetheless would benefit from access to news through a television, or a better way to store food so they make less frequent trips miles to distant markets. Learnings from enterprises such as Solar Sister and Copia, which focus on remote off-grid communities, have the potential to ensure more effective ways in the long term of reaching the last mile with off-grid appliances.

How can the growth of the off-grid appliance market be further accelerated?

POLICY SUPPORT

Governments should recognize the importance of driving energy demand through off-grid appliances and implement policy support through levers such as tax/tariff abatement, consumer protection, and consumer awareness promotion.

In support of the important link between off-grid appliances and electrification, governments should take a holistic approach to energy access and include off-grid appliances. National energy policies should explicitly support off-grid appliance technologies. Today, many policy actors and some donors consider off-grid appliances such as televisions, fans, and refrigerators to be luxury items. This narrative should be challenged and reframed to ensure that decision-makers understand the transformative impact that efficient appliances—for both household and productive use — can have on off-grid households and small businesses. Donors and industry associations should proactively support the off-grid appliance industry by encouraging governments to see off-grid appliances as a critical part of the electrification conversation. This can ensure that off-grid appliances are considered from the get-go when developing policies and programming for increased electrification. Furthermore, the incremental impact off-grid appliances have for women and disabled customers can help drive wider support.

There are increasing examples of government policies incorporating off-grid solutions into their electrification strategies—most notably, Nigeria's Electricity Vision: 30-30-30. Sierra Leone embraced off-grid solutions by signing the UK-Africa Energy Compact in 2016, and Kenya launched the Kenya Off-Grid Solar Access Project (KOSAP) with the World Bank.

All of these programs, however, focus primarily on the source of power—the mini-grid or solar home system. Expanding the conversation around off-grid electrification to include off-grid appliance distribution and demand would ensure that government policies serve customers right to the point of end use. More attention must be given to increasing access to off-grid efficient appliances at a policy level, ensuring that the target beneficiaries of these electrification initiatives can truly see the full benefits of energy access.

Furthermore, as mini-grid markets develop with the massive investments projected over the next decade, national energy policy support for DC mini-grid technologies and standards (rather than just mini-grids with AC distribution) can help unlock faster off-grid appliance uptake at scale. This does not mean picking winners between AC and DC mini-grid standards, but national energy policies should recognize that DC mini-grids can play an important role within the broader array of electrification strategies. Likewise, governments should recognize the synergies of combining DC mini-grid architectures with DC-native efficient off-grid appliances[289] and should support the development of DC mini-grid standards, while also allowing the private sector to make its own optimization decisions across available mini-grid and off-grid technologies.

Beyond a more explicit recognition of the importance of off-grid appliances, improvements in tax/tariff regimes and their enforcement is likely the most important immediate policy priority for the sector. The argument for privileged regulatory and trade treatment of efficient off-grid appliances is particularly compelling for productive use equipment, but even for the household appliances, there is a strong case for governments to treat efficient appliances designed for off-grid settings - which contribute to energy access and drive demand - differently from on-grid appliances. Understanding this narrative, and the role of appliances in reaching many of the SDGs, can help governments move forward in developing sector support programs that incentivize efficient appliance uptake and adoption at scale. There are very few examples of tax/tariff exemptions for appliances today and, where such exemptions exist, implementation and enforcement are often weak or lacking. Beyond setting appropriate VAT and duty levels for priority appliances, governments must also provide more guidance to customs officials working at points of entry and mitigate the challenges of officials applying regulations inconsistently due a lack of knowledge about the products. The World Bank is helping drive advocacy on tax/tariff reduction and capacity-building for customs agencies and regulators—their efforts should continue and be expanded with support from funders and other sector intermediaries such as off-grid and mini-grid industry associations (e.g., GOGLA and AMDA). This should lead to lower customer prices and increase the affordability of devices for the end customer.

289. For a discussion of the linkages between mini-grid development policies and the off-grid appliance market see: Kopec, G., et al., *The future of direct current electrical systems for the off-grid environment,* Smart Villages, 2017, https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/TR8-The-future-of-direct-current-electrical-systems-for-the-off-grid-environment-web.pdf.

Consumer protection is likewise a vital policy concern, and has a key role to play in government, donor, and development partner off-grid appliance promotion initiatives. One of the more pressing consumer protection issues for off-grid appliances is the development and dissemination of well-defined product quality standards. The changing dynamics of the market, with faster growth and declining manufacturing costs, mean that the share of off-grid appliances that are generic will continue to grow. As more generic off-grid appliances enter the market, governments should develop quality assurance guidelines and mechanisms for consumer protection to avoid market spoilage. Industry organizations have an important role to play in working with governments to put these quality assurance mechanisms in place. Improvements in standards must also come alongside improvements in enforcement, including support for product testing and certification programs to help consumers differentiate between low- and high-quality products and related consumer protection measures, like the broader adoption of consumer warranties to limit financial risk. At the same time, it is important to highlight that quality and efficiency standards must be carefully calibrated and phased in at appropriate times depending on the stage of market development. In particular, appliance quality standards should not be overly restrictive during this early stage of market development to avoid impeding experimentation and innovation.[290]

The off-grid appliance industry should also ensure that consumer lending is done responsibly and does not over-burden off-grid households with debt, particularly because the average transaction size for off-grid appliance purchases (e.g., refrigerators) is substantially higher than for basic off-grid energy access kits. Repeated experience in other sectors such as micro-finance shows that self-regulation is challenging without significantly improved transparency on customer transactions, common financing standards, and the presence of appropriate intermediary bodies.

In addition, the off-grid appliance industry must provide regulations for data collection, security, and privacy since many off-grid household appliances feature IoT functionality (e.g., to monitor and remotely optimize appliance performance) and are thus starting to capture significant amounts of data on customer behavior, often with minimal disclosure and a lack of systematic thinking about customer's data privacy and data security concerns.

Somewhat related to the point of consumer protection, there is also the need for much broader engagement on consumer awareness-building and education. The experience of the World Bank's Lighting Global program and other analogous interventions suggests that donors and governments can play an important role in educating consumers and building demand via consumer awareness and marketing campaigns, though leadership on this must come from private sector off-grid appliance enterprises who have the front-line role of educating consumers about their products. Even more important than general awareness building of off-grid appliances and their impacts, the public sector and donors have a vital role to play in educating potential customers to understand their legal, financial obligations and the possible implications of product failure.

Policymakers' support to local appliance manufacturing or assembly, where feasible, has the potential to decrease import costs while also creating local value, employment and overall sustainability. India has been an industry leader in local appliance manufacturing and assembly, reflecting the large domestic market it serves and the government incentives provided. In sub-Saharan Africa, most off-grid appliances are imported from China. Local manufacturing or assembly has the potential to evolve, however, with strong government support and incentives for local production. Fosera has pioneered SHS assembly in Ethiopia and Kenya with its local partner Solinc, which has itself built a profitable business locally assembling PV modules despite stiff competition from overseas. To drive local manufacturing and lower costs for the customer, governments should support tariff exemptions on the component parts of off-grid appliances that cannot be produced locally, and encourage overall investment in the sector.

FINANCE

A dramatic increase in dedicated financing for off-grid appliances is needed to unlock both supply and demand bottlenecks.

The financing of off-grid and weak-grid appropriate appliances needs to be sustained and further expanded by donors and impact investors. Even with business model innovation and falling appliance costs, the widespread scale-up of off-grid appliances will need significant consumer financing. Developing the consumer financing market for appliances will require substantial amounts of concessionary debt and risk capital from donors and impact investors. As the off-grid appliance industry matures, not all of the consumer financing should be channeled via vertically integrated appliance distribution companies as is currently the norm. Instead, donors and sector intermediaries should encourage banks, micro-finance organizations, and new specialist financiers, which have relevant financial risk assessment and risk management competencies and access to capital, to engage on the off-grid appliance financing opportunity. Such a shift would allow for more needed financial innovation—for example, adjustment of repayment periods to match harvest seasons in rural areas—and more streamlined and asset-light business models for appliance distributors, in line with a general move to greater business model specialization apparent in the off-grid solar sector.

290. Efficiency for Access. Promoting High-Performing Off-Grid Appliances. 2019. https://storage.googleapis.com/e4a-website-assets/Promoting_High-Performing_Off-Grid_Appliances.pdf

An essential component of this market diversification is creating and applying a more proactive and customer-centric lens to consumer financing for off-grid appliances. Today's financing reaches only a small fragment of the population. For example, repayment frequency continues to pose a challenge for rural customers whose income flow is seasonal. To address this, Proximity Design in Myanmar has adjusted its model to take payments from customers every four months, in line with the harvesting cycle. Adjustments such as this have the potential to accelerate uptake by making financing affordable for more customers and reducing the risk of locking customers into a debt cycle. Vertically integrated businesses and distributor-financiers need to lean into this type of arrangement and innovation more deliberately. Another opportunity exists for creating financing mechanisms tailored to the needs of customers that buy off-grid appliances for productive use—for example, a shopkeeper buying a refrigerator. These are just two examples; useful innovation in financing products will depend on deeper understanding of the customer and more effective data gathering.

More results-based financing should be implemented, accelerating the market by making off-grid appliances more affordable. While consumer financing is critical to improving overall affordability, it does drive the overall price of the product up for the customer, which risks crowding out some customers. Bringing in more financing to help lower interest rates, for example through results-based financing, can improve customers' long-term ability to pay. EnDev's results-based financing for energy access has seen GBP 40 million committed by DFID, and five years into the project services half a million people.[291] This type of financing is particularly suited to off-grid appliances due to the availability of remote monitoring technology and high incidence of mobile money payments. Governments, donors and other development partners can expand and replicate RBF initiatives such as this to further drive the development of sustainable commercial markets and increase affordability to end users.

Donors are well positioned to encourage the acceleration of appliance-specific customer and distributor financing by supporting more innovation in off-grid appliance financing mechanisms. From a consumer financing perspective, in addition to support for innovative consumer financing models like PAYGO, donors have the opportunity to channel much greater amounts of funding through existing MFIs and asset financing mechanisms. Alongside consumer financing, there is also a critical need for working capital finance for appliance manufacturers, importers, and distributors, an area where donors and other sector intermediaries can play a meaningful role. Improved terms for working capital - given the capital-heavy business models of many off-grid appliance distributors—and the availability of local currency financing are particularly important. Donors can support sector financing needs at three levels. First, by compiling and sharing insights from recent programs and innovations in sector financing, as the appliance space is moving quickly, and it is important that all stakeholders can benefit from any relevant lessons learned. Second, by providing guarantees or other financing tools to financial institutions and telecoms to encourage off-grid appliance financing. GSMA has pioneered this with off-grid appliance distributors and telecom partnerships, and more can be done—in particular, by learning from DFID's results-based financing program with EnDev. Finally, by supporting and encouraging the financing of off-grid appliance distributors, both at a large scale with impact investors and at a more local scale with SME financing.

CUSTOMER INSIGHTS & MARKET INTELLIGENCE

More specific data about off-grid appropriate appliance customers, not just in the context of solar home systems, should continue to be consolidated and shared more intentionally.

Given the high potential for off-grid appropriate appliances to impact the lives of their customers, companies need to improve their mechanisms for sharing market data and insights. The current practice of keeping all data in-house does not allow for more institutional learning about off-grid appliance customers, and how best to reach and serve them effectively. The off-grid appliance sector has increasing amounts of data at its disposal. However, there has been hesitation to share or analyze these data despite the frequent lack of in-house data analytics capacity. While data privacy concerns must be addressed, more effort can be made to effectively bring together such data sources to increase the penetration and impact of off-grid appropriate appliances. Specifically, the right incentives should be created to ensure there is sufficient industry participation. This could be created by providing access to types of analyses or benchmarking data if companies participate, by regularizing data collection in coordination with partners like GOGLA or Mix Market, and—potentially—by creating pooled data storage and data analytics platforms that can ingest and anonymize data and provide analytics support at scale. There is currently much discussion about possible common approaches for energy sector data sourcing and sharing, but the dialogue is largely focused on off-grid and mini-grid distributor data rather than off-grid appliance usage data.

Deeper insights into appliance customer needs and behaviors should be gathered to support more targeted and effective product designs, as well as better distribution and financing business models. There is limited understanding of off- and weak-grid appliance customers. A more rigorous cross-geography customer segmentation, including quantitative demographic, psychographic, and product usage data, but also more qualitative behavioral research, would enable all industry actors

291. Weber, E., et al., *RBF Financing for Energy Access – Lessons Learned,* Energising Development (EnDev) Programme, 2018, https://endev.info/images/e/e4/EnDev_-_Results-based_Financing_for_Energy_Access%2C_Lessons_report.pdf

to benefit from a deeper understanding of customer needs. This research could identify the characteristics of early off-grid appliance adopters, develop a better understanding of willingness to pay for a range of appliances, and understand the core differences between customers purchasing appliances for household vs. productive uses. Deeper customer insights also require increased investment into product field testing to access actual performance in the field and create more real-time loops between product innovations and consumer feedback.[292] Answering these questions can accelerate improvements in product design, support more effective market entry, and maximize positive social impact by ensuring that the right off-grid appliances are provided to the right customers at the right price.

Donors should help close the gap in customer insights by funding or coordinating the development of a more comprehensive segmentation of off-grid appliance customers. This segmentation can be used, alongside additional research, to develop behavioral insights that can inform better policy and business models, and, in turn, amplify the impact of off-grid appliances. Furthermore, donors should lead the conversation and thinking around the development of data guidelines that can pave the way for better customer insights by encouraging more comprehensive data collection.

TECHNOLOGY INNOVATION

Emphasis should be placed on improving the efficiency of off-grid efficient appliances to reduce panel array requirements, as well as ensuring longer product lifecycles and increasing availability of after-care services.

In the coming years, efficiency should continue to be at the heart of off-grid appropriate appliance technology advancements. The more efficient a product can be, the smaller the solar panel and battery needed to power it, and the more affordable the product will be for a customer. Significant improvements have been made in televisions and fans; however, more research is needed for refrigerators and heat-producing appliances. These improvements should be made both in the hardware and software development of products. Refrigerators seem to be at the cusp of finding a more efficient and affordable solution, providing an exciting inflection point in the industry. This research is absolutely vital as affordability is still the top constraint—and efficiency improvements that can improve affordability are, thus, a top opportunity—for driving the off-grid appliance market forward.

Off-grid appliance life-cycles should continue to be prolonged, both for financing and environmental purposes. Products bought with consumer financing must be operational and functioning at least for the duration of the appliance warranty and, ideally for the duration of the appliance loan, which is often three or more years in the case of higher cost appliances like refrigerators. Beyond the need for continued investments into the design of more durable products, appliance manufacturers and distributors also need to work on extending the effective life of appliances by improving their after-care service. Many are already trying to do this by training local technicians and using their remote monitoring services to directly address a problem's severity before dispatching a central resource. More advancements need to be made to bring accessible repairs to customers, and of course, to educate customers that a product should be repaired if it is broken. This is critical to building customer trust, ensuring value for money, and reducing the prevalence of e-waste in countries that are ill equipped to handle it.

The sector must attract increased investment into research that can benefit both AC and DC appliances and—critically—on appliances that are optimized for hybrid AC/DC environments. As the prevalence of weak-grid environments and mini-grid installations increases, as already noted earlier in this chapter, there needs to be research into how AC and DC appliances can best work together. Most of this work lies in understanding how appliance motors work, and if or how they can be modified through a rectifier or inverter without losing energy. There is an opportunity for more direct research into these technologies, and how the market will evolve with two distinct types of power source. This will become even more important as laptops and smartphones, both DC powered appliances, increasingly penetrate off-grid environments.

Donors can support technological advancements through direct program support as well as industry coordination. The role of donors in supporting technological advancement is a key one that has historically often been neglected. This has started to change, but further R&D investment is still required. Important models that require support and emulation include, most immediately, the LEIA Programme, which has a strong focus on off-grid appliance technology innovation support, including mechanisms such as R&D grants for entrepreneurs, technology innovation partnerships with global technology players and academia, as well as targeted technology challenges which build on the earlier Global LEAP Awards approach. Other initiatives worth noting are Shell Foundation's support for the Shenzhen Innovation

292. Field testing is, of course, already being done by some appliance manufacturers as part of their product development cycles, but many such players are poorly positioned to conduct such research at scale across a wide variety of geographies, an areas where donors and donor-funded programs like LEIA could help.

Laboratory, and other North-South and South-South technology transfer and incubation/acceleration programs that are increasingly embedded in the work of donors like the World Bank.[293] Initiatives such as the MECS Program are key to bringing together academics and industry to move a new technology forward. Another important development in this area is the launch of the Access to Energy Institute (A2EI),[294] which is relying on initial funding from the IKEA Foundation and other donors to establish a pre-competitive R&D and innovation platform with a focus on off-grid appliance design, testing, and market research. A2EI has in-house engineering and R&D capacity that complements the appliance sector facilitation efforts of multi-donor platforms like the Efficiency for Access Coalition.

PRIVATE SECTOR PARTNERSHIPS

Conventional appliance players should enter the off-grid efficient market, potentially through public-private partnerships.

Conventional appliance players need to be made aware of the potential USD 12.6 billion market in off- and weak-grid appliance sales, and the potential for this market to grow quickly. Donors and other off-grid sector intermediaries should build multinational company and investor awareness of the large financial opportunity in appliances and provide targeted market entry support. The potential of multi-national actors to bring incremental R&D resources and manufacturing to scale could be transformative for the industry. This includes long-established, globally branded appliance and electronics players, as well as large scale generic appliance manufacturers in Asia, most notably China. The entrance of such multi-national corporations into the market could precipitate a step change in technology developments, and significantly lower prices in the off-grid market, increasing the competitiveness of the industry. These changes could be transformational in the market, particularly as large appliance manufacturers are already starting to focus on the opportunity. For instance, companies like Samsung and LG have already been working on specialized weak-grid TVs and refrigerators which incorporate features like internal surge protection and back-up batteries. Furthermore, via engagement with larger appliance manufacturers, energy efficiency advancements made in off-grid appropriate appliances could also be retrofitted to on-grid appliances already being distributed by large corporations at scale throughout the developing world, helping support a move to reduced fossil fuel emissions globally.

While some multi-national companies and commercial investors are beginning to see the potential—in particular, the USD 10 billion television opportunity—donors and governments could play a decisive role to encourage this by providing more support for private sector actors to enter the off-grid appliance market. Potential levers of support relevant for large corporations and commercial investors include: developing market intelligence and business cases to highlight the economic opportunity, which can help regional executives and product development staff win internal arguments about resource allocation and customer prioritization; targeted advocacy and recognition (e.g., off-grid impact awards) for those private sector actors that are interested in garnering recognition for their SDG contributions; and—critically—improvements in the enabling environment, including streamlined certification and importation procedures and beneficial tax and tariff regimes (e.g., tax holidays, tariff/VAT reduction) for high priority appliances that advance government priorities.

Industry and donors need to broker partnerships by creating a platform for dialogue or business-to-business linkages. These partnerships, particularly with larger conventional appliance players, could be transformative for the off-grid appliance industry. Given the larger global players' lack of distribution networks, smaller regional or local distributors could partner to distribute their products. This is already being done by Lorentz with SWPs in East Africa, for instance, and niche appliance specialists such as Phocos, Steca and SunDanzer have similar models of global innovation combined with local distribution partnerships. Sector intermediaries can help support the formation of such partnerships through innovative financing mechanisms (e.g., challenges and RBF programs that explicitly conditionalize support on partnership formation) and through business development services for priority off-grid markets.

293. See, for instance, the World Bank's work on setting up local incubators/accelerators with a focus on disruptive agricultural technologies, including those at the off-grid energy agriculture nexus. See Umali-Deininger, D. & Kim, J., "Disruptive Agriculture Technology Moonshot—Ready for Lift Off in Sub-Saharan Africa?", 2019, https://blogs.worldbank.org/africacan/disruptive-agriculture-technology-moonshot-ready-lift-sub-saharan-africa. The forthcoming World Bank/IFC PULSE program on productive energy use appliances will also have a focus on technology innovation and technology transfer. See https://www.lightingglobal.org/pulse/.

294. See more information at https://a2ei.org/.

The role of Efficiency for Access in moving the off-grid appliance sector forward

The Efficiency for Access Coalition aims to close the access gap by scaling up and bringing together a range of programs to accelerate energy efficiency in off- and weak-grid appropriate appliances, including consumer and market development, R&D, product testing, policy support, and impacts research. Together, these actions drive markets for super-efficient technologies, support innovation, improve sector coordination, and contribute to the attainment of the United Nations' Sustainable Development Goals.

This report has provided a refreshed and expanded fact base to support industry actors, funders, policymakers, and other stakeholders in making better decisions about how and where they engage with the off-grid appliance opportunity. As the evidence has demonstrated, the growth of the off-grid efficient appliance market is critical to increasing overall energy access levels, and it has significant potential to scale transformative impact for the attainment of the Sustainable Development Goals. The market, which is already approaching significant scale in some product segments, is developing quickly, and will continue to do so rapidly in the next few years. At the same time, many barriers remain and significant levels of intervention are needed to unlock faster growth and achieve impact.

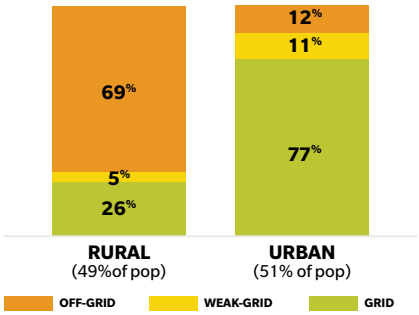
True success and scale for the off-grid appliance sector will require incremental research, knowledge sharing, and sector coordination. These, among others, are the major objectives of the Coalition and its implementing partners. In line with these objectives, this report is part of a wide repository of appliance research available at www.efficiencyforaccess.org.

CÔTE D'IVOIRE APPLIANCE MARKET SNAPSHOT

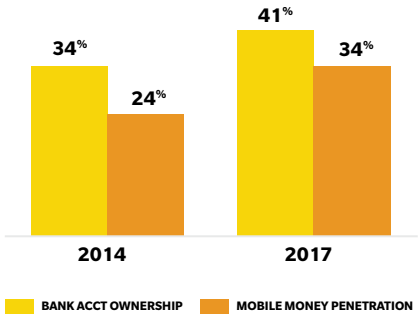
Côte d'Ivoire is a promising market for off-grid appliances. It features a relatively large off-grid population, rising income levels, and increasing mobile money penetration which is enabling the growth of PAYGO models. Numerous off-grid solar firms are prioritizing the market, and this is driving a sharp uptake in bundled appliance sales.

Key Statistics

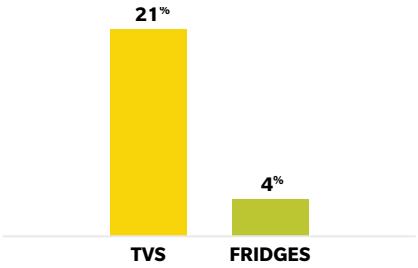
Grid, weak-grid, and off-grid connections in rural and urban areas (%, 2017)[1]



Bank account ownership and mobile money penetration (%)[2]



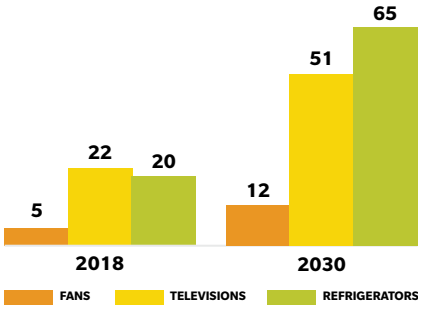
Share of rural population who own household appliances (%, 2011-2012)[3]



Fan ownership data is not available. Industry players report a very small market for fans.

Market Dynamics

Current (2018) and future (2030) obtainable market size (Millions of USD)[4]



Overview of off-grid products currently available in the market[5]

	LEVEL OF DEMAND	TYPICAL PRODUCT RANGE	PRICE (USD)	MARKET DYNAMICS
	Medium	356-406mm	15-50	The market is relatively nascent. A number of partnership approaches are being developed, especially in using MFIs for consumer financing and distribution.
	Very high	24"-32"	200-400	
	Very low	50-250L	200-1,300	

The off-grid appliance market is relatively young in Côte d'Ivoire, but the broader off-grid solar sector is growing rapidly and driving appliance uptake. Several international PAYGO solar companies have entered the market and are selling bundled solar home appliances. These include Baobab+, Zola Electric, Fenix International, Lumos, and PEG Africa. The competitive environment is driving down retail prices and forcing firms to differentiate their product offerings by providing high quality customer service. Consumers are reported to have high demand for televisions and radios, while fans are also in demand given the hot and humid climate.

Enabling Environment

Consumer financing: Traditionally, there has been limited access to credit for off-grid households in Côte d'Ivoire. The MFI sector does not have extensive reach into rural areas and most customers of off-grid appliances have never before taken credit. Over the past few years, off-grid solar firms have started to offer PAYGO financing for bundled appliances, either providing it themselves or in partnership with MFIs, rapidly expanding access to finance for off-grid appliances.

Policy: Côte d'Ivoire has seen a significant expansion of rural electrification, now at 38%, driven by the National Program for Rural Electrification (PRONER). This opens up the market for off-grid appropriate appliances. However, there is a relatively unfavorable tax environment for standalone solar and off-grid appliances which, despite a reduction from 18% VAT, are still subject to 9% VAT and 20-25% import duty. This raises the end cost to consumers and is cited as a major constraint to uptake. There is also some uncertainty over which off-grid appliances are eligible for the VAT reduction. Additionally, a policy under discussion seeks to restrict geographical distribution of standalone systems by suppliers in a bid to push them to address needs in underserved regions, this threatens to make the market less attractive.

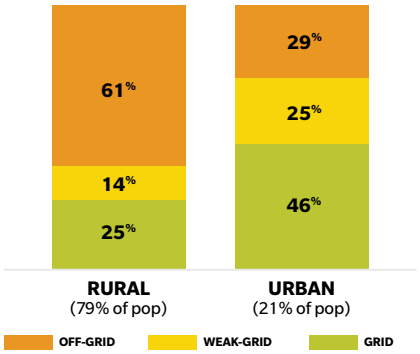
1. International Energy Agency, 2018, World Energy Outlook; Afrobarometer, 2017, Electrification rate; World Bank DataBank, 2018; On-grid refers to reliable connectivity; 2. World Bank Global Findex database, 2018; Bank account ownership refers to ownership of an account in a bank or any other relevant financial institution; 3. Data for TVs and Fridges is from the Côte d'Ivoire Demographic and Health Survey, 2011-2012; Anecdotally, fan ownership is reported to be very low. 4. Dalberg, Market sizing and analysis. 5 CLASP, 2019, Retail market surveys; Dalberg, 2019, Stakeholder interviews.

ETHIOPIA APPLIANCE MARKET SNAPSHOT

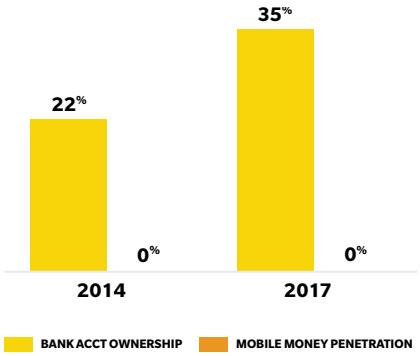
Despite a large off-grid population and national electrification efforts, Ethiopia's market for off-grid appliances has been restricted by a challenging regulatory environment, limiting uptake of both standalone solar systems and appliances.

Key Statistics

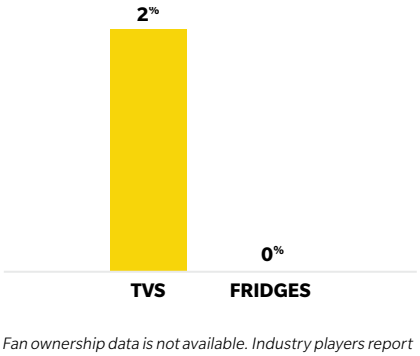
Grid, weak-grid and off-grid connection in rural and urban areas (%, 2017)[1]



Bank account ownership and mobile money penetration (%)[2]



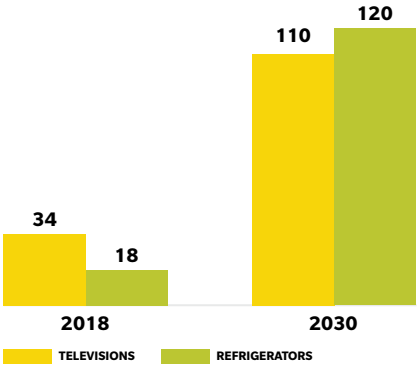
Share of rural population who own household appliances (%, 2016)[3]



Fan ownership data is not available. Industry players report a very small market for fans.

Market Dynamics

Current (2018) and future (2030) obtainable market size in (Millions of USD)[4]



Overview of off-grid products currently available in the market[5]

	LEVEL OF DEMAND	TYPICAL PRODUCT RANGE	PRICE (USD)	MARKET DYNAMICS
	Very Low	— —	— —	Distributors struggle to enter the Ethiopian market—despite its size and potential—due to the challenging regulatory and currency environment.
	Low	22"-24"	200-400	
	Very low	50-100L	700-900	

Local and small importers and wholesalers dominate the market, while international players hesitate to enter because foreign exchange controls prevent them from moving local currency out of Ethiopia. The high cost of appliances, the result of import taxes and foreign exchange restrictions, limits their sales. Purchases of cheaper lighting products such as lanterns are more common.

Enabling Environment

Consumer financing: The Ethiopian mobile money landscape is at a transition point, with Ethiotelecom, the national telecommunications company, in the process of exploring a variety of mobile money options. Unlocking this potential will increase consumers' ability to purchase off-grid appliances, especially as bank account ownership rates remain low.

Policy: The Government of Ethiopia is undertaking an ambitious National Electrification Program targeting universal access to electricity services by 2025. Off-grid services is one of the three core pillars of the program. To enable expansion of off-grid solutions, the Development Bank of Ethiopia has partnered with the World Bank's International Development Association (IDA) to provide USD 40 million in working capital loans to businesses providing household scale solar solutions. However, the Ethiopia market remains less attractive to international off-grid investors because of currency exchange controls and high import duties. Together, these restrictions drive up product prices but are yielding early investments in local manufacturing, with Fosera pioneering a local assembly plant.

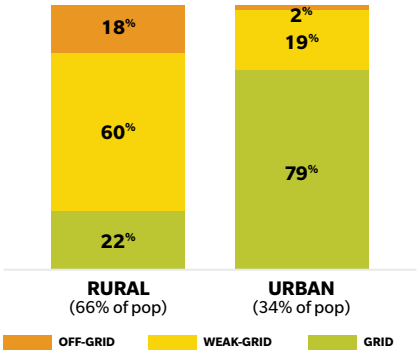
1. International Energy Agency, 2018, World Energy Outlook; World Bank DataBank, 2018; Dalberg estimates of bad-grid population size; On-grid refers to reliable connectivity; 2. World Bank Global Findex database, 2018; Bank account ownership refers to ownership of an account in a bank or any other relevant financial institution; 3. Data for TVs and Fridges is from the Ethiopia Demographic and Health Survey, 2016; Anecdotally, fan ownership is reported to be 0%. 4. Dalberg, Market sizing and analysis. 5 CLASP, 2019, Retail market surveys; Dalberg, 2019, Stakeholder interviews.

INDIA APPLIANCE MARKET SNAPSHOT

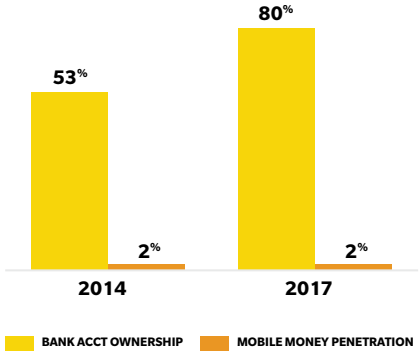
India is the largest potential off-grid appliance market due to its large population and high weak- and off-grid prevalence. Ownership of household appliances is already relatively high—a unique feature distinguishing India from other developing countries. India's connection status is improving rapidly but the grid remains weak in many areas, and demand for more efficient, off-grid appliances is expected to be material in the next five years in off- and weak-grid areas.

Key Statistics

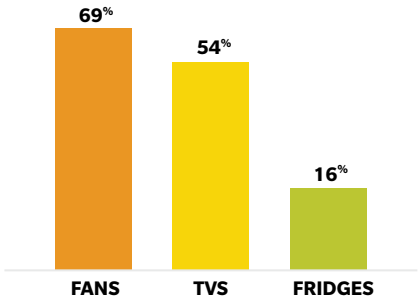
Grid, weak-grid, and off-grid connections in rural and urban areas (%, 2017)[1]



Bank account ownership and mobile money penetration (%)[2]

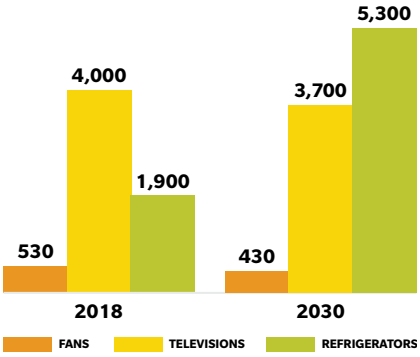


Share of rural population who own household appliances (%, 2015-2016)[3]



Market Dynamics

Current (2018) and future (2030) obtainable market size in (Millions of USD)[4]



Overview of off-grid products currently available in the market[5]

	LEVEL OF DEMAND	TYPICAL PRODUCT RANGE	PRICE (USD)	MARKET DYNAMICS
	Very high	305-406 mm	9-40	The market is primarily served by domestic or generic manufacturers and distributors. It is competitive with many actors and price pressure. Demand for off-grid appliances is likely to remain material in the short-term (3-5 years) despite rapidly improving grid coverage.
	High	21"-32"	200-360	
	High	200-250L	525-825	

Local distributors and retailers drive distribution of off-grid appliances in India. These players partner with microfinance institutions to tap into their customer bases and offer financing. India already has a relatively high penetration of household appliances. Demand for off-grid appliances is expected to remain sizeable over the next 3-5 years, with households in weak-grid areas driving demand. Appliances that can work on both solar and grid-based electricity will be especially desirable because they are suited to the needs of these weak-grid customers. Fans remain India's most demanded appliances due to the hot and humid climate, while televisions are the next most popular product.

Enabling Environment

Consumer financing: Traditional PAYGO financing is not available due to low mobile money account penetration. However, mobile banking infrastructure is very strong (via Unified Payments Interface – UPI). The microfinance sector is well developed and has become the primary provider of off-grid appliance financing to consumers.

Policy: The government has instituted tax concession rates (5% Goods and Services Tax) for locally manufactured appliances such as solar TVs, fans and refrigerators to boost the solar manufacturing industry.

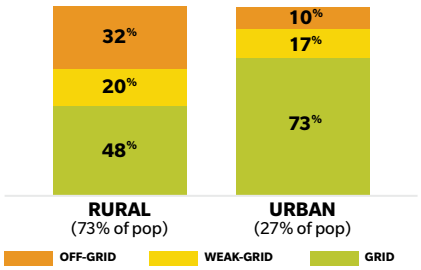
1. International Energy Agency, 2018, World Energy Outlook; World Bank DataBank, 2018; On-grid refers to reliable connectivity; 2. World Bank Global Findex database, 2018; Bank account ownership refers to ownership of an account in a bank or any other relevant financial institution; 3. India Demographic and Health Survey, 2015-2016; 4. Dalberg, Market sizing and analysis; 5 CLASP, 2019, Retail market surveys; Dalberg, 2019, Stakeholder interviews.

KENYA APPLIANCE MARKET SNAPSHOT

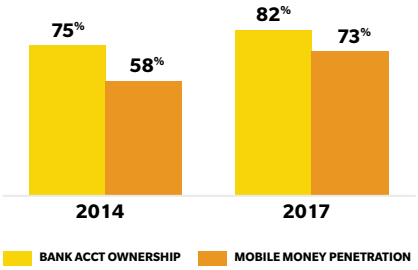
Kenya is the leading market for off-grid appliances in sub-Saharan Africa as a result of its mature solar industry, high mobile money penetration, and fast-growing consumer segment.

Key Statistics

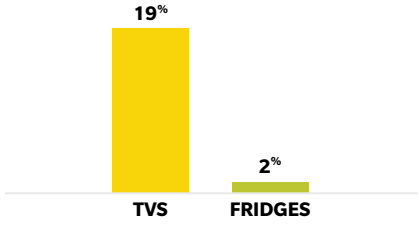
Grid, weak-grid, and off-grid connections in rural and urban areas (%, 2017)[1]



Bank account ownership and mobile money penetration (%)[2]



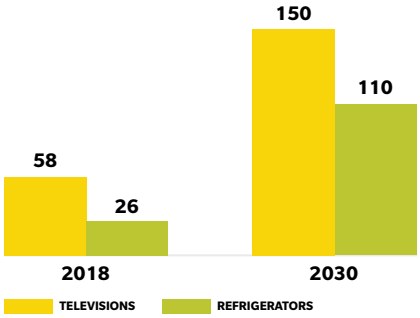
Share of rural population who own household appliances (%, 2015)[3]



Fan ownership data is not available. Industry players report a very small market for fans.

Market Dynamics

Current (2018) and future (2030) obtainable market size in (Millions of USD)[4]



Overview of off-grid products currently available in the market[5]

	LEVEL OF DEMAND	TYPICAL PRODUCT RANGE	PRICE (USD)	MARKET DYNAMICS
	Very low	— —	— —	Established SHS players are accelerating the distribution and uptake of televisions; refrigerators are now starting to find a market as prices decline; fans are not as in demand.
	Very high	24"-32"	200-450	
	Low	35-112L	500-800	

The Kenyan off-grid appliances market is sizable and growing rapidly on the back of the country's existing solar customer base and footprint. Vertically-integrated off-grid solar firms, for whom Kenya is a key market, are upgrading their customers to larger systems and bundling them with appliances. Many generic DC and AC products are being imported from Asia, and though these products do not come with financing solutions, they are driving competition in the market. Televisions are in high demand and partnerships with content providers such as Zuku have further driven uptake. Early market testing of refrigerators indicates that there is significant demand and an off-grid customer base who can afford such products. Interest in fans is low due to the climate and consumer preferences.

Enabling Environment

Consumer financing: The mobile money ecosystem is relatively mature and features high penetration, making Kenya the leading market for PAYGO financing models in sub-Saharan Africa. This continues to make solar home systems and appliances affordable to many customers for whom the upfront cost would otherwise be prohibitive. Today, over 40% of verified sales of off-grid appliances in Kenya are sold using PAYGO. Local banks and MFIs have also started to develop loan products targeting solar products, and there are several working capital facilities expanding access to finance for distributors.

Policy: The Government of Kenya has implemented largely favorable policies for the off-grid energy sector. The national electrification strategy recognizes the important role which standalone solar and mini-grids will play in expanding access to energy for all Kenyans. There are numerous government-sponsored initiatives such as the Kenya Off-Grid Solar Access Project for Underserved Counties (KOSAP) which seeks to use smart subsidies to expand uptake of solar products in undeserved counties. The tax regime has overall been conducive to sector growth, with full VAT and import duty exemptions for off-grid appliances. However, the tax regime has been inconsistently applied by the authorities, so the benefits have not always been realized by industry.

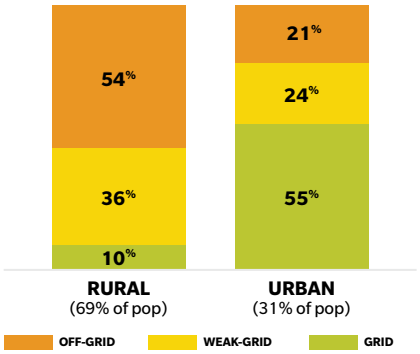
1. International Energy Agency, 2018, World Energy Outlook; Afrobarometer, 2017, Electrification rate; World Bank DataBank, 2018; On-grid refers to reliable connectivity; 2. World Bank Global Findex database, 2018; Bank account ownership refers to ownership of an account in a bank or any other relevant financial institution; 3. Kenya Demographic and Health Survey, 2015; 4. Dalberg, Market sizing and analysis; 5 CLASP, 2019, Retail market surveys; Dalberg, 2019, Stakeholder interviews.

MYANMAR APPLIANCE MARKET SNAPSHOT

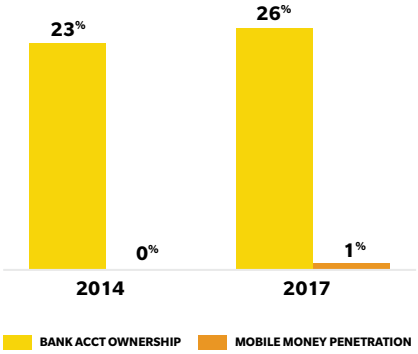
Myanmar represents a considerable appliances market. A national electrification initiative has prioritized the off-grid energy sector with a specific focus on appliances. The plan targets the distribution and sale of 800,000 quality-verified off-grid products, including appliances, for solar home systems and solar mini-grids by 2022.

Key Statistics

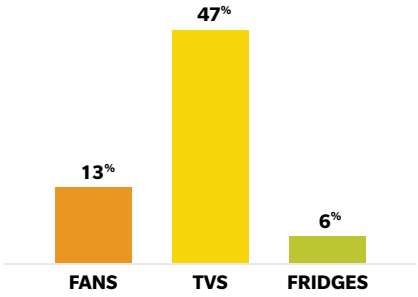
Grid, weak-grid, and off-grid connections in rural and urban areas (%, 2017)[1]



Bank account ownership and mobile money penetration (%)[2]

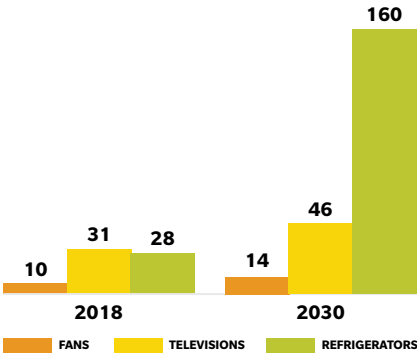


Share of rural population who own household appliances (%, 2015-2016)[3]



Market Dynamics

Current (2018) and future (2030) obtainable market size in (Millions of USD)[4]



Overview of off-grid products currently available in the market[5]

	LEVEL OF DEMAND	TYPICAL PRODUCT RANGE	PRICE (USD)	MARKET DYNAMICS
	Very high	305-406 mm	9-40	Interest from larger brands is growing but trust in the industry is impeded by the influx of poor quality generic off-grid appliances.
	High	21"-32"	200-360	
	High	200-250L	525-825	

While local distributors dominate Myanmar's off-grid appliances market today, established vertically integrated businesses are showing increasing interest. TVs already represent a sizeable segment, with many cheap generic products available today. Refrigerators are high on households' wish lists, though affordability remains a constraint. Given the low penetration, persistently large base of off-grid and weak grid customers, increasing incomes, and strong mobile phone coverage, sales of off-grid refrigerators are likely to grow rapidly.

Enabling Environment

Consumer financing: Historically most purchases have been in cash or for cheaper off-grid appliances like mobile chargers and lights. Micro-finance institutions in partnership with local distributors are starting to avail financing solutions to consumers.

Policy: Absence of government regulation on quality control has led to an influx of cheap, low quality solar appliances in the market, although this is expected to change given the focus on quality-verified products in the national electrification plan and the partnership with Lighting Global.

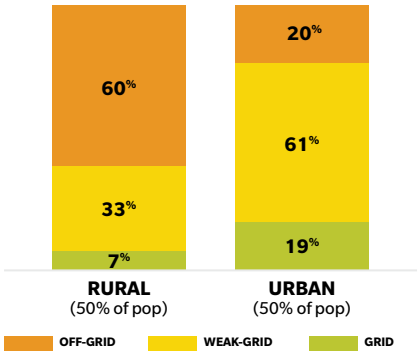
1. International Energy Agency, 2018, World Energy Outlook; World Bank DataBank, 2018; Dalberg estimates of bad-grid population size; On-grid refers to reliable connectivity; 2. World Bank Global Findex database, 2018; Bank account ownership refers to ownership of an account in a bank or any other relevant financial institution; 3. Myanmar Demographic and Health Survey, 2015-2016; 4. Dalberg, Market sizing and analysis; 5 CLASP, 2019, Retail market surveys; Dalberg, 2019, Stakeholder interviews; Product specifications listed here are for India due to data limitations.

NIGERIA APPLIANCE MARKET SNAPSHOT

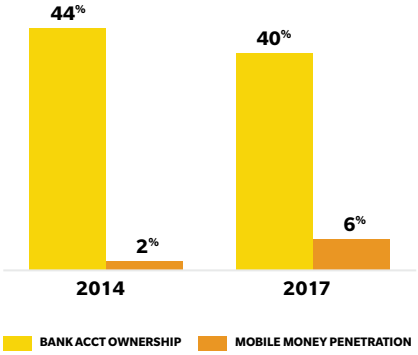
Nigeria represents a vast potential market for off-grid appliances. Many customers have traditionally relied on diesel generator powered appliances and are starting to see off-grid appliances as cost-effective alternatives. However, affordability remains a major challenge.

Key Statistics

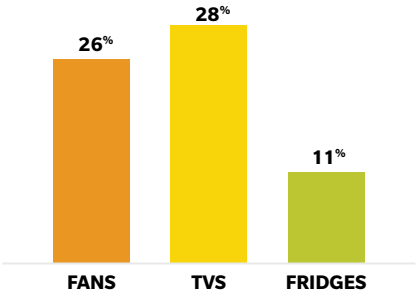
Grid, weak-grid, and off-grid connections in rural and urban areas (%, 2017)[1]



Bank account ownership and mobile money penetration (%)[2]

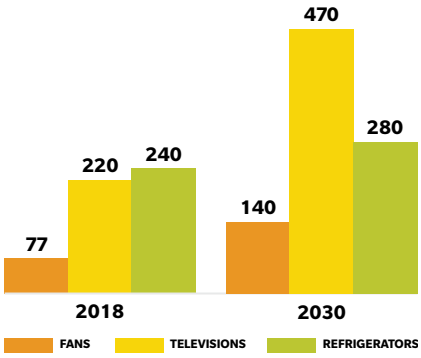


Share of rural population who own household appliances (%, 2015)[3]



Market Dynamics

Current (2018) and future (2030) obtainable market size in (Millions of USD)[4]



Overview of off-grid products currently available in the market[5]

	LEVEL OF DEMAND	TYPICAL PRODUCT RANGE	PRICE (USD)	MARKET DYNAMICS
	Medium	406-600mm	30-45	Distributors are focusing on peri-urban and urban customers whose alternative solutions are powering traditional, inefficient appliances with a generator.
	High	24"-32"	200-400	
	Low	42-250L	250-1,000	

There are many new local businesses looking to serve Nigeria's off-grid appliance market; however, most are importing generic off-grid appliances. Nigeria represents one of the largest bases of urban and peri-urban customers who have supplemented weak-grid access by using costly yet reliable energy from diesel generators. This provides a unique sub-section of customers who could switch to solar home systems and off-grid appropriate appliances.

Enabling Environment

Consumer financing: Consumers predominantly make upfront cash purchases, yet financing solutions such as micro-credit facilities are growing in penetration. Uptake of mobile based PAYGO and other forms of financing is limited by low financial inclusion in Nigeria, especially lower mobile money penetration and declining bank account ownership rates.

Policy: Government bodies responsible for driving uptake of renewable energy in Nigeria include the Solar Department in the Office of the Vice President; the Renewable Energy Association of Nigeria (REAN); the Rural Electrification Agency, which is partnering with the World Bank Group to accelerate investment in mini grids; and the Nigerian Bank of Industry, which administers a dedicated fund for mini-grid expansion. Nigeria has a challenging tax regime for weak and off-grid appliances with solar home systems and their appliances subject to 5% VAT and 5-20% import duty.

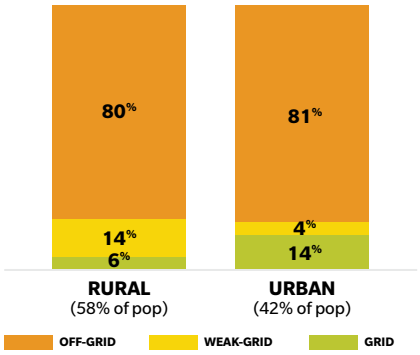
1. International Energy Agency, 2018, World Energy Outlook; Afrobarometer, 2017, Electrification rate; World Bank DataBank, 2018; On-grid refers to reliable connectivity; 2. World Bank Global Findex database, 2018; Bank account ownership refers to ownership of an account in a bank or any other relevant financial institution; 3. Nigeria Demographic and Health Survey, 2015; 4. Dalberg, Market sizing and analysis; 5 CLASP, 2019, Retail market surveys; Dalberg, 2019, Stakeholder interviews.

SIERRA LEONE APPLIANCE MARKET SNAPSHOT

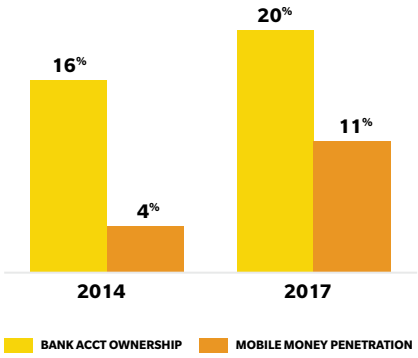
Sierra Leone is a small market with low electrification and relatively low income per capita. While Sierra Leone remains a nascent market for off-grid appliances, recently introduced tax concessions, as well as targeted donor support, have helped incentivize international distributors to enter the market and accelerate growth in the sector.

Key Statistics

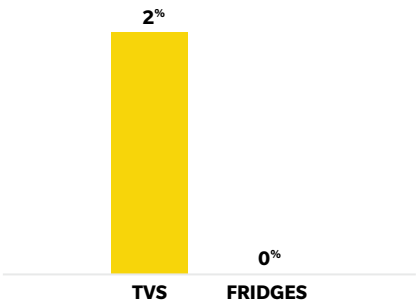
Grid, weak-grid, and off-grid connections in rural and urban areas (%, 2017)[1]



Bank account ownership and mobile money penetration (%)[2]



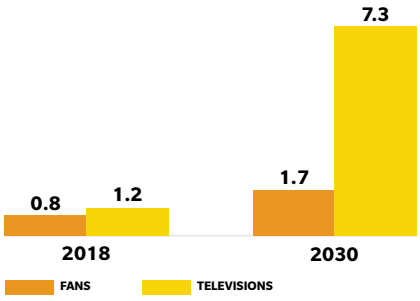
Share of rural population who own household appliances (%, 2013)[3]



Fan ownership data is not available. Industry players report a very small market for fans.

Market Dynamics

Current (2018) and future (2030) obtainable market size in (Millions of USD)[4]



Estimated sales and market size for off-grid refrigerators are negligible given price point and income levels.

Overview of off-grid products currently available in the market[5]

	LEVEL OF DEMAND	TYPICAL PRODUCT RANGE	PRICE (USD)	MARKET DYNAMICS
	Medium	356-406mm	15-50	The market for off-grid appliance is nascent and dominated by generic off-grid appliances.
	High	24"-32"	200-400	
	Low	50-250L	200-1,300	

Uptake of off-grid appliances in Sierra Leone is low. Today, the market is dominated by distributors selling generic, low quality products. Donor-supported initiatives such as the DFID-backed Africa-Energy Compact are helping to drive demand and are moving the market from pico solar to larger solar home systems and mini-grids. These shifts are starting to increase demand for appliances such as TVs and fans. More recently, some larger vertically-integrated off-grid solar firms have entered Sierra Leone, but they are not yet investing in extensive distribution due to the nascency of the market.

Enabling Environment

Consumer financing: Purchasing power among off-grid households remains low, and limited access to finance is constraining growth. The low mobile money penetration rate, currently estimated at below 15%, limits the potential for PAYGO models. Companies such as Easy Solar are testing other mechanisms to extend credit and facilitate incremental payments for customers of solar products.

Policy: The Government of Sierra Leone has prioritized off-grid solar—both standalone and mini-grids—as important to national electrification plans. Recently, it has introduced a zero-rating for both goods and services sales tax and import duties to incentivize sales of off-grid appliances. However, firms report that this exemption does not apply to all solar-powered DC appliances, and implementation by custom officials is inconsistent.

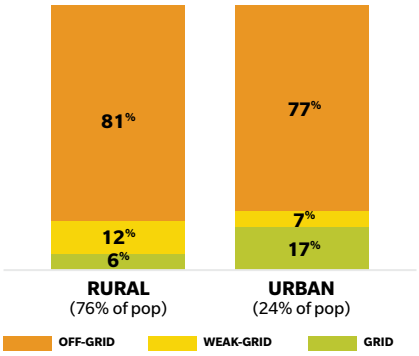
1. International Energy Agency, 2018, World Energy Outlook; Afrobarometer, 2017, Electrification rate; World Bank DataBank, 2018; On-grid refers to reliable connectivity; 2. World Bank Global Findex database, 2018; Bank account ownership refers to ownership of an account in a bank or any other relevant financial institution; 3. Data for TVs and Fridges is from Sierra Leone Demographic and Health Survey, 2013; Anecdotally, fan ownership is reported to be 0%.; 4. Dalberg, Market sizing and analysis; 5 CLASP, 2019, Retail market surveys; Dalberg, 2019, Stakeholder interviews.

UGANDA APPLIANCE MARKET SNAPSHOT

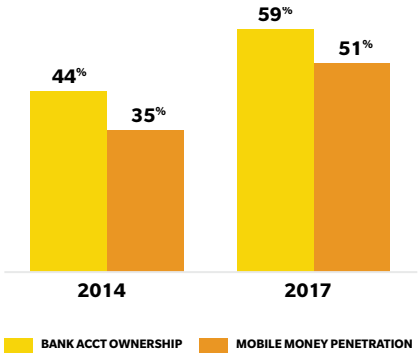
Uganda is a high potential off-grid appliance market with a large off- and weak-grid population. It has seen a sharp increase in mobile money operations and solar home system sales—and both of these trends are providing a foundation for appliance sales.

Key Statistics

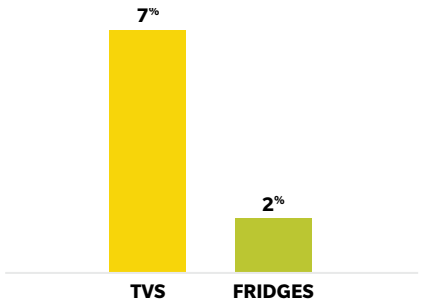
Grid, weak-grid, and off-grid connections in rural and urban areas (%, 2017)[1]



Bank account ownership and mobile money penetration (%)[2]



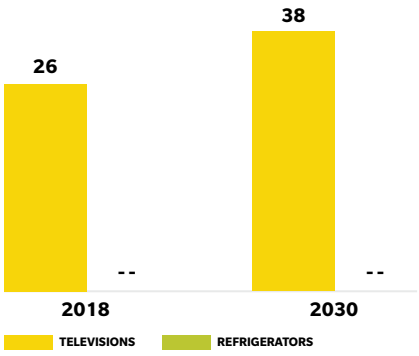
Share of rural population who own household appliances (%, 2016)[3]



Fan ownership data is not available. Industry players report a very small market for fans.

Market Dynamics

Current (2018) and future (2030) obtainable market size in (Millions of USD)[4]



Overview of off-grid products currently available in the market[5]

	LEVEL OF DEMAND	TYPICAL PRODUCT RANGE	PRICE (USD)	MARKET DYNAMICS
	Very low	— —	— —	Distributors plan to roll out larger screen TVs (up to 42") to meet demand for bigger systems. For refrigerators, high prices limit the market, though anecdotal evidence suggests demand is growing.
	Very high	22"-24"	200-350	
	Low	50-100L	700-900	

Both vertically integrated businesses and third party distributors compete in Uganda. The market has seen a recent uptick in demand unlocked by PAYGO providers such as Fenix and Mkopa. Radios and TVs continue to represent the highest sales, with most major companies concentrating on selling these products, especially in peri-urban areas. Demand for refrigerators is growing off a low base, but it remains limited by high price points relative to consumer incomes. Distributors indicate that there is very little demand for fans.

Enabling Environment

Consumer financing: Though affordability continues to constrain the market, the prevalence of mobile money is enabling PAYGO financing models and driving sales. PAYGO options are making it possible for consumers to shift from pico solutions to appliances with reduced upfront energy costs.

Policy: The Government of Uganda is increasingly recognizing the need for off-grid energy to drive rural electrification. Recent government supported initiatives, such as the Uganda off-grid energy market accelerator, have led to growth in the off-grid sector. However, the tax environment for solar home systems is unfavorable, with appliances subjected to 25% import duty, 18% VAT and 6% withdrawal tax. In addition, though recently introduced mobile money charges no longer impact PAYGO consumers, they have led to negative perceptions about the cost of using mobile money.[6]

1. International Energy Agency, 2018, World Energy Outlook; Afrobarometer, 2017, Electrification rate; World Bank DataBank, 2018; On-grid refers to reliable connectivity; 2. World BankGlobal Findex database 2018; Bank account ownership refers to ownership of an account in a bank or any other relevant financial institution; 3. Data for TVs and Fridges is from Uganda Demographic and Health Survey, 2016; Anecdotally, fan ownership is reported to be 0%. 4. Dalberg, Market sizing and analysis; Refrigerator and fan market sizing is not reflected here because data shows a very low base; Data is from 2016, and anecdotal evidence suggests that the refrigerator market has grown since; 5. CLASP, 2019, Retail market surveys; Dalberg, 2019, Stakeholder interviews. 6. Energy Ladder Research, Phase II, SERC.

BIBLIOGRAPHY

Abagi. N., et al. *State of Play and Innovations in Off-grid Refrigeration Technology: Lessons Learned from Current Initiatives. Energy Efficiency,* 2019, https://efficiencyforaccess.org/publications/state-of-play-and-innovations-in-off-grid-refrigeration-technology-lessons-learned-from-current-initiatives.

Access to Energy Institute (A2EI), *The Desirability of Clean Cooking in Off-Grid Households,* A2EI, 2019, https://a2ei.org/resources/uploads/2019/06/A2EI_The_Desirability_of_Clean-Cooking_in_Off_Grid_Households.pdf.

Akanksha, S. *Going Greenfield with Utility Pay-as-you-go Models: enabling access to water, sanitation, and energy in and beyond East Africa,* GSMA, 2017.

Attia, B., and Shirley, R. "Living Under the Grid", GreenTechMedia, 2017, https://www.greentechmedia.com/articles/read/living-under-the-grid-110-million-of-africas-unconnected-customers-represen.

Avila, E., et al. *The Desirability of Clean Cooking in Off-Grid Households.* Access to Energy Institute, 2019, https://a2ei.org/resources/uploads/2019/06/A2EI_The_Desirability_of_Clean-Cooking_in_Off_Grid_Households.pdf.

Batteiger, A. and Rotter, V. "Material Implications of Rural Electrification—A Methodological Framework to Assess In-Use Stocks of Off-Grid Solar Products and EEE in Rural Households in Bangladesh." Recycling, 2018, https://www.mdpi.com/2313-4321/3/1/7/pdf.

Booth, S., et al. *Productive use of energy in African micro-grids,* NREL, 2018, https://www.nrel.gov/docs/fy18osti/71663.pdf.

CLASP, *Off-grid Refrigeration Technology Roadmap,* Efficiency for Access Coalition, 2019, https://storage.googleapis.com/e4a-website-assets/Refrigeration-Roadmap_FINAL.pdf.

CLASP. *Appliance Data Trends,* Efficiency for Access Coalition. 2018, https://efficiencyforaccess.org/publications/appliance-data-trends.

CLASP. *Global LEAP Solar TV RBF: Baseline in East Africa,* Lean Data. Energy for Access Coalition, 2018 (forthcoming)

CLASP, *Off-Grid Appliance Market Survey: Perceived Demand and Impact Potential of Household, Productive Use and Healthcare Technologies,* Efficiency for Access Coalition, 2018, https://efficiencyforaccess.org/publications/off-grid-appliance-market-survey.

CLASP. *Buyer's Guide for Off-grid Fans and Televisions,* Global LEAP, 2017, https://clasp.ngo/publications/global-leap-awards-2017-buyers-guide-for-off-grid-fans-televisions.

CLASP. *Buyer's Guide for Outstanding Off-Grid Refrigerators,* Global LEAP, 2017, https://efficiencyforaccess.org/publications/global-leap-buyers-guide-refrigerators.

CLASP. *Low-Energy Inclusive Appliance Technologies Summaries,* Energy for Access Coalition, 2017, https://efficiencyforaccess.org/publications/low-energy-inclusive-appliance-technology-summaries.

CLASP and Dalberg Advisors, *Solar Water Pump Outlook 2019: Global Trends and Market Opportunities,* Efficiency for Access Coalition, 2019 (forthcoming, see EforA website at https://efficiencyforaccess.org/).

CLASP and Dalberg Advisors. *The State of the Off-grid Appliance Sector Report,* Global LEAP, 2016-2017, https://efficiencyforaccess.org/publications/the-state-of-the-global-off-grid-appliance-market-2017.

Clean Cooking Alliance (CCA). *Gender and Livelihoods Impacts of Clean Cookstoves on Women and Gender in South Asia,* 2015, https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/357-1.pdf.

Clean Cooking Alliance (CCA), Gender and Clean Cooking Factsheet, 2017, https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/352-1.pdf.

Cardoso, D., et al. *Fiscal Policy Analysis: An Assessment of the Tax and Subsidy Options to Accelerate Solar Home Systems in Uganda,* Uganda Off-grid Market Accelerator (UOMA), 2018, https://uoma.ug/wp-content/uploads/2019/03/Fiscal-policy-analysis-report.pdf.

Couture, T., and Jacobs, D. *Beyond Fire: How to Achieve Electric Cooking,* HIVOS, 2019, https://greeninclusiveenergy.org/publication/beyond-fire-how-to-achieve-electric-cooking/

CrossBoundary and Energy 4 Impact. *Innovation Insight: Appliance Financing,* 2019, https://www.crossboundary.com/wp-content/uploads/2019/08/CrossBoundary-Innovation-Lab-Innovation-Insight-Appliance-Financing-Final-07-Aug-2019-1.pdf.

Dubey, S. *A New Chapter for Sub-Saharan Africa's Mini Grids Industry,* World Bank, 2018, https://blogs.worldbank.org/nasikiliza/a-new-chapter-for-sub-saharan-africas-mini-grids-industry.

BIBLIOGRAPHY

Efficiency for Access Coalition. *Solar Water Pump Outlook 2019: Global Trends and Market Opportunities,* 2019. https://efficiencyforaccess.org/publications/solar-water-pump-outlook-2019-global-trends-and-market-opportunities.

Energypedia. "DC mini-grids", 2018, https://energypedia.info/wiki/DC_Mini-grids.

E-Waste Australia. "Televisions Go to Landfill as Digital TV Arrives in Australia." 2018, https://www.ewaste.com.au/ewaste-articles/televisions-landfill-digital-tv-australia/.

GIZ, *What size shall it be? A guide to mini-grid sizing and demand forecasting,* 2016, https://energypedia.info/images/0/0f/Mini-Grid_Sizing_Guidebook.pdf.

Global Off-grid Lighting Association (GOGLA), *Powering Opportunity: The Economic Impact of Off-Grid Solar,* GOGLA, 2018, https://www.gogla.org/sites/default/files/resource_docs/gogla_powering_opportunity_report.pdf.

Global Off-grid Lighting Association (GOGLA) and Vivideconomics. *Off-Grid Solar, A Growth Engine for Jobs Off-grid Solar: On the level, nature and wider impact of employment opportunities in the off-grid solar sector,* GOGLA, 2019, https://www.gogla.org/sites/default/files/resource_docs/gogla_off_grid_solar_a_growth_engine_for_jobs_web_opt.pdf.

Goyal, R. & Jacobson, A., *Energy Access and Off-grid Solar Use in Uganda,* Schatz Energy Research Center (SERC) and UNCDF, 2019, https://sun-connect-ea.org/wp-content/uploads/2019/02/clean_start_paper_20190214.pdf.

Green Mini-Grids (GMG), *Analysis of Barriers to Growth and the Potential Role of the African Development Bank in Supporting the Sector,* Green Mini-Grids Market Development Program, 2016, https://greenminigrid.se4all-africa.org/sites/default/files/GMG-MDP-Document-Series-N1.pdf.

Greenwood, J. et al. "Engines of Liberation", *Journal of Economic Studies,* 2016, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.820.3630&rep=rep1&type=pdf.

GSMA, State of the Industry Report on Mobile Money, GSMA, 2018, https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/02/2018-State-of-the-Industry-Report-on-Mobile-Money.pdf.

Gubbins, P. & Zollmann, J. *Beyond the price tag: The real benefits of off-grid solar,* FSK Kenya, 2016, https://fsdkenya.org/blog/beyond-the-pricetag-the-real-benefits-of-off-grid-solar-2/.

Hankin, E. *Buying Modernity? The Consumer Experience of Domestic Electricity in the Era of the Grid,* Manchester University, UK, University of Mancheseter (dissertation), 2012, https://www.research.manchester.ac.uk/portal/files/54530980/FULL_TEXT.PDF.

Harrison, K. and Adams, T. *An evidence review: How affordable is off-grid energy access in Africa?,* Acumen, 2016, https://acumen.org/wp-content/uploads/2017/07/Evidence-Review-On-Affordability.pdf.

Hossain Ovi, I. "LG, Butterfly set up first ever TV manufacturing facility in Mymensingh." *Dhaka Tribune,* March 2018, https://www.dhakatribune.com/business/2018/03/15/lg-butterfly-set-up-first-ever-tv-manufacturing-facility-in-mymensingh.

IIPS, India 2015-2016 *National Family Health Survey (NFHS-4),* Government of India, 2016, https://dhsprogram.com/pubs/pdf/FR339/FR339.pdf.

Jaeger, M. et al. "Perceptions on the effect of small electric fans on comfort inside bed nets in southern Ghana: a qualitative study." *Malaria Journal,* 2016, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5134074/.

Jensen, R. & Oster, E. "The Power of TV: Cable Television and Women's Status in India", T*he Quarterly Journal of Economics,* 2008, http://bit.ly/1V42jx5.

Knuckles, J. *State of the Mini-Grid Market Globally,* World Bank, 2019, https://atainsights.com/wp-content/uploads/2019/06/2.B.James_.Knuckles.World-Bank-notes.pdf.

Koo, B. et al. *Rwanda Beyond Connections: Energy Access Diagnostic Report Based on the Multi-Tier Framework,* World Bank Group, 2018, http://documents.worldbank.org/curated/en/406341533065364544/pdf/Rwanda-Beyond-connections-energy-access-diagnostic-report-based-on-the-multi-tier-framework.pdf.

Kopec, G., et al. *The future of direct current electrical systems for the off-grid environment,* Smart Villages, 2017, https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/TR8-The-future-of-direct-current-electrical-systems-for-the-off-grid-environment-web.pdf.

Lai, E. et al. *Off-grid appliance performance testing: results and trends for early-stage market development,* Efficiency for Access Coalition, 2019, https://efficiencyforaccess.org/publications/off-grid-appliance-performance-testing-results-and-trends-for-early-stage-market-development.

BIBLIOGRAPHY

Lee, K. et al. "Appliance ownership and aspirations among electric grid and home solar households in rural Kenya", *American Economic Review,* 2016, http://emiguel.econ.berkeley.edu/assets/miguel_research/75/Lee_Miguel_Wolfram_2016a.pdf.

Leo, B., et al. *What Can We Learn about Energy Access and Demand from Mobile-Phone Surveys? Nine Findings from Twelve African Countries,* CGDEV, 2018, https://www.cgdev.org/sites/default/files/what-can-we-learn-about-energy-access-and-demand-mobile-phone-surveys.pdf.

Limi, A. and Diehl, A. *A New Measure of Rural Access to Transport: Using GIS Data to Inform Decisions and Attainment of the SDGs,* World Bank, 2015, http://documents.worldbank.org/curated/en/767961468186548881/pdf/102767-BRI-Box394840B-PUBLIC-TransportICT-Newsletter-Note23-Oct-highres-00000002.pdf.

Magalini, F., et al. *Electronic waste (e-waste) impacts and mitigation options in the off-grid renewable energy sector,* DFID, 2016, https://assets.publishing.service.gov.uk/media/58482b3eed915d0b12000059/EoD_Report__20160825_E-Waste_Study_Final-31.08.16.pdf.

Matsumoto, S. "Household Income Structure and Electrical Appliance Ownership: Evidence from Japanese National Household Survey", *IJEEP,* 2016, https://www.econjournals.com/index.php/ijeep/article/view/1483/929.

McCall, M. & Santana, S. *Closing the Circuit: Stimulating End-Use Demand For Rural Electrification,* Rocky Mountain Institute (RMI), 2019, https://rmi.org/insight/closing-the-circuit/.

McKinsey Global Institute (MGI), *Digital Finance for All: Powering Inclusive Growth in Emerging Economies,* McKinsey, 2016, https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Employment%20and%20Growth/How%20digital%20finance%20could%20boost%20growth%20in%20emerging%20economies/MG-Digital-Finance-For-All-Full-report-September-2016.ashx.

MicroSave & World Wildlife Foundation (WWF) India. *Role of Finance with a Special Focus on Microfinance in Enhancing Clean Energy Access,* World Wildlife Foundation (WWF), 2015, https://d2391rlyg4hwoh.cloudfront.net/downloads/role_of_finance_in_enhancing_clean_energy_access.pdf.

Nahigyan. P. "Solar Power Will Bring Off-Grid Kenyans Satellite TV." Planet Experts, 2016, http://www.planetexperts.com/solar-power-will-bring-off-grid-kenyans-satellite-tv/.

National Renewable Energy Laboratory (NREL), *Tariff Considerations for Micro-Grids In Africa,* NREL and Power Africa, 2018, https://www.nrel.gov/docs/fy18osti/71663.pdf.

Odarno, L., et al. *Accelerating Mini-grid Deployment in Sub-Saharan Africa: Lessons from Tanzania,* WRI, 2017, https://www.wri.org/publication/tanzania-mini-grids.

Ohiare, S. "Expanding electricity access to all in Nigeria: a spatial planning and cost analysis," *Energy, Sustainability and Society,* 2015, https://link.springer.com/article/10.1186/s13705-015-0037-9.

Opiyo, N. "A comparison of DC- versus AC-based minigrids for cost-effective electrification of rural developing communities," *Energy Reports,* 2019, https://www.sciencedirect.com/science/article/pii/S2352484719300617.

Park, W.Y., et al. "Efficiency improvement opportunities in TVs: Implications for market transformation programs." *Energy Policy,* 2013, https://www.sciencedirect.com/science/article/pii/S0301421513002267.

Persistent Energy & Shell Foundation. *Bridging the Gap to Commercial Success for Energy Access Businesses,* Shell Foundation, 2018, https://persistent.energy/wp-content/uploads/2018/11/Bridging-the-Gap-to-Commercial-Success-for-Energy-Access-Businesses.pdf.

Power for All, "Powering Jobs Census 2019: The Energy Access Workforce", 2019. https://www.powerforall.org/resources/reports/powering-jobs-census-2019-energy-access-workforce.

Ravanelli, N. M. "Electric fan use in heat waves: Turn on or turn off?" *Temperature,* 3(3): 358–360, 2016, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5079223/.

Rewald, R. *Energy and Women and Girls: Analyzing the Needs, Uses, and Impacts of Energy on Women and Girls in the Developing World,* Research Backgrounder Series, Oxfam, 2017, https://www.oxfamamerica.org/static/media/files/energy-women-girls.pdf.

Sadouki, M. "The Land of Opportunity for Off-Grid Solar." Greentech Media, 2019, https://www.greentechmedia.com/articles/read/the-land-of-opportunity-for-off-grid-energy#gs.5hzjr6.

Sathaye, N. et al. *Potential Global Benefits of Improved Ceiling Fan Energy Efficiency,* Lawrence Berkeley National Laboratory, 2012, https://eta.lbl.gov/sites/all/files/publications/lbnl.5980e.pdf.

BIBLIOGRAPHY

Sotiriou, A. et al. "Strange Beasts: Making Sense of PAYGO Solar Business Models", CGAP, 2018, https://www.cgap.org/sites/default/files/publications/Forum-Strange-Beasts-Jan-2018.pdf.

Uganda Off-grid Market Accelerator (UOMA). *Mapping the Ugandan off-grid energy market,* Shell Foundation, 2018, https://shellfoundation.org/app/uploads/2018/10/2018-UOMA-Market-Map.pdf.

Umali-Deininger, D. and Kim, J., "Disruptive Agriculture Technology Moonshot—Ready for Lift Off in Sub-Saharan Africa?", 2019, https://blogs.worldbank.org/africacan/disruptive-agriculture-technology-moonshot-ready-lift-sub-saharan-africa.

Weber, E., et al. *RBF Financing for Energy Access – Lessons Learned,* Energising Development (EnDev) Programme, 2018, https://endev.info/images/e/e4/EnDev_-_Results-based_Financing_for_Energy_Access%2C_Lessons_report.pdf.

Wood Mackenzie. "Strategic Investments in Off-grid Energy Access: Scaling the Utility of the Future at the Last Mile", 2018, https://www.woodmac.com/news/editorial/growing-offgrid-energy-access-sector/.

World Bank Group, *Mini-Grids for Half a Billion People: Market Outlook and Handbook for Decision makers,* 2019, https://openknowledge.worldbank.org/bitstream/handle/10986/31926/Mini-Grids-for-Half-a-Billion-People-Market-Outlook-and-Handbook-for-Decision-Makers-Executive-Summary.pdf?sequence=1&isAllowed=y.

World Bank & Dalberg Advisors. *Off-grid Solar Market Trends Report,* World Bank Lighting Global Program, 2018, https://www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report/.

World Bank & Dalberg Advisors. *The State of the Global Clean and Improved Cooking Sector,* 2015, https://openknowledge.worldbank.org/bitstream/handle/10986/21878/96499.pdf.

World Bank & Dalberg Advisors. *Productive Use Leveraging Solar Energy (PULSE),* World Bank Lighting Global Program, 2019, https://www.lightingglobal.org/resource/pulse-market-opportunity/.

World Bank Group, Kenya - *A Thriving Off-Grid Market – With a New Focus on Underserved Areas,* World Bank Lighting Africa Program, 2018, https://www.lightingafrica.org/country/kenya/.

World Health Organization (WHO). *Climate Change and Health Resource Document,* 2018, http://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.

Writankar, M. "White Goods Makers to Turn Champions of Made in India," *Economic Times,* November 2018, https://economictimes.indiatimes.com/industry/cons-products/durables/white-goods-makers-to-turn-champions-of-make-in-india/articleshow/66743569.cms

Zollman, J., et al. "Escaping Darkness: Understanding Consumer Value in PAYGO Solar", CGAP, 2017, https://www.cgap.org/research/publication/escaping-darkness-understanding-consumer-value-paygo-solar.

APPENDIX: INTERVIEW LIST

ORGANIZATION	INTERVIEWEE
SolarNow	Ronald Schuurhuizen
Sundanzer	David Bergeron
Uganda Off - Grid Energy Market Accelerator	Dr. Frank Sebowa
Ministry of New and Renewable Energy, India	Shobit Srivastava
Ministry of Energy, Kenya	Eric Mwangi
BBOXX	Iwona Bisaga
Solar Energy Development Association Ethiopia	Dereje Wondyefraw Woregna
Renewable Energy Asociation of Nigeria(REAN)	Lande Abudu
Renewable Energy Association of Sierra Leone (REASL)	Foday Lansana Suma
Uganda Solar Energy Association (USEA)	Joyce Nkuyahaga
DFID	Steven Hunt
Equity Bank	Anthony Kigora
Baobab+	Loris Durbano
PEG Africa	Nate Heller
OIKO Credit	Mr. O. Cedrick Montetcho
Rubitec Nigeria Limited	Bolade Soremekun
M-Kopa	Karl Bach
SolarKiosk	Andreas Spiess
Fosera	Catherine Adelmann
BBOXX	Amaury Faustenakels
Mobisol	Martin Vogt
Azuri	Alexander Brummelerand/ Nigel Preston
Greenlight Planet	Radhika Thakkar & Sadhil Khanna
Davis & Shirtliff	Norman Chege
Zola (Off Grid Electric)	Kassim Cisse
Global Institute	Tessa Lee
ovSolar	Susan Su
Aptech	Laura Corcoran
World Bank National Electrification Project	James Knuckles
Access to Energy Institute	Elliot Avila
Solar Sister	Katherine Lucy
cKinetics	Upendra Bhatt
Youmma- Embraco	Gabriel Frigieri Miguel Saud
Renewable Energy Association of Myanmar (REAM)	Aung Myint
Ecozen Solutions	Prateek Singhal
Smart Power Myanmar	Adriana Karpinska
SmarterGrid International	Heather Onoh
Proximity Design	Taiei Harimoto
EnVentures	Julius Mujuni
Sosai Technologies	Habiba Ali
Cello	Owen Evans
Energy Saving Trust	Stewart Muir

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