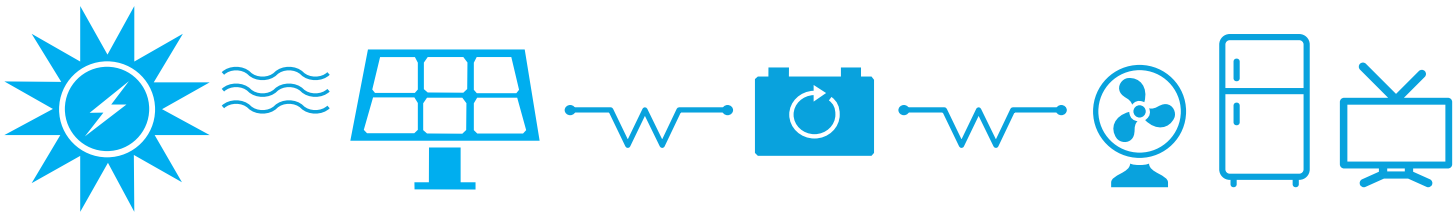
Global LEAP
Lighting and Energy Access Partnership

THE STATE OF THE GLOBAL OFF-GRID APPLIANCE MARKET



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CLEAN ENERGY MINISTERIAL
Accelerating the Global Clean Energy Transition

Dalberg

Photo Credit: Abbie Trayler-Smith; / Panos Pictures

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The report contains the first-ever snapshot of the global off-grid appliance market, and includes information on key market trends in three of the most important and promising appliance categories: fans, televisions, and refrigerators. The report presents a data-driven analysis of the current and potential scale of the global off-grid appliance market, as well as a discussion of barriers to the development of this market. It draws on input provided by a wide range of market stakeholders, from manufacturers and industry representatives to technical experts, policymakers, and other researchers.

Global LEAP would like to thank all those who provided support and feedback as this report was developed, including Dalberg Global Development Advisors who conducted the primary research and analysis, and CLASP who scoped and managed the project. Global LEAP would like to extend special thanks to the experts who served as peer reviewers for this project, including Quzai Ahmad Faruque (Rahimafrooz Renewable Energy Ltd.), Richa Goyal (Schatz Energy Research Center, Humboldt State University), Justin Guay (David and Lucile Packard Foundation), Arne Jacobsen (Schatz Energy Research Center, Humboldt State University), Ga Rick Lee (Schatz Energy Research Center, Humboldt State University), Won Young Park (Lawrence Berkeley National Laboratory), Koen Peters (Global Off-Grid Lighting Association), Karl Skare (d.light), and Kate Steel (Power Africa, USAID).

We encourage you to visit GlobalLEAPawards.org and contact us with any questions or feedback.

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FOREWORD

Global markets for clean energy technologies such as solar lanterns and solar home systems have grown phenomenally over the past few years, benefiting millions of un-electrified people globally. Yet, these markets have largely provided only basic electrification services so far—typically power to charge a mobile phone and one or two lights for four to six hours a day. This is consistent across solution types, whether it is solar portable lights, solar home systems, and even small-scale mini- and micro-grids. While the growth of markets delivering these basic services is a huge achievement and a critical first step in the energy access ladder, capturing the true socio-economic benefits of access to electricity will require provision of higher levels of energy services to off-grid consumers to improve livelihoods, health, and education.

A major challenge to delivering these life-transforming energy services is the fact that mainstream appliances, equipment and other end-use technologies consume too much power to be cost-effectively supported by available off-grid energy supply technologies. The good news is that just as LED-enabled off-grid solar lighting emerged a few years ago, a new class of energy-efficient appliances is becoming available. Smarter designs, technological spillovers from developed energy markets, and falling prices are enabling the emergence of new classes of energy-efficient appliances built with off-grid energy systems in mind. These super-efficient off-grid appliances, such as televisions, fans and refrigerators, consume a fraction of the power required by mainstream versions, reducing the overall costs of providing service. For example, Global LEAP-supported research shows that coupling solar home systems with super-efficient appliances, including a TV, fan, mobile charger, and LED lights, requires 75% less power and reduces overall costs by as much as 50%.

In addition to helping un- and under-served populations move up the energy ladder faster and at least cost, these appliances will also have a symbiotic relationship with off-grid energy supply technologies by boosting demand for existing solar products while also providing new revenue streams for off-grid companies. Several early movers are already successfully bundling such appliances with their off-grid energy products. Despite the relative nascence of this sector, there is significant optimism that this could provide the critical pathway by which off-grid energy finally moves beyond basic services and off-grid consumers move quickly and meaningfully up the energy ladder.

Despite the tremendous potential, there are still many barriers that constrain our ability to truly leverage the potency of energy efficiency as an energy access resource. Critical market infrastructure such as distribution, sales and maintenance networks is lacking, and there is limited market data to help energy access actors make informed decisions. The proliferation of low-quality products undermine these markets by eroding investor and customer confidence, there are limited sources of low-cost capital for companies seeking to develop and market these products.

This report – sponsored by the Global Lighting and Energy Access Partnership (Global LEAP), a Clean Energy Ministerial initiative led by the U.S. Department of Energy – seeks to deepen our understanding of the current state of this burgeoning off-grid appliance market, explore key market trends and areas of future opportunity, and explore linkages and interdependencies with existing off-grid clean energy markets. This work is an important contribution to broader energy access efforts, recognizing that achieving universal energy access goals will require a greatly increased focus on the development of complementary markets for high-performing end-use products that can deliver expanded energy services in energy-constrained settings.

David Turk

Deputy Assistant Secretary for International Climate and Technology

U.S. Department of Energy

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The global off-grid appliance market is critical for increasing access to electricity and services.[1] Over two billion people worldwide lack access to reliable electricity.[2] Renewable energy technologies, especially solar, are helping bridge this gap. Signs of success already exist in the fast-growing Solar Portable Lamps (SPLs) and Solar Home System (SHS) product market.[3] Renewable/hybrid mini-grids, the markets for which are still quite nascent, are also showing promise and often have better potential for higher loads.[4] While the desire to power larger electrical appliances has in part driven the growth in these off-grid energy solutions, most off-grid solutions sold today provide only basic, low-power energy services, such as lighting and mobile phone charging. Under-electrified households often cannot afford or access enough energy to power additional services, such as cooling, refrigeration, and entertainment. However, we know from the purchase behavior of electrified households in the same income segment that demand for these appliances is very high. Hence, just as LEDs revolutionized the off-grid lighting market by dramatically increasing efficiency and reducing energy costs, increasing the viability of the under-electrified appliance market will require additional innovations in cost-effectiveness, energy efficiency, and market availability. Off-grid appropriate appliances also add new revenue streams to off-grid business models, supporting the high overheads of building out a rural sales and service channel. This is critical for furthering the social impact of off-grid energy solutions and achieving scale. Viewing the off-grid appliance market and the clean energy market as inextricably linked will position stakeholders to unlock the market's potential.

Promoting off-grid appliances beyond lighting and cooking is important to further drive social impact. Country-level data and surveys in key markets all point to televisions, cooling, and refrigeration as the next priority for households after satisfying basic lighting and communication needs; in fact, some households prefer televisions to lighting.[5] These appliances can significantly improve the quality of life for under-electrified households by enhancing productivity, increasing social awareness, and facilitating improved livelihoods. Several studies have shown how televisions can foster positive behavior change, including financial behavior, family planning, literacy, and health.[6] Refrigerators not only help preserve the nutritional value of food and reduce wastage of perishable products, but can also contribute to income generation for micro-entrepreneurs (e.g., owners of roadside kiosks selling chilled water in India).[7] Another crucial application for refrigerators in off-grid areas is storing vaccines, which need to be at a specific temperature to be effective (2°C to 8°C). In tropical climates, fans can serve as a basic appliance of comfort, helping households and small businesses increase productivity and quality of life**.**

However, awareness and understanding of the off-grid appliance market is limited, and a need exists to advance the global discussion. In addition to energy supply and access, the conversation on energy usage in under-electrified markets has largely focused on opportunities for lighting, cooking, and mobile phone charging. Efforts to deliver these services can now serve as a springboard for expanding focus on a wider set of applications. The investigation that underlies this report found a substantial market for a broader set of appliances and off-grid energy services.

An improved understanding of the off-grid appliance market will lead to opportunities for new and existing market players. This report explores three off-grid appliance product categories—fans, televisions, and refrigerators—that present significant short- to mid-term opportunities. It begins with an estimation of the potential global demand and growth projections for these product categories. The report then explores the key trends on the supply and demand side of the market that underpin these projections.

The global off-grid appliance market is poised for significant growth and has the potential to become a $4.7 billion market by 2020; increasing energy efficiency is the key driver of this commercial opportunity. Improvements in energy efficiency enable off-grid households to run more appliances on the limited amount of electricity that off-grid energy systems typically provide. This, in turn, fuels consumer demand for new types of products. LED technology has already had this impact in the off-grid lighting market. Super-efficient LED lighting products that run on only a few watts can meet off-grid household lighting needs while requiring significantly less energy supply than conventional lighting technologies. This has a significant impact on costs. It also drives rapid sales growth for both LED lighting products and the solar energy devices used to power them.[8] Introducing similarly high-quality, super energy-efficient appliances into the off-grid market will allow consumers to enjoy improved consumption of energy services, without requiring a significant transformation of existing energy supply or business models. The projected growth of the SHS market—estimated to be a $1.3 billion market by 2024[9]—and the greater access to energy it enables will also be a major driver for increasing demand of off-grid appliances. As a result of efficiency gains and increased energy access, this report estimates off-grid fans, televisions, and refrigeration devices combined will represent a potential market of over $4.7 billion by 2020. This would mean an annual growth of 15 percent for fans, 25 percent for televisions, and 37 percent for refrigerators. In addition, the analyses that underpin this estimate were rooted in conservative assumptions about key market variables, and the opportunity could be substantially greater.

1 Note: We have used the term 'under-electrified' throughout the report to refer to the population that either has no grid connectivity or currently enjoys less than 6 hours of power per day, when connected to the grid. The term 'off-grid' appliances has been used to refer to household level appliances that are able to work with the off-grid energy systems common to the developing world, including solar home systems, solar home system kits, and mini- and micro-grids.

2 "Achieving Universal Energy Access," United Nations Foundation, accessed July 15, 2015, http://bit.ly/1Q7uV42

3 For more information see "Overview of the Off-Grid Lighting Market in Africa", *Lighting Africa*, January 2013, http://bit.ly/1o3eEHl; "Investment and Finance Study for Off-Grid Lighting", *A.T. Kearney and Global Off-Grid Lighting Association*, June 2014, http://bit.ly/11gv7fl; Paul Waide et al.," Analysis Of The Potential Future Of The Lighting Global Quality Assurance Program", *Navigant and Global LEAP*, August 2015, http://bit.ly/1T7GFZD

4 "The Business Case For Off-Grid Energy In India" *Climate Energy Group*, 2014, http://bit.ly/19vANGS

5 "Off-Grid Appliance Market Survey", *Global LEAP,* April 2015, http://GlobalLEAP.org/awards

6 Melissa Dittman, "Changing Behavior Through TV Heroes", *American Psychological Association*, Vol 35, No. 9, October 2004, accessed August 1, 2015, http://bit.ly/20oOE53

7 Charles Dhanaraj, Balasubrahmanyan Suram and Prasad Vemuri, "Godrej Chotukool: A Cooling Solution for Mass Markets," *Richard Ivey School of Business*, November 2011.

8 Amol Phadke et al., "Powering a Home with Just 25 Watts of Solar PV Super-Efficient Appliances Can Enable Expanded Off-Grid Energy Service Using Small Solar Power Systems", *Lawrence Berkeley National Laboratory*, April 2015, http://1.usa.gov/1XiLwaY

9 Navigant and Global LEAP, 2015.

Continued product innovation, quality improvements, financing efforts, and supply chain development are crucial to realizing this potential. Recent and expected technological advances suggest that we are close to a reality where commonly available solar home systems support several appliances, especially televisions, fans, and refrigerators, at a cost that under-electrified populations can afford. However, several product-specific barriers remain. While some television manufacturers have already made significant progress, the challenge is scale, distribution, and affordability. For fans, the primary challenge is quality and competition from many low-quality generic products that have flooded the market. Refrigeration, the most power-hungry of the appliances surveyed in this report, still requires significant technological progress to bring down energy load requirements, as well as market development investments.

Value should be the primary driver of innovation in off-grid appliance product design. Energy efficiency and price are crucial considerations for the off-grid appliance market, but appliances must first and foremost provide value to off-grid consumers. Efficiency improvements and price reductions must not come at the cost of product quality and usability. Below, we provide market projections for off-grid appliances in five years with respect to median product category, price, and efficiency. These take current under-electrified buying patterns and best-in-class products and project price, design, and technology trends forward.

FIGURE 1: Example viable off-grid products for 2020

EXAMPLE OFF-GRID PRODUCT SPECIFICATIONS	TELEVISION	FAN	REFRIGERATOR
Size	19”	12”	50–80 L
Retail Price of Product (not inclusive of supporting energy source)	≈$85 USD	≈$12 USD	≈$200 USD
Wattage	8–10 W	8 W	30–40 W
Example Technology Requirements	• LED technology • Variable voltage • Efficient optical films • Compatibility with relevant signal type	• Brushless DC permanent magnet motor technology	• Brushless and variable speed DC compressors • 11 cm of polyurethane insulation (or alternatives), • High efficiency gasket materials.
Additional design/ value-add considerations	• Greater functionality around wi-fi connectivity and content compatibility (e.g. built-in USB port) • Innovations in LCD panel design to use less lighting, and wider viewing angles	• Table fan considered to be one of the most popular • Improved blade design (e.g. twisted, tapered blades),	• Chest-style • Locating the compressor on top

Early movers are beginning to provide proof points for the potential of this market. Several television models have already emerged that fit within the energy specifications viable for off-grid communities. For example, existing players in markets such as Kenya and Bangladesh are projecting annual sales of 10,000–20,000 units for next year. These are healthy numbers for such a nascent market with very limited players and distribution. Fans have already become an important part of the mix with SHS. In Bangladesh, since the beginning of the IDCOL SHS program[10] in 2003, sales for off-grid fans reached 250,000–300,000.[11] In India, individual enterprises supply over 10,000 fans every month in limited markets,[12] and indicate that the growth will rise substantially in the next few years. For refrigerators, affordability continues to be a major barrier. However, we project that retail prices of off-grid refrigerators will decrease by 25–30 percent in the next five years, which will help drive uptake.[13] For all appliances, innovative consumer financing must accompany reduction in price in order to overcome the affordability challenge.

Development organizations, government, and civil society have an important role to play in addressing several critical challenges. We identified three changes as imperative to accelerating this market:

- **Increased information availability and business intelligence:** Existing players and potential entrants require information about the scale of the global off-grid appliance market, insight into the dynamics of key regional and national markets, and details about technical and design requirements.
- **Expanded financing options:** Alongside the need for continued reduction in costs, the limited availability of finance solutions for consumers, manufacturers, and distributors inhibits rapid growth of this market. Microfinance for SHS and pay-as-you-go solutions have already provided significant acceleration to SHS and solar lantern markets. Making the next wave of appliances available to under-electrified households requires similar financial mechanisms.
- **Friendly policies and market-supportive regulations:** High import tariffs and duties, the lack of common technology standards and quality control mechanisms, and limited government incentives currently inhibit the off-grid appliance market. For example, off-grid appliances do not yet receive the same treatment in terms of VAT or duties that solar products enjoy in many countries. Unlocking this market’s potential requires such policies.

Governments and development agencies have a role in accelerating the growth of the off-grid appliance market, helping with technology transfer and disseminating information (to both consumers and manufacturers). At the same time, as the solar lighting market has already shown, interventions need to be judicious in order to promote and not crowd out private sector engagement. The market fundamentals for off-grid appliances are strong; they just require the right encouragement.

10 The IDCOL Solar Home Systems program supports clean energy access in Bangladesh. Through partnerships with NGOs and microfinance institutions, IDCOL supports financing, distribution, and maintenance of SHSs for rural households. Millions of solar home systems have been sold through this program to date.

11 Interviews with experts, manufacturers, and distributors, 2015

12 Ibid.

13 Ibid.

II. INTRODUCTION

Access to energy is critical to development outcomes. Universal access to sustainable energy is fundamental to meeting nearly every global challenge and opportunity. The new Sustainable Development Goals underscore the need to bring billions up the development ladder—access to clean energy is a core enabler of this. Clean energy access has important linkages to health, livelihood, and employment as well as environmental sustainability. Therefore, it is essential for strengthening economies, protecting ecosystems, and achieving equity.[14] However, with erratic energy prices and an ever-increasing demand due to rapid population growth, achieving universal energy access is, and will continue to be, a critical challenge that requires both public and private sector focus.

A. The state of the energy access market

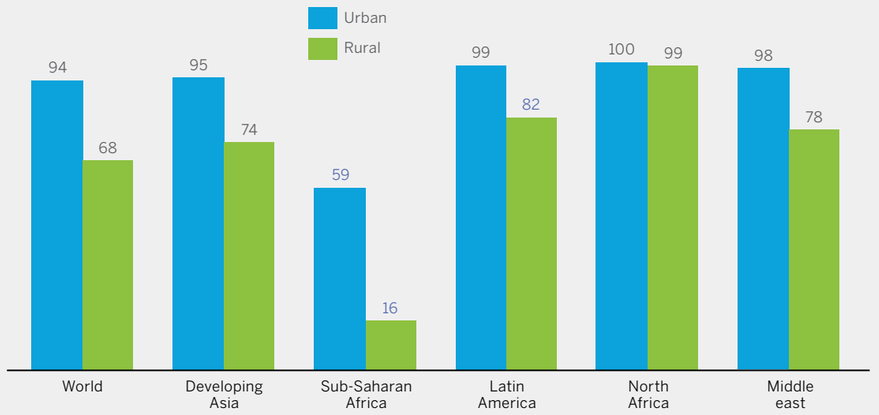
A significant portion of the global population continues to have no, or poor, access to electricity. About 1.28 billion people lack access to electricity,[15] and another one billion people have access only to an unreliable grid.[16] More than two-thirds of the population of Sub-Saharan Africa—620 million people—lack access.[17] Hundreds of millions more live without access in developing Asia.[18] These numbers, however, mask a myriad of important segments within these populations. For example, populations with an "unreliable grid" can often receive less than two hours of electricity a day, resulting in conditions similar to off-grid populations.

Most of the global off-grid population is concentrated in rural areas of developing, low-income countries. Parts of Asia and Sub-Saharan Africa suffer from the most severe energy shortages. In both regions, rural populations are disproportionately affected (Figure 2, next page).

The majority of off-grid households rely on dirty fuels to address basic energy needs. These dirty fuels often comes with significant negative externalities. Most off-grid households[19] rely on kerosene for lighting. Solid fuels (e.g., wood and charcoal) serve as the primary source of energy for cooking needs for 40 percent, or nearly 3 billion, of the total global population.[20] The negative externalities resulting from extensive reliance on traditional solid fuels and kerosene are well-documented. These include health risks (disproportionately higher for women), environmental degradation, lost opportunities for income generation, reduced access to education, and ultimately, a proliferation of extreme poverty.

Off-grid households pay a high premium for limited energy access. Traditional fuel sources are disproportionately more expensive than grid electricity and less able to meet even the most limited energy needs. For example, in order to get the same amount of light output for the lifetime of a bulb, kerosene costs as much as 325 times more than an incandescent bulb and up to 1,625 times more than the cost of a compact fluorescent light.[21] This is also true of the non-lighting services that energy enables. In off-grid communities, entrepreneurs offering mobile phone charging or selling chilled beverages can charge several times more than what gird electricity would cost for the same services.

FIGURE 2: Comparison of rural vs. urban access to electricity
Electrification rates (%, 2014)



Source: International Energy Agency (IEA), "World Energy Outlook 2014," Energy Access Database, 2014.

Under-electrified populations spend billions on energy inputs. Most under-electrified households are concentrated within the Base of the Economic Pyramid (BoP). The World Resources Institute (WRI)'s "Next 4 Billion" report estimates that the 4 billion BoP households globally spend an estimated $433 billion on energy per year—the largest expense for this segment after food and housing. On average, 9 percent of BoP household is spending on energy. In Indonesia, Nigeria, and Pakistan, for example, the BoP energy market accounts for 90 percent of the total national energy expenditure; in India and Uganda, it is more than 50 percent.[22]

Diverse interventions, ranging from national rural electrification plans to multilateral initiatives, are playing an important role in reducing market barriers to delivering clean energy to off-grid communities. The UN has launched the Sustainable Energy for All (SE4All) initiative, a multi-stakeholder partnership between governments, the private sector, and civil society to achieve universal access to modern energy and double the global rate of improvement in energy efficiency by 2030.[23] Several governments, particularly in developing economies, have launched initiatives to secure the provision of universal access to energy. For example, India's Rural Electrification Policy of 2006

14 "Achieving Universal Energy Access," *United Nations Foundation.*
15 "World Energy Outlook Electricity Database", *International Energy Agency,* 2014, http://bit.ly/1XiLC28
16 Achieving Universal Energy Access," *United Nations Foundation.*
17 "Africa Energy Outlook", *International Energy Agency,* 2014, http://bit.ly/1YKonA8
18 World Energy Outlook Electricity Database, 2014.
19 This report will refer to the population with no access to a grid or unreliable access to a grid collectively hereafter as "off-grid households," and qualify the term with other descriptors (e.g., rural, BoP, bad-grid) wherever it adds clarity.
20 Achieving Universal Energy Access," *United Nations Foundation.*
21 Evan Mills," The $230-billion Global Lighting Energy Bill", *International Association for Energy-Efficient Lighting and Lawrence Berkeley National Laboratory,* June 2002, http://1.usa.gov/1PlqjtL
22 Allen Hammond et al., "The Next 4 Billion: Market Size and Business Strategy at the Base of the Pyramid", 2007, *World Resources Institute and International Finance Corporation*, http://bit.ly/1KFG5AL
23 "Our Vision," Sustainable Engergy for All, accessed Aug. 7, 2015, http://bit.ly/1Weqvgo

created financing solutions to incentivize private sector investment in energy access projects.[24] Countries in Africa, including Ethiopia, Liberia, Mali, Senegal, and Tanzania, integrated off-grid solar solutions within their rural electrification programs, and are facilitating the creation of a viable commercial market for solar lighting products.[25] Lighting Global, a key initiative of the International Finance Corporation (IFC) and the World Bank,[26] is mobilizing the private sector to build sustainable markets that provide affordable, modern off-grid lighting services to off-grid consumers. The Global Off-Grid Lighting Association's (GOGLA) primary goal is to aid efforts that work toward achieving universal energy access by 2030. Power Africa and Energising Development (EnDev) have employed results-based financing approaches to stimulate innovation in the off-grid sector. In short, the global effort has been significant.

However, the energy gap is likely to persist. According to estimates from the International Energy Agency, the global electrification rate is likely to increase from 79 percent in 2009 to 85 percent by 2030—helping 1.7 billion people gain access to electricity.[27] However, population increase in off-grid areas will offset this growth, especially in Sub-Saharan Africa. About 1.2 billion people worldwide will likely still lack access to electricity in 2030, and Sub-Saharan Africa will contribute the largest number of people to the off-grid population, with approximately 650 million. Nor do projections suggest the energy gap will significantly taper as the century progresses; a recent report on electricity access in Sub-Saharan Africa suggests that by 2040, while 1 billion people will have access, 540 million will remain unelectrified.[28]

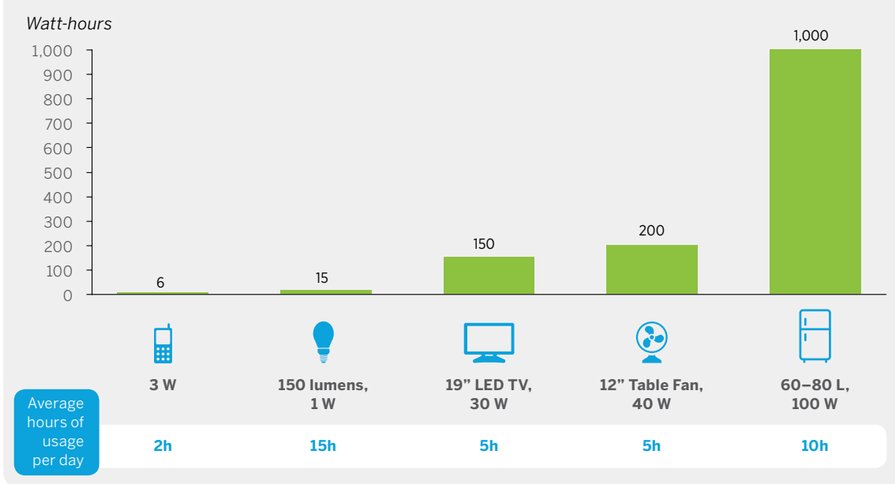
B. The importance of the off-grid appliance market

Energy generation is only half the battle in providing meaningful energy access. The ultimate goal of energy access is to provide equal access to the services that energy enables, which increase productivity, health, leisure, and other positive social outcomes. Hence, access to energy supply is only half of the equation—viable opportunities to use energy to deliver services is the other half. In energy-constrained environments, energy efficiency is critical to mitigate technical and cost constraints. The introduction of increasingly affordable LEDs was a watershed moment for lighting, as the technology provided a cost, quality, and efficiency combination that suddenly made electrical lighting viable for hundreds of millions of under-electrified families. Consumers can only go beyond lighting to energy services such as entertainment, cooling, and refrigeration at scale if super-efficient off-grid appropriate appliances become available. Most currently available appliance products require more electricity than off-grid energy systems supply, making it hard for under-electrified consumers to advance up the energy ladder (see Figure 3).

Energy efficiency unlocks the viability of off-grid appliances. Inexpensive appliances will not be accessible to the under-electrified population unless they can afford to power them. A recent report[29] finds that just powering four basic appliances—a television, refrigerator, fan, and water pump—at typical mini-grid power rates would exceed the energy budget of a poor household ($3–$5 per day) by over 60 percent.[30] Energy efficiency is hence critical for such appliances to meet the economic reality of the under-electrified segment. Lessons from the off-grid lighting industry are instructive. From 2009 to 2014, LED price and efficiency gains provided an average savings of $23.57 on the retail price of solar lighting systems.[31]

A broader set of energy services can help off-grid energy companies manage high customer acquisition costs and overheads. Many energy entrepreneurs are witnessing strong revenue growth, but see limited margins and poor economies of scale. The fundamental challenge they face is a customer base they cannot serve without significant upfront investment (e.g., large capital expenditure to build local mini-grids or establish last-mile distribution and marketing capacity), who generally will only buy a few watts of energy to power a few LED lights and charge a mobile phone. To achieve economies of scale, the private sector needs under-electrified populations to move up the energy ladder. This will increase the total amount of energy services off-grid companies can sell and diversify their revenue streams by enabling the sale of off-grid appliances. Figure 4 shows the break-even revenue for a collection of mini-grids in India, which demonstrates

FIGURE 3: Average energy consumption of mainstream household appliances
Adjusted for average hours of use



24 Christina Gradl and Claudia Knobloch, "Energize the BoP! Energy Business Model Generator for Low-Income Markets: A Practitioners' Guide," (Berlin, Germany: Endeva, June 2011), http://bit.ly/1PlrOTO

25 "Lighting Africa Market Trends," 2013, http://bit.ly/1mZgohm

26 Lighting Global is the World Bank Group's platform supporting sustainable growth of the international off-grid lighting market as a means of increasing energy access to people not connected to grid electricity.

27 "World Energy Outlook," International Energy Agency, 2012, http://bit.ly/1osa0m6

28 "Africa Energy Outlook," International Energy Agency, 2014, http://bit.ly/1YKonA8

29 Shashi Buluswar, Zach Friedman, Priya Mehta, Subarna Mitra, and Roger Sathre, "50 Breakthroughs: Critical Scientific and Technological Breakthroughs Required for Sustainable Global Development," Institute for Globally Transformative Technologies, 2014, http://bit.ly/1T7JCJI

30 The study bases its analysis on the following assumptions: (i) electricity via solar PV mini-grid costs $0.24 per KWH, and (ii) the average total monthly consumption for these appliances is 80KWH per month. The power consumption discussed throughout this report is rated power, and not on-mode power consumption. Rated power can be regarded as the maximum power consumption of an appliance, and is a more conservative measure, which helps explain the energy solution capacity required to run an appliance.

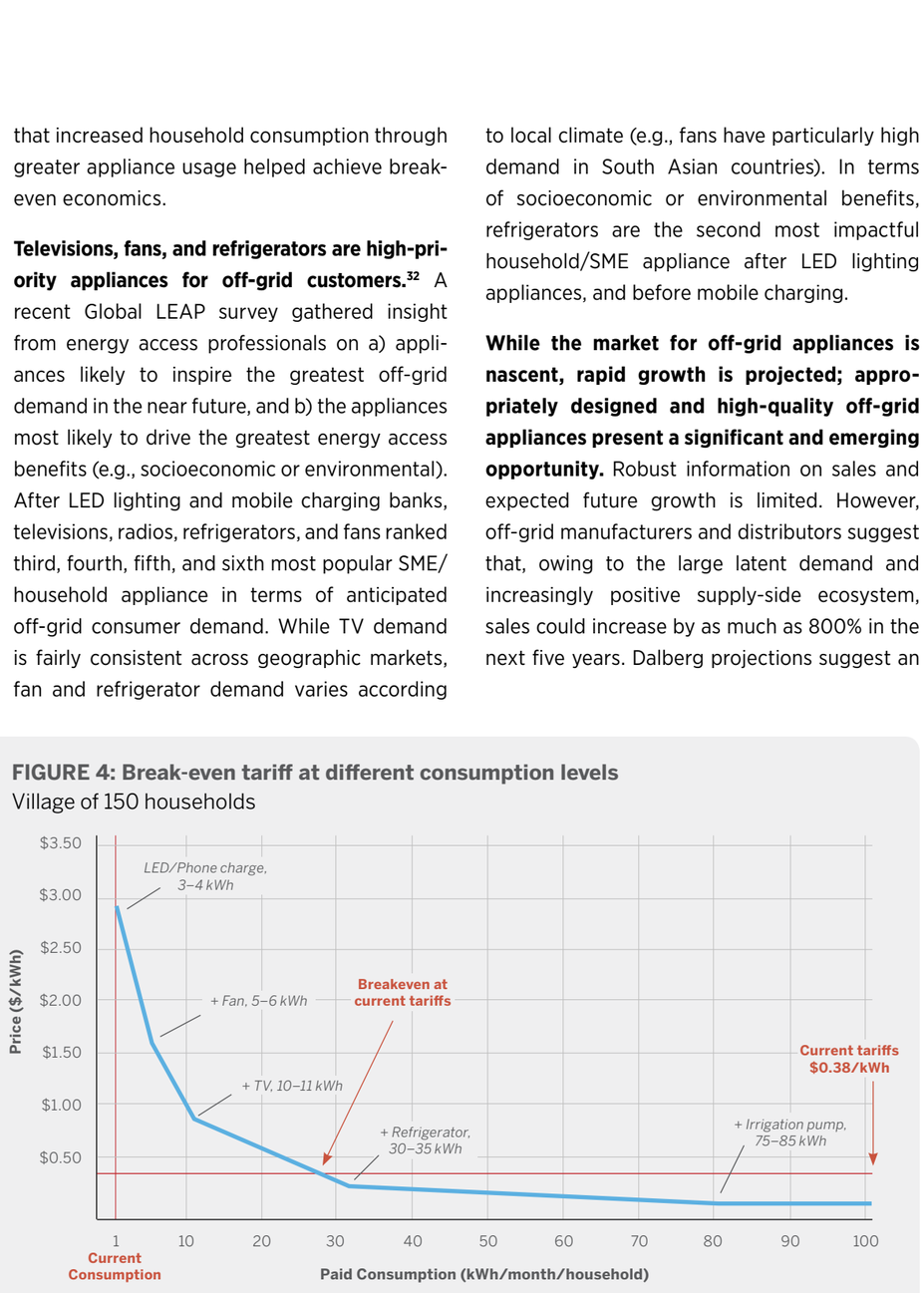
31 Buluswar et al.

that increased household consumption through greater appliance usage helped achieve break-even economics.

Televisions, fans, and refrigerators are high-priority appliances for off-grid customers.[32] A recent Global LEAP survey gathered insight from energy access professionals on a) appliances likely to inspire the greatest off-grid demand in the near future, and b) the appliances most likely to drive the greatest energy access benefits (e.g., socioeconomic or environmental). After LED lighting and mobile charging banks, televisions, radios, refrigerators, and fans ranked third, fourth, fifth, and sixth most popular SME/household appliance in terms of anticipated off-grid consumer demand. While TV demand is fairly consistent across geographic markets, fan and refrigerator demand varies according to local climate (e.g., fans have particularly high demand in South Asian countries). In terms of socioeconomic or environmental benefits, refrigerators are the second most impactful household/SME appliance after LED lighting appliances, and before mobile charging.

While the market for off-grid appliances is nascent, rapid growth is projected; appropriately designed and high-quality off-grid appliances present a significant and emerging opportunity. Robust information on sales and expected future growth is limited. However, off-grid manufacturers and distributors suggest that, owing to the large latent demand and increasingly positive supply-side ecosystem, sales could increase by as much as 800% in the next five years. Dalberg projections suggest an over $4.7 billion opportunity in 2020 for off-grid televisions, refrigerators, and fans alone.

FIGURE 4: Break-even tariff at different consumption levels
Village of 150 households



Source: Institute for Transformative Technologies

C. Objectives of the study

Foundational market intelligence is required to address information gaps within the off-grid appliance market and stimulate growth. No report to date comprehensively addresses the state of the market for off-grid appliances; identifies key trends, drivers, and barriers; or projects future market potential. This report aims to address these gaps by providing a holistic understanding of the size of the market opportunity and key market trends. It also hopes to inform discussions around financing, policy interventions, and business innovation that can help further develop and stimulate the market.

The objective of this study is threefold:

- To estimate the size of the addressable market for off-grid appliances, understand consumer demand and preferences for off-grid products, and explore opportunities that can catalyze growth;
- To assess supply-side trends for the off-grid appliances, including currently available products, business models for engagement, and barriers along the off-grid appliance value chain; and
- To inform intervention strategies for off-grid stakeholders that will further stimulate and develop the market.

D. Scope

This study focuses on televisions, fans, and refrigerators, for the following main reasons.

- **Appliance ownership trends in off-grid and mainstream markets:** Projections suggest these appliance categories will have high demand amongst off-grid consumers for household use, after LED lighting and mobile charging.[33] Trends in prominent off-grid markets substantiate this projection. These products, particularly fans and televisions, are already in great demand by off-grid consumers. For example, more than 40 percent of households with access to an SHS in Bangladesh own a small table fan.[34] These households also demonstrate high ownership of televisions.[35] Mainstream consumer trends, which show steep adoption curves for durable goods like televisions and refrigerators once a household reaches a threshold consumption level, support the likelihood of high demand for these products.[36] Country-level studies in hot climate regions indicate that households demonstrate a particularly high preference for purchasing fans and televisions, once they have access to electricity. For example, in India, households already equipped with mobile phone chargers and electric lighting typically sought an electric fan first, followed by a television.[37]
- **Potential for Impact:** Research suggests ownership of these appliances has positive socioeconomic effects from information/

32 United Nations Foundation and CLASP, "Global LEAP Off-Grid Appliance Market Survey," 2015. Global LEAP conducted the survey between Dec. 18, 2014 and Jan. 13, 2015, amongst energy access professionals, namely members of the United Nations Foundation's Energy Access Practitioner Network and the International Finance Corporation's Lighting Global community.

33 Ibid.

34 Interview with leading off-grid appliance distributor in Bangladesh, Oct. 3, 2015.

35 M. Asaduzzaman, Mohammad Yunus, A. K. Enamul Haque, AKM Abdul Malek Azad, Sharmind Neelormi, and Md. Amir Hossain, "Power from the Sun: An Evaluation of Institutional Effectiveness and Impact of Solar Home Systems in Bangladesh," Bangladesh Institute of Development Studies, May 30, 2013.

36 Richard Dobbs, Jaana Remes, James Manyika, Charles Roxburgh, Sven Smit, and Fabian Schaer, "Urban World: Cities and the Rise of the Consuming Class," McKinsey Global Institute, June 2012, http://bit.ly/1osapoK

37 Sambhu Singh Rathi, Aditya Chunekar, and Kiran Kadav, "Appliance Ownership in India: Evidence from NSSO Household Expenditure Surveys 2004–05 and 2009–10," Prayas Energy Group, Sept. 2012, http://bit.ly/1SIyg0h

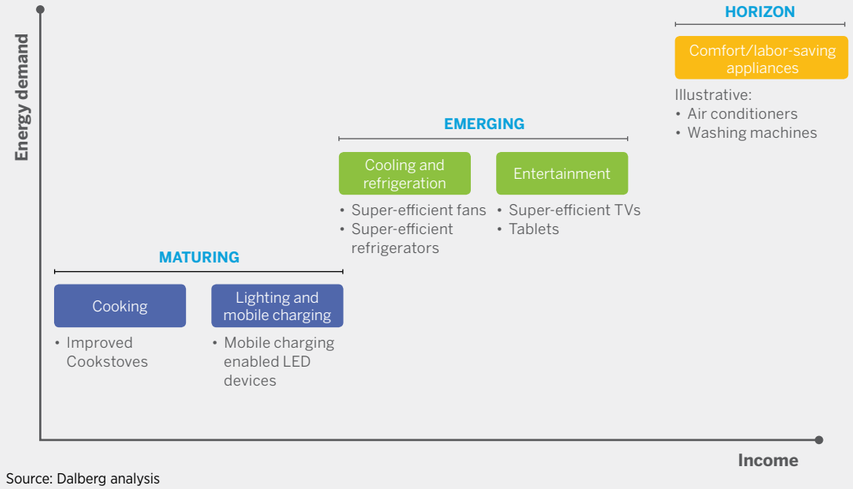
education, health, and productivity perspectives.[38]

- **Supply-side factors:** Prominent energy access enterprises in off-grid markets are already focused on supplying these appliances.

Figure 5 defines the differing levels of maturity of appliances that are available for off-grid uses. They are 1) mature technologies (e.g., mobile charging enabled LED devices, clean cookstoves), 2) emerging technologies (e.g., fans, tablets, televisions, refrigerators), and 3) horizon technologies (e.g., air conditioners, electric water filters/coolers). For the purpose of this study, we define emerging appliances as existing, near-term technologies and appliances that a BoP off-grid customer can feasibly adopt. Such appliances are our focus.

The study projects out to 2020 in recognition of the fast-changing dynamics of the market. No large data sets exist that characterize ownership patterns of appliances amongst under-electrified consumers. This report attempts to model both current and future demand. This market is evolving rapidly, and projections are critical for calibrating near-term investment to the market's long-term potential. Change also makes accurate projection challenging, and the data this report presents is a starting point for deeper investigation into investment potential.

FIGURE 5: Energy ladder for BoP off-grid households



Source: Dalberg analysis

38 Hildegard Paulino Barbosa, Julio Cesar Ferreira da Silva, and Ed Porto Bezerra, "The Importance of Digital TV for Countries in Development: A Case Study of Brazil," Federal University of Paraiba, 2012, http://bit.ly/20oQy5A; Melissa Dittman, "Changing Behavior Through TV Heroes," American Psychological Association 35, no. 9 (Oct. 2004), http://bit.ly/20LCQPU; Charles Dhanaraj et al., "Godrej Chotukool: A Cooling Solution for Mass Markets." Interviews with experts, manufacturers, and distributors, 2015.

39 Bangladesh, Colombia, India, Kenya, Myanmar, Nigeria, South Africa, Tanzania, Uganda, and United States.

The methodology section below provides more detail on how we have modeled the market.

Lastly, the report primarily focuses on household appliance use. While some household appliances, particularly refrigerators, might drive industry, this report does not address off-grid appliances for purely institutional or small business purposes.

E. Methodology

The study employed a three-pronged research approach.

A. **Secondary research:** Desk research using existing secondary resources investigated the current state of the market, including market research studies, household survey data, manufacturer and distributor websites, scientific literature on technology research and development, as well as country-level databases to ascertain electrification level, income and expenditure patterns, and appliance penetration.

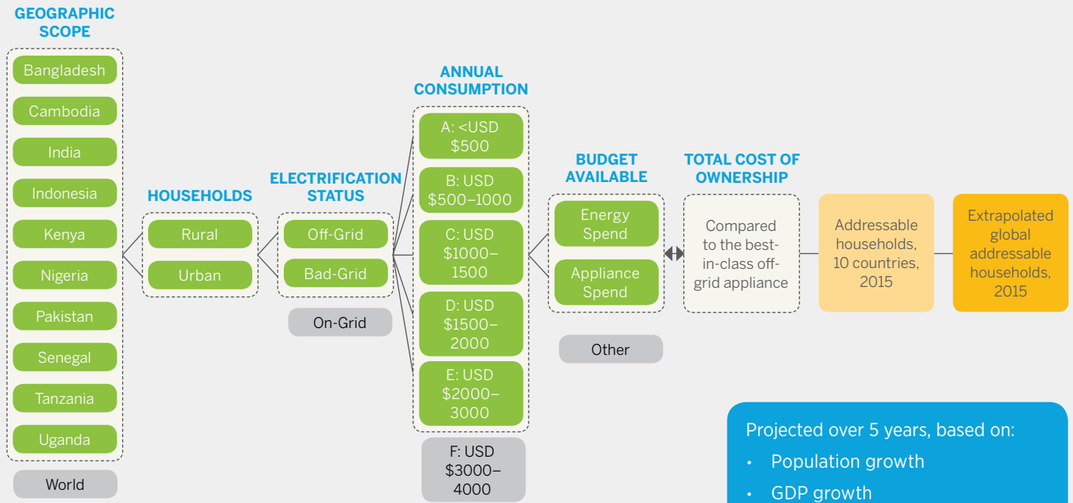
B. **Primary research:** In-depth, semi-structured interviews with over 35 prominent stakeholders in the global off-grid appliance market, including off-grid appliance manufacturers, distributors, financiers, and technical experts from ten countries[39] provided uniquely relevant insight on customer preferences, ground-level realities on both the supply and demand side of the market, broader trends in the off-grid appliance market, and key opportunities to further develop the market.

C. **Development of a proprietary market model and analyses:** A proprietary model estimated the total potential market size for individual appliances based on affordability and energy access. Below is a brief description of the primary inputs and analyses used in the development of this model.

- **Geographic scope:** The analysis focuses on ten prominent country-level off-grid markets in Sub-Saharan Africa and Asia that will represent close to 53 percent of the global off-grid population in 2020.[40] The households in these markets have been divided into off-grid, bad-grid (estimated at 0–6 hours of grid connectivity per day), and on-grid (6–24 hours of grid connectivity per day). The total potential market these ten countries represent was extrapolated to arrive at global figures. Population data comes from the United Nations Department of Economic and Social Affairs, Population Division.
- **Electrification rate:** This measurement addresses rates for off-grid and bad-grid households and potential to access alternative energy sources. The study used national electrification data and assumptions about grid quality to assess these two electrification segments across rural and urban areas.
- **Distribution of households across consumption segments:** The distribution of off-grid and bad-grid households was determined across five consumptions segments (A: < $500 USD, B: $500–1,000 USD, C: $1,000–1,500 USD, D: $1,500–2,000 USD, E: $2,000–3,000 USD), using the World Bank's PovcalNet, in order to model expected purchasing ability and patterns between households of varying incomes. The figure below represents the distribution

40 Bangladesh, Cambodia, India, Indonesia, Kenya, Nigeria, Pakistan, Senegal, Tanzania, and Uganda.

FIGURE 6: Illustrative model methodology, estimation of addressable households for off-grid appliances



Source: Dalberg

of households within our ten countries of focus across the dimensions of consumption as well as electrification.

- **Budget available within consumption segments:** Using data from the World Bank's Global Consumption Database, we estimated the budget available for households in each consumption segment to spend on relevant appliances and energy supply. Estimates for household spending come from actual consumption patterns and the portion of household consumption constituted by energy expenditure[41], not broader assumptions rooted solely in price and household income trends. Note that since limited access to electricity and limited availability of efficient off-grid products negatively impacts consumption to a greater degree than affordability, the estimates are likely conservative.

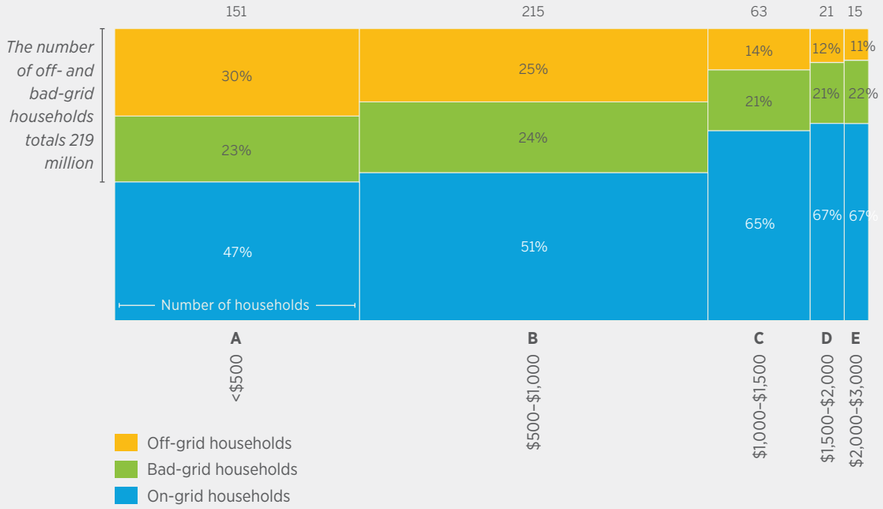
- **Cost of ownership:** In consideration of the ability to purchase and power the relevant appliance products, we consider not only the cost of the appliance, but also the cost of the accompanying energy solution (i.e., an SHS). Estimates include the up-front and lifetime cost of ownership for purchasing and powering each appliance. The lifetime cost reflects the annual cost of the accompanying off-grid energy solution that will power the appliance. Note that this analysis not only takes into account instantaneous power draw, it also incorporates an estimated average number of hours of energy consumption; for example, a television with a wattage rating of 20W used for two hours would consume the same amount of power as a fan with a wattage rating of 10W used for four hours.

- **Projections to 2020:** To examine the market potential in 2020, we project forward trends in population growth, expansion of grid electrification, GDP growth, changes in income distribution, and reductions in price and energy consumption of target appliances.

41 Energy-related consumption was assumed to be 10% of the annual household consumption for countries in Asia, and 9% for countries in Africa; from Allen Hammond, William J Kramer, Julia Tran, Rob Katz and Courtland Walker, The Next 4 Billion: Market Size and Business Strategy at the Base of the Pyramid. http://bit.ly/1QI5DPM (2007).

FIGURE 7: Estimated distribution of off-grid and bad-grid households in ten countries of focus

Number of households in millions, 2015



Source: Dalberg

III. THE SIZE OF THE OPPORTUNITY

The under-electrified already spend over USD $500 million on fans, televisions, and refrigerators today. Households that currently receive some grid power and/or have access to DC batteries or diesel generators are purchasing fans, televisions, and in rarer cases, refrigerators. Demand has been strong even though limited energy severely restricts the use of the appliance. This demonstrates both the large latent demand and the fact that many of these goods are status symbols.[42] Estimated current spending by off- and bad-grid households on currently available mainstream fans, televisions, and refrigerators are 60 million, 390 million, and 75 million, respectively.

Estimated Actual Current Global Spend, Off- and Bad-Grid Households, 2015

USD $60 million	USD $390 million	USD $75 million

Source: Dalberg analysis

If today's best-in-class off-grid appliances were available to all, the addressable market could be worth almost three times that amount, or close to USD $1.5 billion annually. There are already energy-efficient appliances specifically designed for off-grid conditions. These include, for example, a 15W/19" television at $104 USD, a 45W/50L refrigerator at $300 USD, and a 12W/12" table fan at $18 USD. While to date few households have purchased these appliances, wider SHS and appliance supply and distribution would vastly increase sales. Based on affordability and current spending patterns on energy and household appliances, greater product availability would almost triple demand to USD $1.5 billion.

Estimated Potential Current Global, Off- and Bad-Grid Households, 2015

Off-grid	Off-grid	Off-grid
USD $250 million	USD $1 billion	USD $220 million

Source: Dalberg analysis

In 2020, the estimated annual potential spend on off-grid televisions, fans, and refrigerators could be $4.7 billion in total. Individually for each appliance, this translates into a potential value of $500 million for off-grid fans, $3.1 billion for off-grid televisions, and $1.1 billion for off-grid refrigerators. From 2015 to 2020, we expect the potential spend by under-electrified consumers on fans, televisions, and refrigerators respectively to grow annually at a rate of 15 percent, 25 percent, and 38 percent, respectively. Expected decreases in price, increasing energy efficiency (which reduces cost of ownership), and growth in population and household consumption levels drive this. These estimates, based on existing consumption trends (with current levels of energy access and off-grid appliance supply), are intentionally conservative; the actual potential in 2020 could be even higher.

Estimated Global Potential Future Annual Spend, Off- and Bad-Grid Households, 2020

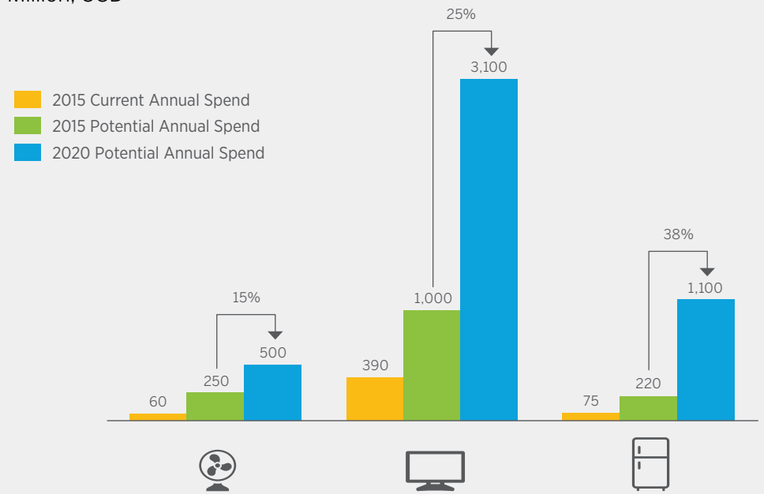
Off-grid	Off-grid	Off-grid
USD $500 million	USD $3.1 billion	USD $1.1 billion

Source: Dalberg analysis

Estimates of potential annual spending suggest a total cumulative market opportunity of 309 million fans, 208 million TVs, and 65 million refrigerators in 2020 (Figure 10).[43] Based on past consumption patterns and affordability analysis for both the appliance and the related energy costs, the study projects that the cumulative opportunity for off-grid appliances to be sold over the next few years is significant. This is only a potential number based on affordability and need, and does not take into account actual ability for supply to effectively reach and market to these customers. It also does not account for the potential opportunity for households to purchase more than one of any type of product.

The market is supply constrained. Realizing the market potential requires new entrants and significant scale-up of existing players. In any given market, the number of players supplying off-grid appliances beyond lights often numbers less than ten. Like lighting, the latent demand is significant. Meeting even existing potential demand will require new entrants, including some of the global consumer electronics giants, and strong continued investment by existing players.

FIGURE 8: Estimated potential value of addressable market for target off-grid appliances in 2015 and 2020
Million, USD



Source: Dalberg analysis

42 S. Dutta and S. Regani., "A Note on the Refrigerator Industry in India," IBS Center for Management Research, 2003, http://bit.ly/1Rq8A78.

43 Note that consumer research and insights from key stakeholders lead us to conclude that demand for fans in East African countries is close to non-existent.

FIGURE 9: Estimated addressable off-grid and bad-grid households for target products (2015)

# of HH (millions)	Bangladesh	Cambodia	India	Indonesia	Kenya	Nigeria	Pakistan	Senegal	Tanzania	Uganda
Target HH that can purchase and power a fan	2.2	1.0	36.7	9.2	-	2.8	2.1	0.1	-	-
Target HH that can purchase and power a television	0.9	0.9	8.7	3.7	0.5	1.3	3.5	0.4	5.7	1.1
Target HH that can purchase and power a refrigerator	-	-	2.4	-	-	-	0.9	0.02	1.0	-
	*Total addressable households for off-grid appliances – **ten countries only***					*Total addressable households for off-grid appliances – **global (extrapolated)***				
Fans	54 million					109 million				
Televisions	27 million					53 million				
Refrigerators	4 million					9 million				

Source: Dalberg analysis

FIGURE 10: Projected addressable off-grid and bad-grid households for target products (2020)

# of HH (millions)	Bangladesh	Cambodia	India	Indonesia	Kenya	Nigeria	Pakistan	Senegal	Tanzania	Uganda
Target HH that can purchase and power a fan	10.4	2.6	100.4	19.9	-	10.3	10.2	02	-	-
Target HH that can purchase and power a television	7.3	2.3	57.5	12.3	0.6	3.5	8.6	0.6	8.5	2.4
Target HH that can purchase and power a refrigerator	0.7	0.9	13.1	6.3	0.04	1.7	4.5	0.09	4.9	-
	*Total addressable households for off-grid appliances – **ten countries only***					*Total addressable households for off-grid appliances – **global (extrapolated)***				
Fans	154 million					309 million				
Televisions	104 million					208 million				
Refrigerators	32 million					65 million				

Source: Dalberg analysis

The off-grid TV market already presents a major commercial opportunity. TVs are a priority purchase for households even under poor electrification conditions. SHS distributors already indicate that the ability to power a TV is an important demand driver for their consumers.[44] Several SHS distributors are successfully bundling TVs with SHS systems as a way of boosting demand for larger SHSs.

The fan market is low-hanging fruit. Most demand for fans comes from South Asia due to the climactic conditions. While some products are available on the market at an affordable price point, concerns about product quality and energy consumption dampen demand. Improvements in design may be the key to tap into this nearly three billion dollar market.

Low penetration and rapidly evolving product design position the refrigerator market for significant growth. Steep prices and energy requirements mean that even households with diesel generators can rarely purchase and use refrigerators. Technological advancements that improve performance while enabling relatively substantial price reductions will unlock latent demand.

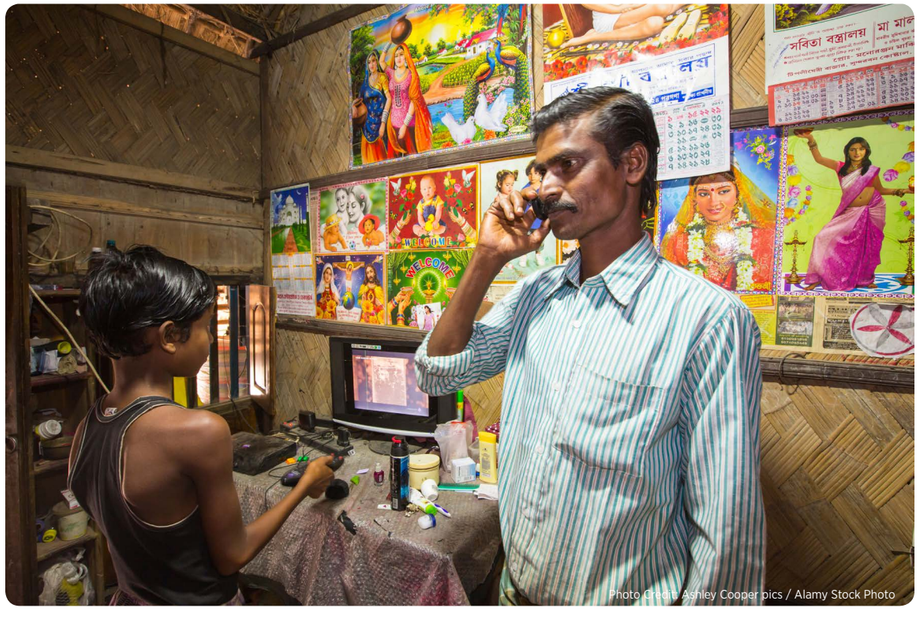


Photo Credit: Ashley Cooper pics / Alamy Stock Photo

44 Interviews with experts, manufacturers, and distributors, 2015.

IV. KEY TRENDS IN THE OFF-GRID APPLIANCE MARKET

A. Televisions

The off-grid television market has the potential to grow at a rate of 25 percent annually. Estimates suggest that the annual spend on off-grid televisions in 2020 could reach USD $3.1 billion.

Technology advancements to bring the cost and energy consumption of televisions down to an appropriate level for off-grid markets are already underway. There are more opportunities to make televisions suitable for off-grid communities. These include improvements in viewing angle and picture quality to facilitate large audiences, flexible voltage to accommodate electricity fluctuation concerns, and compatibility with different content technologies (e.g., terrestrial, cable or satellite, or SD cards).

Importance and priority of televisions in the off-grid market

Consumer behavior already demonstrates the importance of televisions in the off-grid market. As noted above, many SHS companies have been providing television products in response to customer demand. Televisions can dramatically increase quality of life for off-grid households by providing access to information and entertainment. In some off-grid communities, televisions are also seen as important status symbols, which increases demands.

TVs can lead to positive socio-economic outcomes. A 2008 study in India concluded that the introduction of cable 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.[45] Research has also found that social messages embedded in serial dramas with gripping storylines change financial behavior, family planning, literacy, and health in Africa, Latin America, and Asia (Figure 11).[46] Examples of successful programs include the following:

- A Spanish-language telenovela aims to impart financial knowledge to Latino immigrants in the United States. The television show has had positive impacts on viewers' attitudes with regard to bank account usage and preparation for homeownership.[47]
- A popular television show in Kenya aims to provide information to farmers on improving their livelihoods and incomes, with half a million households reporting changes to agricultural practices, leading to a net economic impact of USD $24 million.[48]

Comments about televisions in off-grid markets

"The off-grid population is an aspirational population, while they might live in poor conditions....owning a bigger TV set is a big status symbol."

— Off-grid TV manufacturer, South Africa

"Customers prioritize TVs even more than a light."

— Off-grid appliance distributor, India

45 Robert Jensen and Emily Oster, "The Power of TV: Cable Television and Women's Status in India," The Quarterly Journal of Economics 124, no. 3 (2008): 1057–1094, http://bit.ly/1V42jx5

46 Melissa Dittman, "Changing Behavior Through TV Heroes," American Psychological Association 35, no. 9 (Oct. 2004), http://bit.ly/20LCQPU

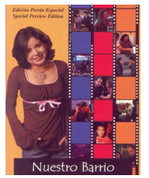
47 Lisa Xu and Bilal Zia, "Financial Literacy Around the World," World Bank Policy Research Paper, June 2012, http://bit.ly/1034HOR

48 Monique Cohen and Candace Nelson, "Financial Literacy: A Step for Clients Towards Financial Inclusion," Microcredit Summit Campaign, accessed Aug. 1, 2015, http://bit.ly/1TSBX2z

- In Mexico, a show about people struggling with and overcoming illiteracy led one million people to enroll in literacy programs.
- In Tanzania, a series of dramas highlighting the country's high fertility rate led to broader discussion of family planning in low-income households (Figure 11).

Beyond these noted development outcomes, TVs remain a centerpiece for modern consumption of entertainment. Promoting greater access helps fulfil a strong latent demand by under-electrified consumers for what they perceive as better quality lives.

FIGURE 11: Impact of TV shows on BoP households



NUESTRO BARRIO, a Spanish-language soap opera, or telenovela, has been designed to reach Latino immigrants in the United States with financial education.

- The story follows a middle-class Latino family in the United States as they encounter financial obstacles.
- A study demonstrates that during the tenure of the telenovela from 2006 to 2008, North Carolina saw an increase in bank inquiries and account openings from their Latino demographic.
- Other results have shown that the television show has had positive impacts on viewers' attitudes with regard to preparation for homeownership.

MAKUTANO JUNCTION is a popular soap opera with over seven million viewers in Kenya alone.

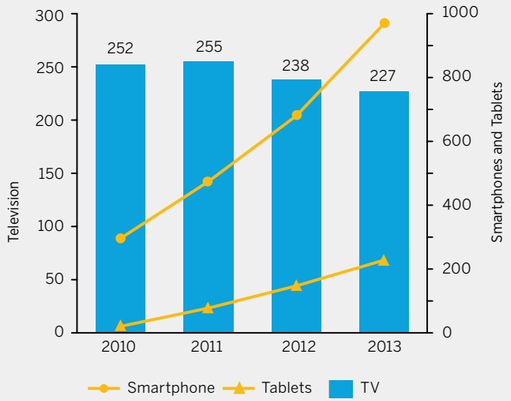
- The show informs viewers of their rights and service delivery entitlements through compelling stories in a soap format, covering a range of development issues including financial education.
- Information from interviews with viewers, market research, and feedback via text message is used for measuring impact.
- Pre-broadcast, 36% of viewers agreed with the statement, "all parents have the right to become primary school committee members"; after the broadcast, the number grew to 96%.

SHAMBA SHAPE UP, a television show in Kenya, aims to provide information to farmers on how to improve their incomes and livelihoods, by visiting local farms to give them a "makeover."

- A financial expert visits the farms to demonstrate relevant financial principles that can also be easily adopted by viewers (e.g., investment needed for fertilizers).
- According to research conducted in 2014, half a million households reported that they made changes to their agricultural practices as a result of the show, leading to a net economic impact of $24 million.
- It is suggested that even if 10 percent of the estimated audience of 10 million adopt the practices the show promotes, this would result in an additional $210 million of revenue generated.

Source: Jonathan Spader, Janneke Ratcliffe, Jorge Montoya, and Peter Skillern, "The Bold and the Bankable: How the Nuestro Barrio Telenovela Reaches Latino Immigrants with Financial Education," Journal of Consumer Affairs 43 no.1 (2009): 56–79.

FIGURE 12: Global shipments of entertainment devices
In million units



Source: Statista

Market opportunity for manufacturers

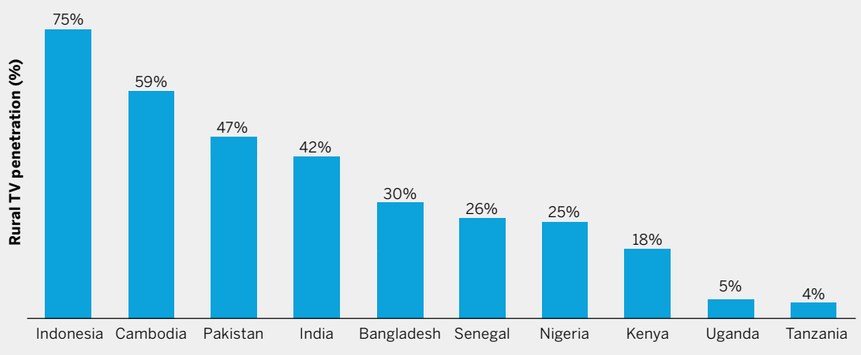
The off-grid market represents an opportunity to mitigate stagnating sales in conventional TV markets. Traditionally, developed markets have made up a significant majority of the global TV market. However, with the increasing saturation of these markets, a lack of need for frequent replacement, and the growing use of smartphones, tablets, and PCs for consumption of content traditionally viewed on TVs, TV sales have decreased globally for two years running (Figure 12). Off-grid markets thus represent a major growth opportunity for TV manufacturers.

Rural penetration of televisions varies across the globe, but in general is tied to levels of rural electrification, income levels, and density. Rural penetration of televisions ranges from as low as 4 percent in Tanzania[49] to 75 percent in Indonesia[50] (Figure 13). Alongside electrification levels and affordability, findings indicate a correlation with density. Density can improve product availability and distribution costs. It can also correlate with availability of content, given that the per-viewer broadcasting costs decrease for content providers in high-density areas.

Most televisions used in rural areas are older generation, energy-inefficient CRT (cathode ray tube) televisions. The power consumption for a small CRT television is more than three times that of an LED/LCD television of the same size.[52] This limits their applicability both to places where some grid power is available and to richer households with substantial diesel generation capacity.

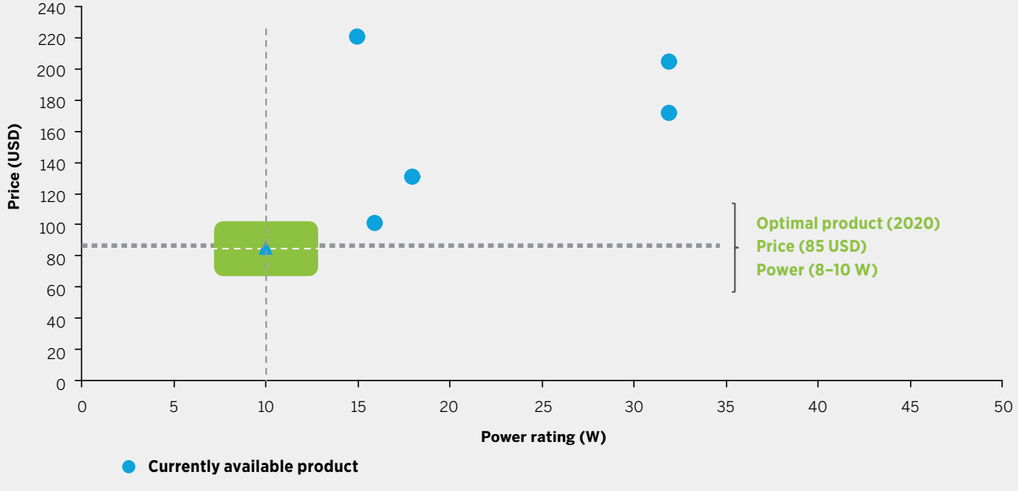
Technological advancements have yielded LED products that are suitable for the off-grid market. With increasing LED efficiencies, television options have started aligning with the energy reality in rural and off-grid regions. While a majority of 19" LED televisions have rated wattage of around 15W, a few outliers that consume only 10W are emerging in the market today. In addition to market-driven improvement in core LED technology, programmatic interventions like the 2013-14 Global LEAP Awards for off-grid color televisions have called attention to the need to develop and market high-quality, energy-efficient, appropriately-designed, and affordable off-grid televisions.[53]

FIGURE 13: Estimated rural penetration of televisions (2009–2013)[51]



Source: Demographic and Health Surveys, National Census (2009–2013); Dalberg analysis

FIGURE 14: Estimated price vs. power rating of currently available off-grid TVs



Source: Interview with manufacturers and distributors; Alibaba; Dalberg analysis

49 "Tanzania Housing Condition, Household Amenities and Assets Monograph," Population and Housing Census, 2012.

50 "Indonesia Demographic and Health Survey Statistics," Ministry of Health, Aug. 2013.

51 "Household Consumption of Various Goods and Services in India," NSS 66th Round, Feb. 2012; "Indonesia Demographic and Health Survey Statistics," Ministry of Health, Aug. 2013; "Tanzania Housing Condition, Household Amenities and Assets Monograph," Population and Housing Census, 2012; "Uganda Demographic and Health Survey," Uganda Bureau of Statistics, Aug. 2012; "Senegal Demographic and Health Survey—Multiple Indicator Cluster Survey (EDS-MICS)," ICF International, Feb. 2012; "Pakistan Demographic and Health Survey," National Institute of Population Studies, Dec. 2013; "Kenya Demographic and Health Survey," Kenya National Bureau of Statistics, June 2010; "Bangladesh Demographic and Health Survey 2011," National Institute of Population Research and Training, Jan. 2013; Nigeria LSMS, "Integrated Surveys on Agriculture General Household Survey Panel," National Bureau of Statistics, 2012; and "Cambodia Inter-Censal Population Survey 2013," National Institute of Statistics, Nov. 2013.

52 Alan Hedge, "Ergonomics Considerations of LCD versus CRT Displays," Department of Design & Environmental Analysis, Cornell University, accessed June 5, 2015, http://bit.ly/1Lhgvgt

53 "2013–2014 Off-Grid Color Television Awards," Global LEAP, accessed June 5, 2015, http://bit.ly/1Xy1g9X.

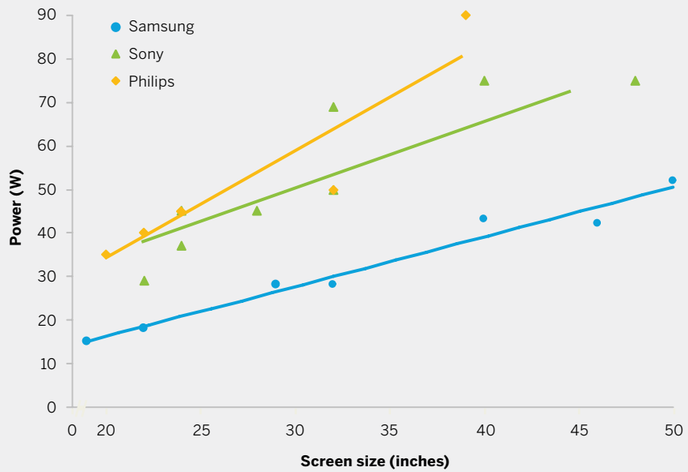
Analysis and projections suggest that a 19" LED/LCD TV offers the best trade-off between price, power consumption, and appeal for the average under-electrified consumer. At present, a majority of the energy-efficient TV models for off-grid markets are around the 15" screen size. However, rural customers would prefer larger TVs because they often have large families that watch together and invite large groups to watch them. The cost of producing 19" LCD panels has decreased significantly, narrowing the price differential between 15" and 19" TVs.[54] TVs larger than 19", however, remain substantially more expensive and consume more power. As a result, 19" TVs are expected to be the most popular product in the off-grid market through 2020. If efficiency and cost improvements are dramatic, many consumers may trade their savings for larger screen sizes.

Technology trends

Innovations in the LED backlit panel could bring the total cost of production of a 19" TV to below $90 USD in the next few years. The LED backlit panel accounts for more than half the total cost of the TV (≈52 percent).[55] As the efficiency of LED lights improves, the cost of the LED panel will decrease, due to improvement in the efficiency of individual LEDs and because fewer LEDs can sustain the same picture quality. Reports suggest that the average LED efficacy for TVs has increased by almost 50 percent recently (50–70 lm/W in 2010, to 100–125lm/W in 2012).[56] Continued efficiency and cost gains in the LED panel will reduce the retail price of a 19" TV to ≈$85 USD by 2019 (Figure 17).

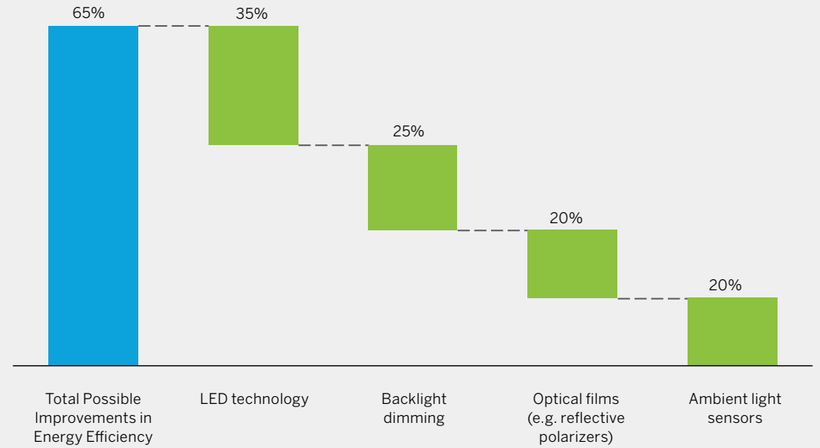
Improving panel transmittance and the efficiency of optical films can also drive overall improved efficiency. The final luminance the screen emanates is less than 10 percent of the initial luminance the LED backlight source generates, largely because of polarizers in the panel that absorb luminance.[57] Studies suggest that small efficiency improvements in the polarizers can have a significant impact on a television's energy consumption by decreasing the initial luminance the LED backlight must supply.[58] Reflective polarizers, for example, can improve TV efficiency by 20–30 percent. [59] The capacity to dim the LED backlight when displaying dark images also has a significant impact—depending on input images and dimming method, it can improve the energy efficiency by 10-60 percent.[60] Further, ambient light sensors that adjust brightness relative to light levels can improve energy efficiency by another 20 percent.[61] Finally, panel designs that decrease the luminance required by the LED backlight, improving its transmittance, will further decrease the overall energy consumption.

FIGURE 15: Power consumption vs. screen size for Samsung, Sony, and Phillips TVs



Source: Company websites; Amazon.com; Dalberg analysis

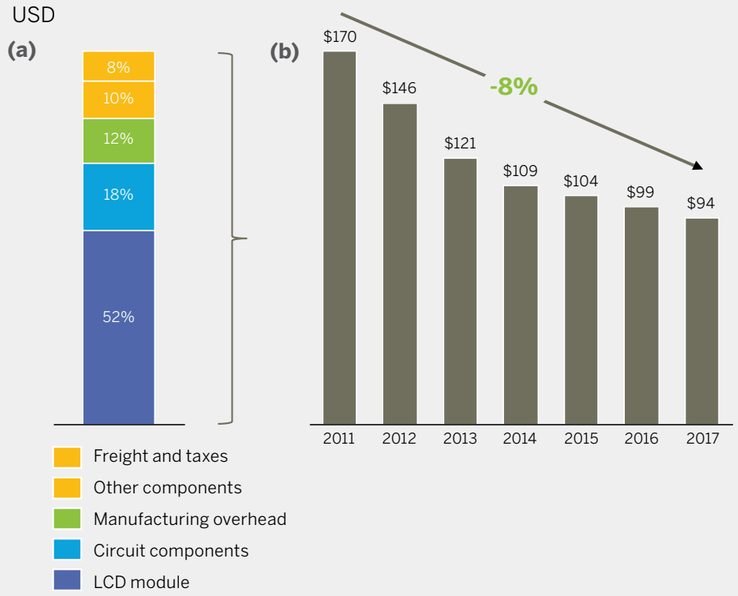
FIGURE 16: Energy efficiency improvement options for mainstream televisions
% relative contribution to total possible improvement



Source: Park, et al.; Dalberg analysis

54 Interview with expert in Television Technology, LG Resources Institute, March 1, 2015.
55 Won Young Park, Amol Phadke, Nihar Shah, and Virginie Letschert, "Efficiency Improvement Opportunities in TVs: Implications for Market Transformation Programs," Energy Policy 59 (2013): 361–372, http://bit.ly/1XiPNet
56 Ibid.
57 Ibid.
58 Ibid.
59 Won Young Park, Amol Phadke, and Nihar Shah, "Efficiency Improvement Opportunities for Televisions In India: Implications for Market Transformation Programs," Energy Efficiency 7, no.5 (2014): 811–832, http://bit.ly/1Kc01eF
60 Ibid.
61 Park, et al. 2013.

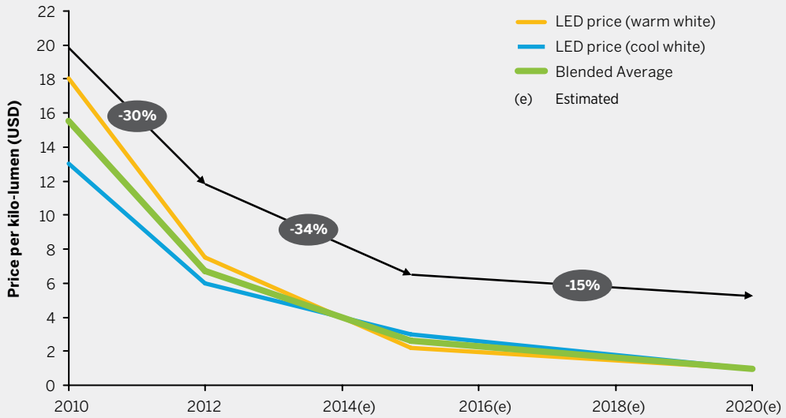
FIGURE 17: (a) Breakdown in cost of production; (b) Projections for the retail price of 19" TV



Source: Expert interviews; Dalberg analysis

FIGURE 18: Evolution of LED prices

USD per kilo-lumen; 2010–2020



Source: Department of Energy; Lighting Africa; Dalberg analysis

Other entertainment devices

Driven by global technology trends and reductions in LED costs, tablets and LED projectors may also have potential in the off-grid market. Low-cost tablets are currently available at competitive price points, and as a result could be considered a substitute for televisions. To date, a lack of aspirational value (TVs serve as a conspicuous asset), small screen-size and therefore reduced viewing angles and distances for larger groups of people, high digital literacy requirements, and the need for internet connectivity to access content have inhibited demand. However, given affordability, portability, and low energy requirements, their relevance for some off-grid households is high. While LED projectors attached to tablets would permit viewing by a large audience, content compatibility, price, energy requirements, and general awareness pose barriers to adoption.

USB-C port: An innovation in favor of universality

USB-C ports have great potential to complement off-grid, energy-efficient televisions. The USB-C port is emerging as the new industry standard connector, and may transform the current consumer electronics landscape. USB-C ports offer several advantages. First, they allow power transfer both ways, enabling charging for both the host and peripheral devices (phones, computers, etc.). Second, they support a much higher power output (20V, 100W) than normal USB ports, so even higher capacity devices like computers can use the USB-C port to charge, eliminating the need for big and inefficient power adapters.[62] Using USB-C ports in off-grid televisions would thus offer a distinct advantage, creating an open platform where one single, robust solution can facilitate power and connectivity for a range of devices. The current landscape of many different plug and connector types is an unnecessary market barrier.

Quality considerations

Factors that can affect the viewing experience for off-grid consumers merit equal attention to improvements in energy efficiency, and efficiency gains should not compromise these factors. These are set out below.

- **Picture quality:** Because of efficiency improvements, the average number of LED lights used in television displays has been decreasing (e.g., a projected decrease of 35 percent in number of LED lamps used for a 32" TV in 2015, as compared to 2011).[63] However, while using less than optimal LED lights can achieve higher efficiencies, it can have a negative impact on the illumination and the picture quality, affecting off-grid consumers' experience. Therefore, the objective should be to achieve maximum energy efficiency at an optimal illumination point.
- **Audio quality:** LED televisions have two kinds of lighting—direct lighting, which has a full array of LEDs spread across the back of the panel, and edge lighting, in which LEDs are located on the sides of the panel.[64]

62 Dong Ngo, "USB Type-C: One Cable to Connect Them All," CNET, March 9, 2015, http://cnet.co/1V44n8b

63 Park, et al. 2013.

64 David Carnoy and David Katzmaier, "LED TVs: 10 Things You Need to Know," CNET, June 4, 2010, http://cnet.co/1SIAX24

Edgelit LED TVs are more efficient as they employ fewer LEDs, and achieve greater thinness as the extra LED layer is eliminated.[65] As a result, Edgelit LED TVs are the most popular model in the television market today. However, increasing thinness means that the speaker drivers also need to be much smaller, which affects the sound quality of lower-end TVs disproportionately.[66] Off-grid appliance distributors suggest that poor sound quality in modern off-grid televisions often results in poor consumer experience and affects product uptake. Therefore, manufacturers need to focus on providing high-quality in-built or separate sound systems that can help achieve optimal sound levels.

- **Viewing angles:** Viewing angles are the maximum angle at which a television allows viewing without unacceptable deterioration in brightness levels and overall picture quality.[67] Providing good viewing angles usually poses a challenge to designers of LED televisions, regardless of the LED backlighting they employ, and even premium manufacturing segments face this problem.[68] Off-grid appliance distributors suggest that off-grid consumers may desire a TV that as many as 100 people can watch at a time, making viewing angles of particular concern to this market.[69]

B. Refrigerators

The off-grid refrigerator market has the potential to grow at a rate of 37 percent annually. Estimates show annual spending on off-grid refrigeration products in 2020 could reach USD $1.1 billion, given expected technology innovation leading to increased energy efficiency and price reductions, modified design, and improved supply.

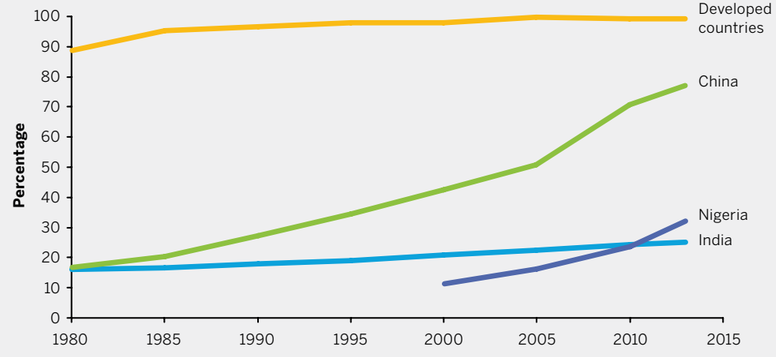
Refrigerators require a large initial current surge to turn on—often more than twice what running the appliance requires. Reducing this initial surge will greatly enhance the viability of refrigerators for off-grid communities. Minimizing thermal loss either through improved door functionality (e.g., more effective gaskets or magnetic linkages) or improved insulation materials will improve efficiency and lower the energy demands of refrigerators. Overall, off-grid refrigeration products require additional research and development on technology and design to unlock their commercial potential.

Key considerations for off-grid refrigerator products

Off-grid refrigerators designed for household use can also support income-generating activities. Refrigerators improve quality of life in off-grid households by preserving the nutritional value of food; consumers in tropical climates demonstrate a particularly high need for refrigeration to address food storage challenges.[70] However, high up-front costs and energy consumption create a barrier to uptake of refrigerators for household use only.[71] Unlike other product categories, demand for refrigerators will be driven in part by their potential contribution to income-generating activities. For example, the Indian conglomerate Godrej and Boyce targeted Chotukool, a low-cost, portable thermoelectric refrigerator, at rural customers for household use. However, the household market for this product has not been nearly as strong as the small enterprise market, such as roadside kiosks and small grocery stores selling chilled water, milk, soft drinks, or chocolates. A prominent global solar product distributor reports that sellers of drinkable yoghurt in rural, off-grid regions of its African markets are driving demand for its off-grid refrigerators.[72] In Bangladesh, refrigerators are in high demand among fishermen, who use them to preserve their catch before its transportation to market.[73]

Refrigerators used in off-grid regions are often energy inefficient and potentially dangerous. In areas with only unreliable grid electricity, many households will run standard AC refrigerators for only 2–4 hours a day. Given the high initial current surge the appliances demand every time they turn back on, this is a highly energy-inefficient method of use. Intermittent refrigeration also provides minimal prevention of spoilage of perishable food and preservation of its nutritional value, and can lead to mistaken belief that spoiled food is fresh. Another common off-grid option is propane refrigeration, which is not optimal for several reasons. Propane refrigerators are energy inefficient and have high operating costs. Further, propane refrigerators can be dangerous because of the presence of highly combustible materials.[74] The cooling systems of propane

FIGURE 19: Global household penetration of refrigerators (1980–2013)



Source: Euromonitor International; Alliance Bernstein; Lawrence Berkeley National Laboratory

65 Ibid.
66 "HDTV: Getting the Best Sound Quality," SmartReview, Jan. 10, 2015, http://bit.ly/20oTzTw
67 "Wall Mounting: A Solution to LCD/LED Viewing Angle Issues," SANUS, http://bit.ly/1Q7zTO4
68 David Carnoy and David Katzmaier, "LED TVs: 10 Things You Need to Know."
69 Interview with off-grid appliance manufacturer, Africa, Feb. 7, 2015.
70 Interviews with appliance distributors in India and Nigeria, Feb. 4, 2015, Feb. 23, 2015, and July 15, 2015.Interview with off-grid appliance distributor, India, July 15, 2015.
71 Interview with off-grid appliance distributor, Australia, Feb. 16, 2015.
72 Interview with off-grid appliance distributor, Bangladesh, Oct. 3, 2015.
73 Larry Schlussler, "Off Grid Refrigeration: Solar Electric vs. Propane," Sun Frost, July 25, 2014, http://bit.ly/20LGvgv.
74 Ibid.
75 Tassos Stassopoulos, "Cold Facts in Emerging Market Fridges," Alliance Bernstein Blog, July 20, 2014, http://bit.ly/1nYSGol

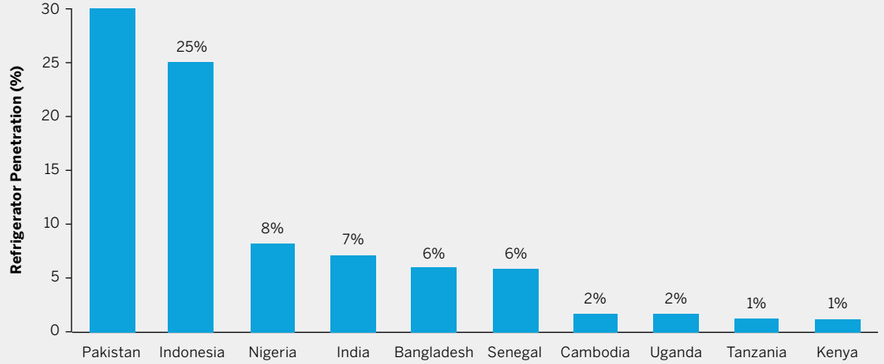
refrigerators often leak, creating a risk of fire and explosion. Propane refrigerators also generate carbon monoxide, and thus require a direct outside air supply and exhaust mechanism.[75]

Market opportunity for manufacturers

The off-grid refrigerator market is extremely nascent. The market for refrigerators in the developed world is more or less saturated and presents limited opportunity for growth, with a 99 percent penetration rate and a low replacement rate of 10–15 years.[76] The penetration of refrigerators in developing countries, specifically in rural areas, remains extremely low (Figure 20). Studies indicate that, historically, the penetration of refrigerators starts to take off at an average annual per capita income of USD $2,500.[77] Developing low-cost, high-quality, energy-efficient refrigerators customized for rural, off-grid markets can contribute to the increased uptake of refrigerators for households at even lower income levels.

Mainstream manufacturers primarily focus on achieving higher efficiencies for refrigerators sold in leading markets. After air conditioners, refrigerators are the second most energy-intensive appliances, consuming 13.7 percent of the total energy an average household uses in the developed world.[79] Due in large part to improved technologies and a heavy policy focus on the efficiency of refrigerators from the governments in leading markets, refrigerators manufactured in 2014 are on average 30 percent more efficient

FIGURE 20: Estimated rural penetration of refrigerators (2009–2013)[78]



Source: Demographic and Health Surveys, National Census (2009–2013); Dalberg analysis

76 Richard Dobbs, Jaana Remes, James Manyika, Charles Roxburgh, Sven Smit and Fabian Schaer, "Urban World: Cities and the Rise of the Consuming Class," McKinsey Global Institute, June 2012, http://bit.ly/1osapoK

77 "Household Consumption of Various Goods and Services in India," NSS 66th Round, Feb. 2012; "Indonesia Demographic and Health Survey Statistics," Ministry of Health, Aug. 2013; "Tanzania Housing Condition, Household Amenities and Assets Monograph," Population and Housing Census, 2012; "Uganda Demographic and Health Survey," Uganda Bureau of Statistics, Aug. 2012; "Senegal Demographic and Health Survey—Multiple Indicator Cluster Survey (EDS-MICS)," ICF International, Feb. 2012; "Pakistan Demographic and Health Survey," National Institute of Population Studies, Dec. 2013; "Kenya Demographic and Health Survey," Kenya National Bureau of Statistics, June 2010; "Bangladesh Demographic and Health Survey 2011," National Institute of Population Research and Training, Jan. 2013; Nigeria LSMS, "Integrated Surveys on Agriculture General Household Survey Panel," National Bureau of Statistics, 2012; and "Cambodia Inter-Censal Population Survey 2013," National Institute of Statistics, Nov. 2013.

than in 2000, reducing the average energy consumption to ≈400 KWH per year.[80]

Despite increasing efficiencies, these large, standard household refrigerators are not viable for off-grid communities. Even an extremely energy-efficient AC refrigerator, such as urban electrified households use, consumes too much energy for an off-grid household. The energy consumption of an average refrigerator can range from 1 to 2.5 kWh per day,[81] which is significantly higher than what most off-grid power systems can support. An off-grid solar system would need at least 2 kWp of capacity to support such a product, and even then would only be able to power the refrigerator for a few hours each day.[82] Second, while the upfront cost of a small AC refrigerator may be as low as $200 USD, the requirement of much higher and relatively constant energy input means that the lifetime costs—particularly on an off-grid system—can increase significantly. Refrigerators with greater energy efficiencies are also considerably more expensive, further complicating their viability in off-grid markets. Finally, these refrigerators require an extremely high initial surge of energy, such that a standard refrigerator that runs on 800W will consume 1600W when the refrigerator is first switched on and the compressor initiates.[83]

The off-grid market favors smaller refrigerators; the average preference is for the 50–80L size. Ethnographic studies suggest that rural, under-electrified consumers prefer smaller refrigerators than urban electrified households.[84] Given limited financial resources, the stocking needs of off-grid households are relatively low. Most of these consumers purchase groceries very often, because of their staggered income patterns. Hence, they need a cooling solution that helps them keep fresh produce and leftovers for only one or two days. For households that also use refrigerators for livelihood generation purposes, irregular cash flows and low sales also limit their storage needs. Most of these households and small shops have space constraints and prefer a smaller, portable solution that can be moved around easily to accommodate other assets.[85] Therefore, small refrigerators (50–80L) are seen by the industry as the highest demand in the off-grid segment.

Key barriers on both price and energy consumption need to be addressed in order for refrigerators to be viable for off-grid communities. Very few off-grid enterprises in key markets currently offer a refrigerator to their consumers.[86] These enterprises cite high upfront costs and energy consumption, relative to other off-grid appliances, as the major barriers to the uptake of refrigerators. Based on insights from off-grid suppliers in Africa and Asia, small off-grid refrigerators need to decrease in price to approximately $200 USD and work on less than 40 watts in order for these products to be viable for the rural, off-grid customer.[87] However, as Figure 21 suggests, currently available products do not approach this configuration.

78 Sean Boyle, Justin Loiseau, Mary Cooper, Nicole Meyer, Min Dong, Daniel Turner, Selena Elmer, and Sarah White, "Energy Efficiency and Recycling in Public Housing Apartments," UNC Institute for the Environment, 2012, http://bit.ly/1O365Rv

79 Tyler Wells Lynch, "Your Next Fridge Will Be More Efficient. Here's Why," Reviewed.com, Updated Sept. 16, 2014, http://bit.ly/1V45nt3

80 "Residential Refrigerator Qualifying Product List" Consortium for Energy Efficiency Program Library, accessed Oct. 14, 2015, http://bit.ly/23XdbTf

81 Interview with SHS enterprise, Nigeria, Feb. 23, 2015.

82 Kevin Hunt, "What You Should Know About Using a Portable Generator," Hartford Courant, Oct. 29, 2012, http://bit.ly/1Q7AnnA

83 "How Can You Enter an Emerging Market—and Improve the Lives of Millions?" Innosight, accessed July 1, 2015, http://bit.ly/1WeuxWa

84 Charles Dhanaraj et al., "Godrej Chotukool: A Cooling Solution for Mass Markets," http://bit.ly/1KFMmMO

85 Out of the 17 off-grid enterprises interviewed, about six offer a refrigerator currently, but only on a demand basis.

86 Interviews with SHS suppliers in Bangladesh and Africa, February 2014.

87 Interview with Super-efficient Equipment and Appliance Deployment (SEAD) Initiative, May 19, 2015.

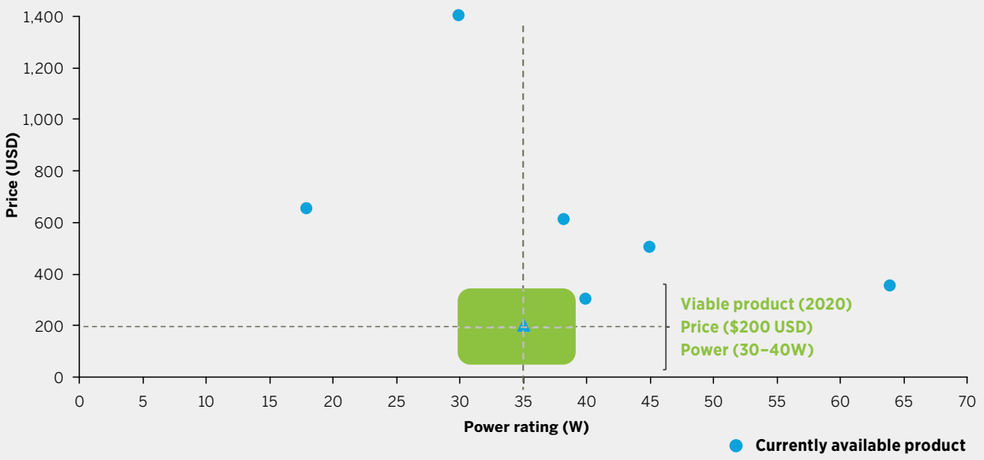
Technology trends

The compressor and insulation are the most significant drivers of energy efficiency in a compressor refrigerator. The compressor consumes more energy than any other aspects of a refrigerator.[88] Insulation traps air and slows down the transfer of heat from the surroundings to the refrigerator's cold interior, reducing the energy the appliance requires. As the efficiency of insulation increases, the efficiency of the compressor becomes the major determinant of overall energy consumption.[89]

Effective insulation can help increase the overall energy efficiency of a refrigerator by up to 30 percent, and many off-grid refrigerators already employ such insulation. Most refrigerators currently use about 1.5 inches of polyurethane foam for insulation. Increasing the thickness of the insulation can reduce thermal loss, and hence increase energy efficiency. Some off-grid refrigerators use about 4–4.5 inches of polyurethane insulation—interviews with stakeholders indicate that this can reduce energy consumption by as much as 30 percent.[90] Research suggests that insulation thicker than 4.5 inches does not result in any further significant improvement.[91] Increasing the thickness does, however, lead to higher cost of production and reduces the portability of a refrigerator, which can affect product uptake.

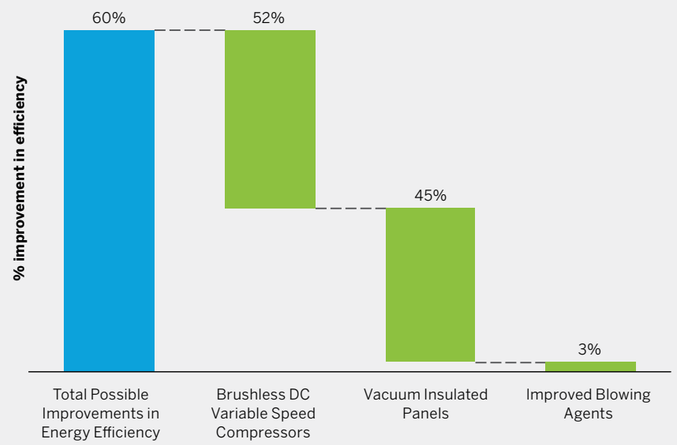
Emerging insulation technology has the potential to radically improve off-grid refrigerator performance and portability, but is 8–10 years away from commercialization. There is a need to develop alternative insulation materials that can help improve the energy efficiency of off-grid refrigeration without negatively affecting purchase price or consumer appeal. Vacuum insulated panels (VIPs) are a form of ultra-thin, high-performing thermal insulation technology that is much more effective at preventing heat loss than other insulation materials.[92] For example, VIPs that are one-inch thick have the same insulation performance as six-inch thick polyurethane insulation.[93] However, VIPs are significantly more expensive to manufacture than the polyurethane insulation (25–30 percent more on an average), which has prevented their widespread commercial use. VIPs are also fragile, leading to greater costs in handling processes and installation. Experts indicate that it could be ten years before a transformation in insulation technology, such as broad uptake of VIPs, is commercially available.[94] More effective blowing agents, which are the mechanism through which insulation is applied to refrigeration systems, can improve the distribution of insulation and also lead to minor gains in energy efficiency. For example, Whirlpool has recently launched Solstic, a new blowing agent that increases overall energy efficiency of refrigerators by 2–3 percent.[95]

FIGURE 21: Comparison of price vs. power consumption of currently available off-grid refrigerators



Source: Interview with manufacturers and distributors; Alibaba; Dalberg analysis

FIGURE 22: Energy efficiency improvement options for mainstream refrigerators
Percent relative contribution to total possible improvement



Source: D. Clodic and A. Zoughaib, "Technical and Economical Evaluation of Vacuum Insulated Panels for a European Freezer"; Tim Somheil, "Whirlpool Refrigerators Become First Commercial Application for a Polyurethane Insulation System Using HFO Blowing Agent"; Expert interviews; Dalberg analysis

88 Ibid.

89 Currently, many providers including Sundanzer, Phocos and Barefoot Power provide refrigerators with 4 inches of insulation.

90 Mir-Akbar Hessami, "Calculating Energy Rating of Domestic Refrigerators through Laboratory Heat Transfer Measurements and Computer Simulations," Paper presented at the Proceedings of Clima 2000 Conference, Aug. 30 to Sept. 2, 1997; See, also, L.B. Christensen, "The Insulation of Freezers and Refrigerators: How Thick Should It Be?," International Journal of Refrigeration 2, no. 2 (March 1981): 73–76.

91 D. Clodic, and A. Zoughaib, "Technical and Economical Evaluation of Vacuum Insulated Panels for a European Freezer," Paper presented at the International Refrigeration and Air Conditioning Conference, 2000, accessed June 12, 2015, http://bit.ly/1XiW5KZ.

92 Mir-Akbar Hessami, "Calculating Energy Rating of Domestic Refrigerators through Laboratory Heat Transfer Measurements and Computer Simulations."

93 Edward A. Vineyard and James R. Sand, "Fridge of the Future: Designing a One Kilowatt-Hour/Day Domestic Refrigerator-Freezer," American Council for an Energy-Efficient Economy, http://bit.ly/20VSEvX.

94 Interview with refrigerator manufacturer, India, March 1, 2015.

95 Tim Somheil, "Whirlpool Refrigerators Become First Commercial Application for a Polyurethane Insulation System Using HFO Blowing Agent," Plastics Today, July 25, 2014, http://bit.ly/20LLzS0.

Innovations in variable speed compressors (VSC), which can result in energy savings of up to 40 percent, offer more immediate efficiency gains. Brushless DC compressors that have variable speed can adjust the refrigeration capacity by controlling the motor speed, and are more energy efficient. In addition to their impressive efficiency gains, VSCs reduce the initial current surge that fixed-speed AC motors require. VSCs can also better utilize the variable solar energy resources by allowing a compressor to operate longer. Refrigerators with VSCs have begun to enter the off-grid refrigeration market.

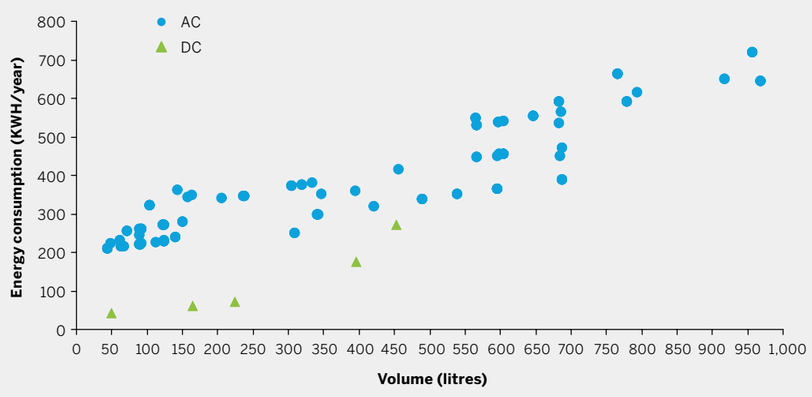
While DC compressor refrigerators designed for the off-grid setting are currently more expensive than energy-efficient AC refrigerators, increased production will likely reduce their retail price. Off-grid DC refrigerators tend to be significantly more expensive than mainstream AC refrigerators in part because production levels are extremely low.[96] Additionally, the advanced technologies DC refrigerators require (e.g., high-efficiency variable speed compressors discussed above) increase manufacturing costs. Suppliers estimate that as they reach scale the prices of off-grid DC refrigerators will reduce by 25–30 percent.[97] In addition, the relative energy efficiency of future DC products implies a lower off-grid energy supply requirement, further reducing costs (Figure 23). Figure 24 suggests that, over a ten-year period, the overall cost of an AC versus DC refrigerator is almost equal, even at today's retail prices.

Product design innovations can also contribute to significant improvement in energy efficiency for off-grid refrigerators. Improving gasket materials and magnetic linkage technology so that doors close completely and are airtight will increase the insulating effect of the doors and require less energy to keep the refrigerator cool. Experts also suggest that placing the compressor on top of the refrigerator rather than below, as is often the case with standard refrigerators, can reduce the impact of the compressor's waste heat in warming the refrigerator. Sun Frost already manufactures a refrigerator with the compressor on the top. Finally, a chest-style refrigerator that opens from the top loses less cold air when the door is opened. Off-grid refrigerator suppliers including Sundanzer, Phocos, and Barefoot Power offer chest-style refrigerators today. In general, however, even the most modern, energy-efficient refrigerators lose energy due to frequent door opening.

To eliminate the reliance on batteries, manufacturers of off-grid refrigeration products are focusing on direct drive technology to store energy during periods of limited sunlight; this technology is being explored for vaccine refrigerators specifically. Direct drive technology, also called phase change technology, stores solar energy in a frozen phase change material (PCM), which provides cooling for 5–6 days during the night and cloudy days, eliminating the need for battery systems (Figure 25).[98] However, refrigerators using the PCM technology currently have much higher energy consumption.

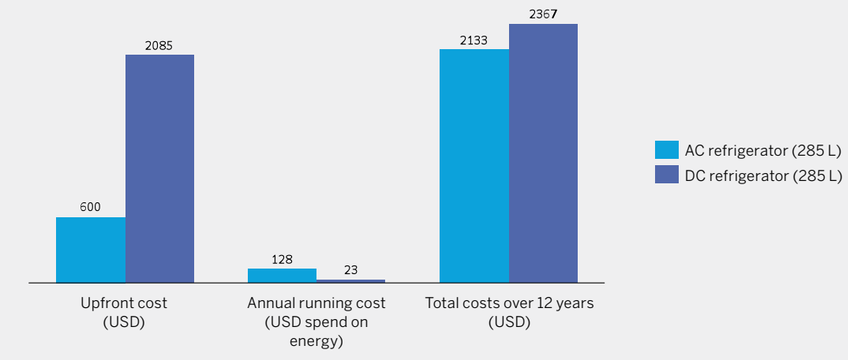
Emerging refrigeration technologies, such as thermoelectric, magnetic, or thermos-acoustic cooling, are not yet commercially viable. Figure 26 provides a brief description of emerging refrigeration technologies, and their respective energy consumption as compared to compression technology.[99] While refrigeration products

FIGURE 23: Comparison of annual energy consumption of AC vs. DC refrigerators



Source: Karina Garbesi, Vagelis Vossos, and Hongxia Shen, "Catalog of DC Appliances and Power Systems"; CEE list of AC energy-efficient refrigerators in 2015; Manufacturers' websites

FIGURE 24: Average energy consumption and lifetime costs of 285L refrigerator



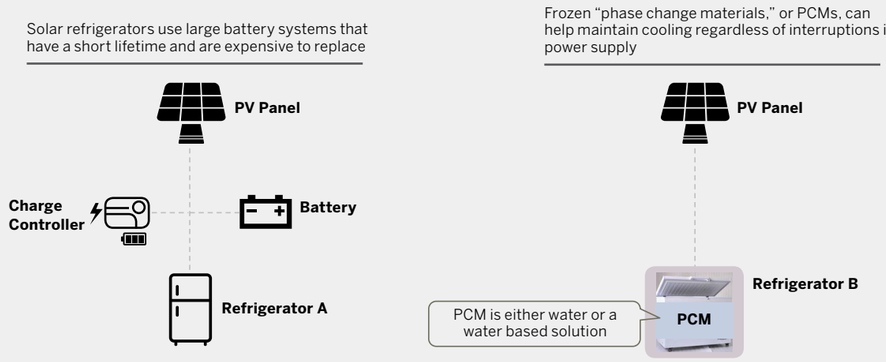
Source: Sun Frost; Energy.gov

96 Karina Garbesi, Vagelis Vossos, and Hongxia Shen, "Catalog of DC Appliances and Power Systems," Energy Analysis Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, Oct. 2011, http://1.usa.gov/1QVZzAA.

97 Interview with off-grid appliance distributors, Uganda and Australia, Feb. 13 and 16, 2015.

98 "Direct-drive Solar Vaccine Refrigerators—a New Choice for Vaccine Storage," Optimize, May 2013, http://bit.ly/1nZ2uif; and "The Prospects of Alternatives to Vapor Compression Technology for Space Cooling and Food Refrigeration Applications," Pacific Northwest National Laboratory and U.S. Department of Energy, March 2010, http://1.usa.gov/1TSJBdd.

FIGURE 25: Replacement of batteries with 'phase change materials' in an off-grid refrigerator



using thermoelectric cooling are available and relatively low-cost, low energy efficiency has rendered their application to be limited to niche markets, such as for camping. Products using magnetic or thermos-acoustic cooling are not yet available on the market today. Camfridge, a UK-based magnetic cooling company, is currently collaborating with Whirlpool to launch a household refrigerator.[100] The only application of thermos-acoustic cooling technology in refrigeration to date has been a Ben & Jerry's prototype developed at Penn State University in the USA.[101]

Quality considerations

Efficient and effective cooling is predicated on quality in all aspects of refrigerator design. Apart from transformative technological developments, the cooling performance of off-grid refrigerators depends on an effective compressor and door sealing, as described below.

- **Compressor selection and quality:** Since a compressor contributes the most to the end-price of a refrigerator, manufacturers of off-grid refrigerators have often selected inferior compressors in order to control costs.[102] However, compressors are an important driver of cooling performance, and poor-quality compressors can compromise both cooling and appliance longevity.
- **Quality of door seals and linkages:** Regardless of the cooling capacity of the compressor, poor sealing of the refrigerator doors can result in significant cooling loss and the build-up of frost and ice on the back walls of the refrigerator. Anecdotal evidence suggests some off-grid refrigerators have required frequent replacement of door seals and latches.[103] Durable and effective door seals and linkages improve performance.


Photo Credit: Jake Lyell / Alamy Stock Photo

FIGURE 26: Overview of alternative refrigeration technologies

TECHNOLOGIES	DESCRIPTION	ENERGY CONSUMPTION	COMMERCIAL VIABILITY	COST
Thermoelectric cooling	Transfers heat between two different types of materials using a thermoelectric chip	high	yes	low
Magnetic cooling	Cools material through exposure to a changing magnetic field	low	no	n.a.
Thermo-acoustic cooling	Uses high-amplitude sound waves to transfer heat	low	no	n.a.

Source: Camfridge; RAC Plus; NPR

99 Ibid.; "The Prospects of Alternatives to Vapor Compression Technology for Space Cooling and Food Refrigeration Applications." J.S. Lewis, I. Chaer, and S.A. Tassou, "Fostering the Development of Technologies and Practices to Reduce the Energy Inputs Into the Refrigeration of Food: Reviews of Alternative Refrigeration Technologies," Centre for Energy and Built Environment Research, School of Engineering and Design, Brunel University, July 2007, http://bit.ly/1TSKLoZ.

100 "Camfridge—Clean, Green & Magnetic," Camfridge, accessed Oct. 14, 2015, http://www.camfridge.com/.

101 "Sounds Cool! The Ben & Jerry's Project," Penn State University, Aug. 2015, http://bit.ly/1PNSF1i.

102 Interview with off-grid appliance distributors, Africa and Bangladesh.

103 Jeffrey Yago, "Solar-powered Refrigerators," Backwoods Home Magazine, Nov./Dec.2006, http://bit.ly/1RqofDw.

C. Fans

The off-grid fan market has the potential to grow at a rate of 15 percent annually. Estimates suggest annual spending on off-grid fan products in 2020 could reach USD $500 million, given expected technology innovation leading to increased energy efficiency, modified design, and improved supply.

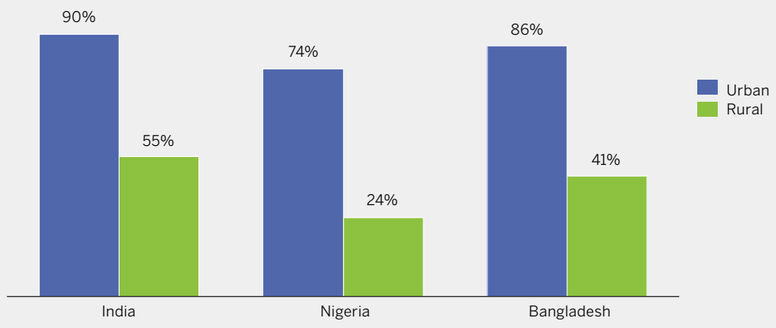
Table fans are likely to be one of the most popular cooling products for the rural, off-grid consumer; however, fans with other form factors that provide equivalent value could be just as viable, depending on consumer taste and infrastructural requirements. Given that the off-grid fan market is crowded, and consumers are fairly sensitive to price, incremental improvements in cost and energy efficiency are likely to increase product viability. Future innovations in the off-grid fan market will primarily come from brushless DC motors, variable speed drives, and improvements in blade design.

Demand drivers for fans in the off-grid market

Climate is a major determinant of demand for fans in off-grid markets. Consumers consider fans a necessity in regions with hot and humid climate conditions. The comfort they provide can contribute to increased productivity in off-grid households in such regions. Off-grid energy providers in South Asia suggest that fans are in very high demand in their markets, on par with LED lights and mobile charging applications in certain locations.[104] In other areas, however, such as East Africa, the demand for fans is little to none.[105]

Penetration rates differ drastically between rural and urban areas. Electric fans in developing countries are a highly mature product category, and urban markets are saturated (Figure 27). Contemporary appliances have a lifetime of eight years on average. In addition, air conditioners are becoming the preferred cooling technology in many urban markets in the developing world. From 2003–2013, developing countries have registered some of the highest growth rates in the air conditioner markets (e.g., 30 percent compound annual growth rate in India). However, air conditioners remain out of reach for most households in rural markets. Since the penetration of electric fans in rural regions of developing countries remains below 50 percent in key off-grid markets (Figure 28), this category of consumer is the key to growth in the fan market.

FIGURE 27: Total urban vs. rural penetration (percent) of electric fans in select countries (2012–2013)[106]

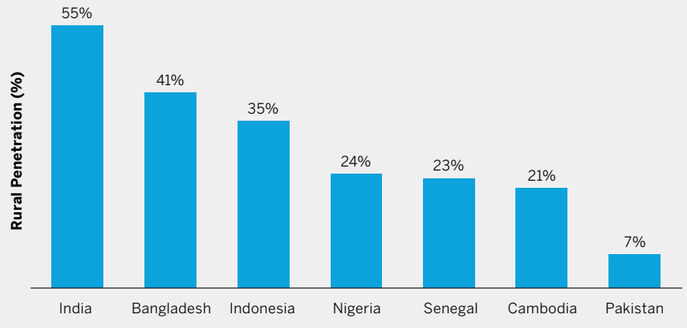


Source: Demographic and Health Surveys and Country Census Data (2009–2013)

Market opportunity for manufacturers

Table and pedestal fans are the most popular designs in off-grid markets. At present, off-grid fan manufacturers primarily offer four categories of fans: (i) table fans for cooling smaller spaces; (ii) pedestal fans that provide an adjustable height and oscillation for convenient operation; (iii) ceiling fans; and (iv) box fans that are encased in a square covering for placement in windows. A table fan is typically the first cooling appliance that a household with limited resources and infrastructural constraints purchases. Their efficacy in small spaces, high portability, low price, and low energy consumption makes them attainable and attractive to many rural, off-grid households. Pedestal fans offer better airflow at a relatively minor price and energy differential. Ceiling fans are the most popular fan type in electrified markets of developing countries. For example, in India, ceiling fans generated 80 percent of the total sales volume of cooling products in 2014.[109] While ceiling fans are desirable for rural, off-grid households as well, infrastructural constraints (e.g., ceiling height requirements), relatively higher price, and high-energy consumption present a variety of challenges for uptake. Box

FIGURE 28: Estimated rural penetration of electric fans (2009–2013)[107]



Source: Demographic and Health Surveys and Country Census Data (2009–2013)

104 United Nations Foundation and CLASP, 2015; "BoP Consumer Willingness to Pay Survey," Dalberg, 2014.

105 1Interviews with off-grid appliance distributors, Africa, Feb. 2015.

106 "Household Consumption of Various Goods and Services in India," NSS 66th Round, Feb. 2012; "Bangladesh Demographic and Health Survey 2011," National Institute of Population Research and Training, Jan. 2013; and "Nigeria LSMS—Integrated Surveys on Agriculture General Household Survey Panel," National Bureau of Statistics, 2012.

107 Note: For Pakistan, the penetration of room coolers is taken to be the substitute for electric fans. For other Asian and African countries, where data is not available, penetration of existing devices in these countries has been used to estimate penetration of fans. "Household Consumption of Various Goods and Services in India," NSS 66th Round, Feb. 2012; Indonesia Demographic and Health Survey Statistics," Ministry of Health, Aug. 2013; "Senegal Demographic and Health Survey—Multiple Indicator Cluster Survey (EDSMICS)," ICF International, Feb. 2012; "Pakistan Demographic and Health Survey," National Institute of Population Studies, Dec. 2013; "Kenya Demographic and Health Survey," Kenya National Bureau of Statistics, June 2010; "Bangladesh Demographic and Health Survey 2011," National Institute of Population Research and Training, Jan. 2013; Nigeria LSMS, "Integrated Surveys on Agriculture General Household Survey Panel," National Bureau of Statistics, 2012; and "Cambodia Inter-Censal Population Survey 2013," National Institute of Statistics, Nov. 2013.

108 "Air Treatment Products in India," Euromonitor International, April 2015, http://bit.ly/1TcUHKS.

fans often require attachment to a window, which decreases their portability and appropriateness for poorer, rural houses. The majority of analyses in this section of the report focus on table fan products because of their wide prevalence and broad market.

A 12" table fan is considered the median preference for an off-grid household. The small and compact size of a 12" table fan allows for higher portability from one room to the other, depending on the needs of the household. Larger fans can seem bulky in small spaces or consume too much power for pure off-grid systems.

DC fans, specifically, are most relevant for this market, given high efficiency gains and a lower lifetime cost of ownership. While the upfront cost of an average 12" DC table fan is 50 percent higher than that of an AC fan, the DC fan has an overall lifetime cost of ownership almost 70 percent lower than the AC fan, including the running costs (Figure 30).

The crowded nature of the fan market and the low aspirational value of the product have made the market quite price-sensitive. Given the relatively low technological requirements and easy manufacturing process, generic brands have flooded the market across regions. Competition from low-price, low-quality generic products has given larger manufacturers little incentive to invest in new, energy efficient, appropriate technologies for the off-grid market because consumers typically choose fan products primarily based on price. Key suppliers in off-grid markets suggest that average rural, off-grid customers will be comfortable paying $10–15 USD for a 12" table fan.[109]

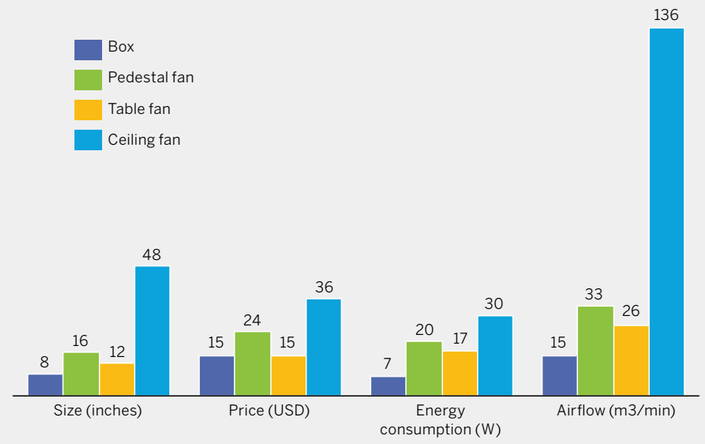
Fan products must continue to improve energy performance while maintaining affordability to increase market share. At present, the energy consumption of most commercially available fans is higher than a typical rural household can afford. While the upfront wattage of a fan is lower than that of a television, a fan is used for much longer durations, at times as long as 24 hours, which increases the energy consumption disproportionately. For example, a 10W off-grid fan with ten hours of usage would consume 100Wh of energy, while a 16Wh off-grid TV viewed for four hours would consume 64W. Currently available 12" off-grid fans range from 10–30W; none are currently under 10W, which consumption data and distributor input suggests would bring the running costs down enough to support far greater penetration into rural off-grid markets.[110]

Technology trends to increase energy savings

Several technological and design improvements have the potential to drive significant efficiency gains. However, improvements in energy efficiency should not reduce airflow and affordability.

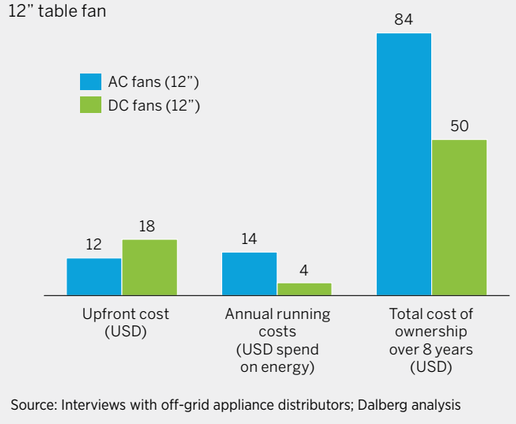
- **Innovation in electric motors.** Motors, more than any other component, drive the energy consumption of a fan. As a result of developments in electronic commutation and the increased availability of high-performing magnetic materials, brushless DC (BLDC) motors are becoming increasingly common.

FIGURE 29: Comparison of average size, FOB price, energy consumption, and airflow configurations for different off-grid fans



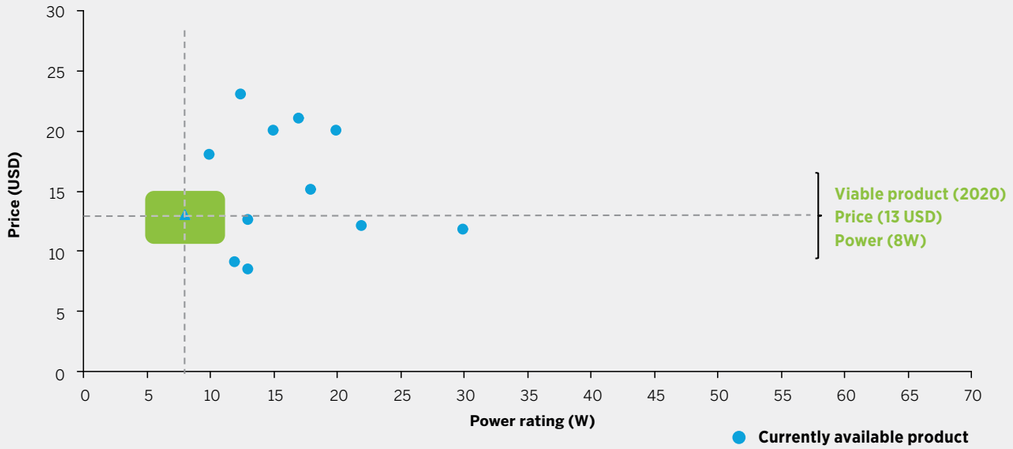
Source: Alibaba; Dalberg analysis

FIGURE 30: Comparison of the price and energy consumption of AC vs. DC fans



Source: Interviews with off-grid appliance distributors; Dalberg analysis

FIGURE 31: Estimated price vs. power rating of currently available off-grid 12" fans

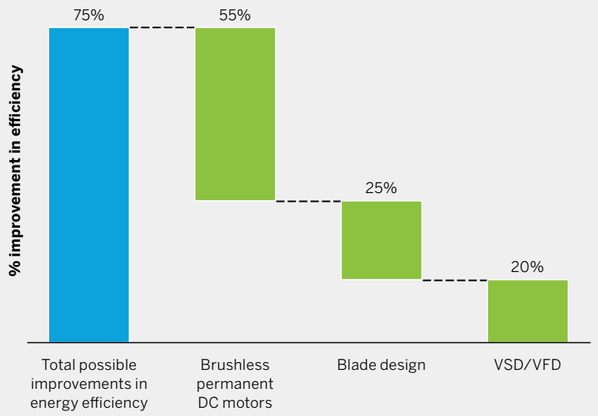


Source: Interview with manufacturers and distributors; Alibaba; Dalberg analysis

109 Interview with off-grid appliance distributor, Bangladesh, April 20, 2015 Interview with off-grid appliance distributor, Bangladesh, April 16, 2015.

110 Interview with off-grid appliance distributor, Bangladesh, April 16, 2015.

FIGURE 32: Energy efficiency improvement options for mainstream fans
% relative contribution to total possible improvement



Source: Nakul Sathaye et al., "Potential Global Benefits of Improved Ceiling Fan Energy Efficiency"; Paul Waide and Conrad U. Brunner, "Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems"; Dalberg analysis

BLDC motors do not have the friction losses inherent in standard motors, which makes them much more efficient. These motors are also smaller in size, with about 45 percent less materials needed for manufacturing, as opposed to a standard motor.[111] Using BLDC motors can increase the energy efficiency of a fan by more than 50 percent (Figure 32).[112] Many off-grid fans available in the market already use BLDC motors to increase the efficiency of their products. Projections suggest increased usage of BLDC motors in mainstream applications resulting in higher production volumes will decrease the cost of BLDC motors in the coming years. In addition to BLDC motors, advanced core design, low-resistance conductors, and low-friction bearings can provide further efficiency gains for off-grid fans.[113]

- **Variable speed and variable frequency drives (VSDs/VFDs).** VSDs/VFDs are a control technology that efficiently controls fan flow by making adjustments to the rotational speed. These controllers adjust the frequency supplied to a motor based on the required load (e.g., airflow), and thus help the motor operate over a wide range of speed. These technologies offer two major advantages: first, they can adjust the electric power input continuously to the required flow volume, which reduces the losses in partial load (e.g., mechanical resistance elements); second, they can help eliminate the need for components like gears, transmission, and clutches.[114] VSDs have the largest benefits for applications like fans and pumps, where power consumption is a function of the rotational speed.[115]
- **Improved blade design.**[116] Off-grid table fans can use twisted, tapered blades with an airfoil to reduce energy lost to turbulence and flow separation. However, widespread adoption of this design improvement has been delayed by real and perceived customer aesthetic preferences and costs.[117]
- **Smaller motors.** Motors used in fans are often oversized, and it is often possible to use smaller motors that are more efficient and cheaper. The initial premium of a higher-efficiency motor can be addressed by downsizing, which improves the efficiency and leads to a 5–10 percent lifetime costs savings.[118]


Photo Credit: Charles O. Cecil / Alamy Stock Photo

111 Louis-Benoit Desroches and Karina Garbesi, "Max Tech and Beyond Maximizing Appliance and Equipment Efficiency by Design," Lawrence Berkeley National Laboratory, July 20, 2011, http://bit.ly/1osozGu.
112 1Nakul Sathaye, Amol Phadke, Nihar Shah, and Virginie Letschert, "Potential Global Benefits of Improved Ceiling Fan Energy Efficiency," Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, April 2013, http://1.usa.gov/20p4zAp.
113 Louis-Benoit Desroches and Karina Garbesi, "Max Tech and Beyond Maximizing Appliance and Equipment Efficiency by Design."
114 Paul Waide and Conrad U. Brunner, "Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems," International Energy Agency, 2011, http://bit.ly/1PlMVdR.
115 Ibid.
116 Nakul Sathaye et al., "Potential Global Benefits of Improved Ceiling Fan Energy Efficiency."
117 Daljit Singh, Avinash Barve, and Girish Sant, "Ceiling Fan: The Overlooked Appliance in Energy Efficiency Discussions," Prayas Energy Group, 2012, http://bit.ly/1Kca8Ag.
118 Paul Waide and Conrad U. Brunner, "Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems". Interview with an off-grid appliance distributor, Africa, Feb. 16, 2015.

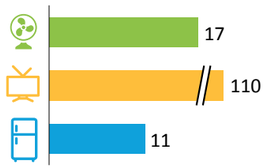
V. COUNTRY CASE STUDIES

Country Snapshot: Bangladesh

Market Overview

- Strong government support and consumer financing options, leading to a 60% CAGR in the last decade for SHSs, with 3 million systems installed
- Evidence suggests strong demand for target off-grid appliances (e.g., TVs, fans)

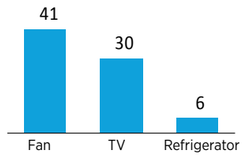
Potential Annual Spend, 2020



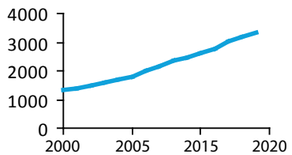
USD, millions

Market Overview

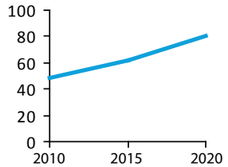
Rural penetration of household appliances (%, 2011)



GNI per capita, current USD PPP (2000–2014)



Electrification growth (%)



Current Market Landscape

Demand	Size Preference	Price (USD)	Major Suppliers
Very high	12"-14" Tabletop	$13-30	Maks Renewable Energy; Super Star Solar
High	15"-19"	$75-220	
Very low	60-80L	$300-500	

Early Innovator Case Study: Super Star Solar

Fan: Product Specs	Design Features	Market Status
12": $18–19 USD, 11–14W 16": $20–30 USD, 16–18W	Brushless DC motors and plastic body for fans	Between 200K–250K fans sold to date

Trends in the SHS market

- Fastest growing SHS market globally, given government support and targeted financing
- Millions of SHSs installed
- 60,000 new residential SHSs installed every month, with goal to install 6 million by 2017
- 60% CAGR for the SHS market in the last ten years

Country-Specific Market Barriers

- Like India, Bangladesh is significantly inhibited by high import tariffs, which can be as high as 90 percent.
- While IDCOL financing supports acquisition of SHSs, pay-as-you-go financing doesn't extend to off-grid appliances, making consumer affordability a challenge. Innovative consumer financing options can help jump-start growth.

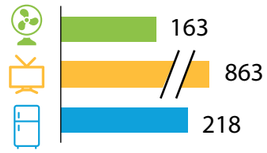
Source: *National Bureau of Statistics*, June 2010, "Bangladesh Demographic And Health Survey 2011", National Institute of Population Research and Training, January 2013, Edgar Meza, "Bangladesh installs 3 million residential solar systems", PV magazine, November 11, 2014. World Bank, World Energy Outlook, United Nations Department of Economic and Social Affairs, Population Division, Interview with off-grid appliance manufacturers and distributors, Dalberg analysis.

Country Snapshot: India

Market Overview

- Largest off-grid and under-electrified population in the world
- Greatest addressable market for target off-grid appliances globally
- Government support coupled with strong emergence of private sector models

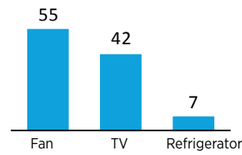
Potential Annual Spend, 2020



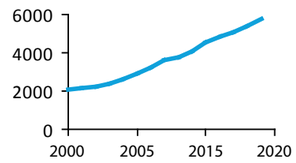
USD, millions

Market Overview

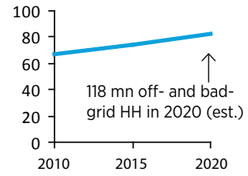
Rural penetration of household appliances (%, 2010)



GNI per capita, current USD PPP (2000–2014)



Electrification growth (%)



Current Market Landscape

Demand	Size Preference	Price (USD)	Major Suppliers
Medium-to-high	12"-16" Tabletop	$20-40	Barefoot; ONergy; SELCO; REMI; Simpa Network; Phocos
Very high	19"-22"	~$200	
Low	45-55L	$70-625	

Early Innovator Case Study: ONergy

Fan: Product Specs	Design Features	Market Status
10": 12W 16": 12-14W	Superior airflow, pedestal, and box fans	N/A

Trends in the SHS market

- Nascent market, with potential for rapid and significant growth
- 40 SHS players, with 80 percent system integrators, selling 1,000 units on an average every year
- Approximately 518,000 SHSs sold in 2014, with the total market of $35 million
- Market projected to grow at 60 percent per year to reach USD $200–250 million by 2018, with sales of over 3 million SHSs

Country-Specific Market Barriers

- Like Bangladesh, India is significantly inhibited by high import tariffs, which can be as high as 90 percent.
- In India, consumer financing is a significant challenge, and there is a need for additional MFIs for partnerships, and mobile money platforms, specifically in the most prominent off-grid regions (e.g., Bihar, Uttar Pradesh).

Source: Household Consumption of Various Goods and Services in India", *NSS 66th Round*, February 2012; The Climate Group, 2015; World Bank; World Energy Outlook; United Nations Department of Economic and Social Affairs, Population Division; Interview with off-grid appliance manufacturers and distributors; Dalberg analysis

Country Snapshot: Kenya

Market Overview

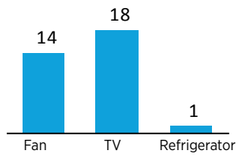
- Mature solar market, with good rural connectivity and effective policy environment around duties and quality control
- Most penetrated rural market for portable solar lanterns in Africa, indicating consumer willingness for solar solutions

Potential Annual Spend, 2020

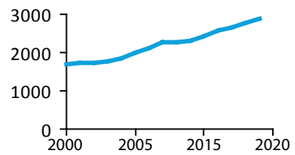
USD, millions

Market Overview

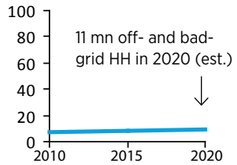
Rural penetration of household appliances (%, 2010)



GNI per capita, current USD PPP (2000–2014)



Electrification growth (%)



Current Market Landscape

Demand	Size Preference	Price (USD)	Major Suppliers
Very low	N/A	~$15	Barefoot Power; BBOXX; Omnivoltaic
Very high	15”–19”	$75-200	
Very low	50–55L	~$300	

Early Innovator Case Study: Sola

空 sola

TV: Product Specs	Design Features	Market Status
15”: 75 USD, 8W 19”: 90 USD, 13–16W	Working on multiple content compatibility and good viewing angles	Estimated sales of 200,000 units by the end of 2015

Trends in the SHS market

- One of the largest solar markets and most dynamic per capita
- 320,00 SHSs installed from the mid-1980s to 2010
- Low penetration rates (4.4% of rural households), indicating significant unmet demand
- Annual growth rate of solar PV systems around 10–15 percent since 1990s, mostly stemming from demand for residential SHSs; trend to continue

Country-Specific Market Barriers

- In Kenya, solar equipment and components receive government exemption from taxes. However, lack of clarity on which products qualify leads to several inconsistencies in implementation.
- Consumer financing for solar lighting and SHSs has traditionally been strong, with hire-purchase schemes, consumer loans by the development organizations, and savings and credit co-operatives, e.g., Women Enterprise Development Institute. Opportunity exists for organizations to extend financing support beyond lighting and energy provision.

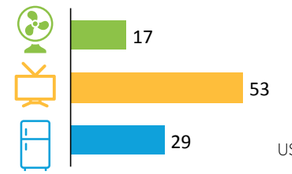
Source: “Kenya Demographic And Health Survey,” *Kenya National Bureau of Statistics*, June 2010; Daniel Kammen and Arne Jacobson, “Solar Innovation And Market Feedbacks: Solar Photovoltaics In Rural Kenya”, 2012, http://bit.ly/1WeEtin; P. Rolffs (et al.), “Financing Sustainable Energy for All: Pay-as-you-go vs. traditional solar finance approaches in Kenya”, STEPS Centre, 2014, http://bit.ly/1Lhvd7a; World Bank; World Energy Outlook; United Nations Department of Economic and Social Affairs, Population Division; Interview with off-grid appliance manufacturers and distributors; Dalberg analysis.

Country Snapshot: Nigeria

Market Overview

- Largest potential solar market in Africa, with the largest off-grid population in Africa and strong prospects for economic growth
- High penetration of household appliances, indicating affordability and consumer willingness to access target off-grid appliances

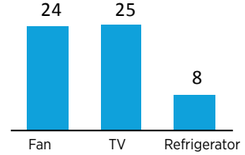
Potential Annual Spend, 2020



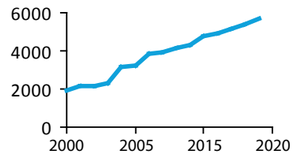
USD, millions

Market Overview

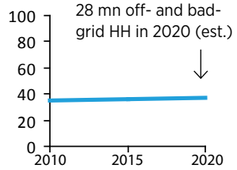
Rural penetration of household appliances (%, 2010)



GNI per capita, current USD PPP (2000–2014)



Electrification growth (%)



Current Market Landscape

Demand	Size Preference	Price (USD)	Major Suppliers
Medium	10”-12 Tabletop	~$15	Barefoot Power; BBOXX; Mitva Duron Solar
Very high	15”–19”	$75-120	
Low-to-medium	50–55L	~$300	

Early Innovator Case Study: Barefoot Power

Barefoot Power

Refrigerator: Product Specs	Design Features	Market Status
55L, $300 USD Runs on a standalone 155W panel	4 inches of polyurethane as insulation to minimize thermal loss	Est. reduction of 25–30% price in 2–3 years

Trends in the SHS market

- Very young market with very few higher capacity SHSs, which can power appliances, being sold currently
- High dependence on petrol generators and batteries
- Increasing energy demand, stemmed by household appliances; sustained and growing demand for appliances will likely drive demand for SHS in the future

Country-Specific Market Barriers

- In Nigeria, the domestic solar industry has been awarded “pioneer status,” with corporate tax exemptions; however, imports are still subject to a 20% tariff.
- Players such as Azuri Technologies and Solar Kobo offer unique payment models for SHSs to address affordability challenges—e.g., SolarKobo undertakes the initial cost of the SHS and the installation, and customers have a monthly payment fee of $25.

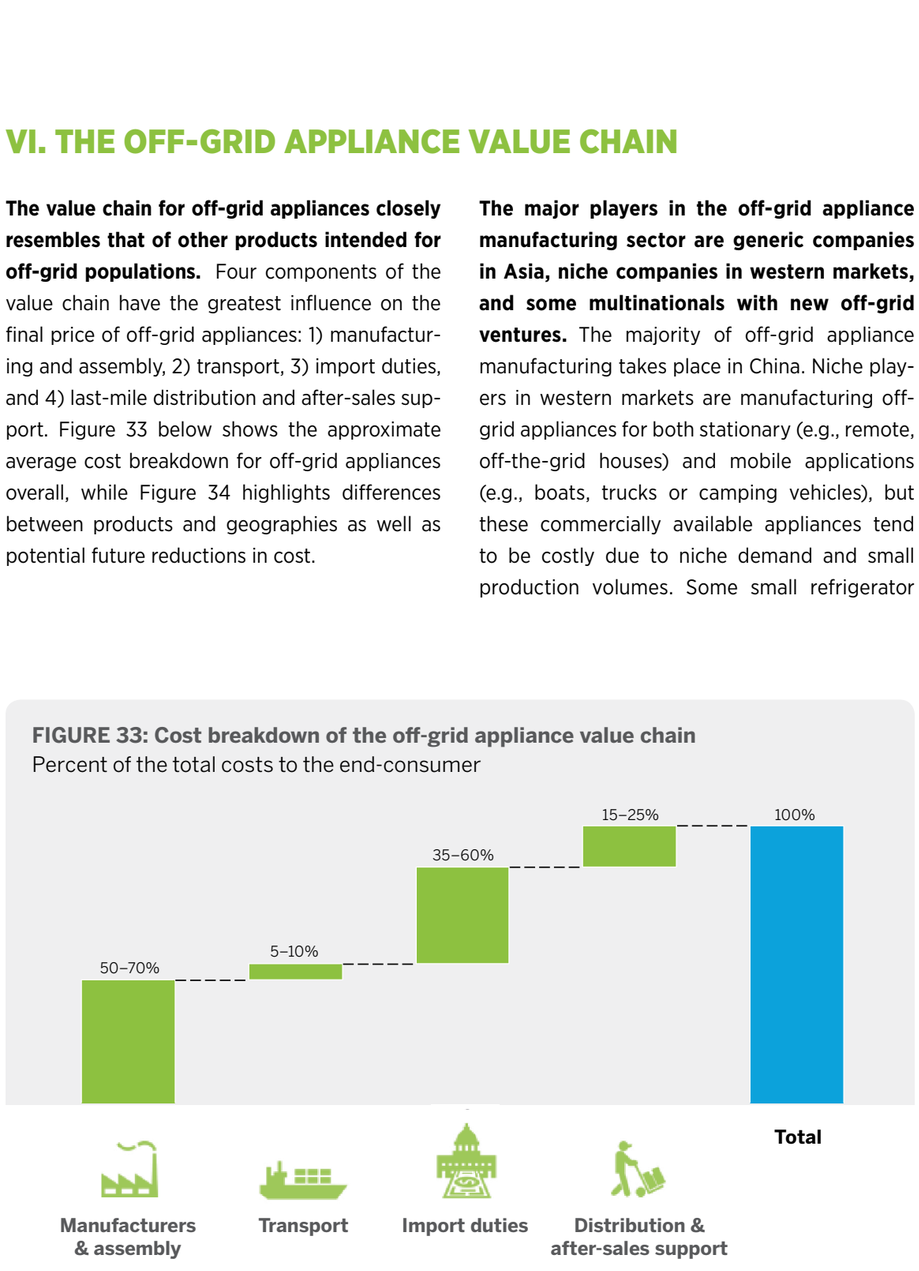
Source: “Nigeria LSMS Integrated Surveys on Agriculture General Household Survey Panel”, *National Bureau of Statistics*, 2012; World Bank; World Energy Outlook; United Nations Department of Economic and Social Affairs, Population Division; Interview with off-grid appliance manufacturers and distributors; Dalberg analysis.

VI. THE OFF-GRID APPLIANCE VALUE CHAIN

The value chain for off-grid appliances closely resembles that of other products intended for off-grid populations. Four components of the value chain have the greatest influence on the final price of off-grid appliances: 1) manufacturing and assembly, 2) transport, 3) import duties, and 4) last-mile distribution and after-sales support. Figure 33 below shows the approximate average cost breakdown for off-grid appliances overall, while Figure 34 highlights differences between products and geographies as well as potential future reductions in cost.

The major players in the off-grid appliance manufacturing sector are generic companies in Asia, niche companies in western markets, and some multinationals with new off-grid ventures. The majority of off-grid appliance manufacturing takes place in China. Niche players in western markets are manufacturing off-grid appliances for both stationary (e.g., remote, off-the-grid houses) and mobile applications (e.g., boats, trucks or camping vehicles), but these commercially available appliances tend to be costly due to niche demand and small production volumes. Some small refrigerator

FIGURE 33: Cost breakdown of the off-grid appliance value chain
Percent of the total costs to the end-consumer



Source: Interviews with manufacturers, distributors and energy service providers; Dalberg analysis

FIGURE 34: Product and geography-specific considerations across the off-grid appliance value chain

	Product-specific considerations	Geographic variations	Expected or potential reductions in cost
Manufacturing & Assembly	• While the contribution of manufacturing costs to overall product cost does not vary between products, refrigeration technology requires the greatest research and development (R&D) effort.	• The majority of manufacturing is currently concentrated in a few countries, which don't represent the target market for these products; therefore, no real geographic variations in manufacturing exist. • Some distributors import products as components and finish assembling them in-country.	• Manufacturing costs for all three target products are expected to reduce over time, given technology advancements and increased volumes.
Transport	• Size primarily drives transport costs, which is therefore particularly challenging for refrigeration products, especially at the last mile.	• SHS distributors suggest that transportation in some countries in Sub-Saharan Africa is not regulated or safe, beyond poor road infrastructure.	• Stakeholders do not see any foreseeable reductions in transport costs.
Taxes & Tariffs	• Relevant general electric appliance taxes affect all three products.	• High taxes and tariffs particularly affect India and Bangladesh. • Taxes and tariffs are inconsistent in other parts of the world; for example, some manufacturers have received exemption in East Africa.	• Off-grid appliances may achieve blanket exemptions in the future, either by bundling themselves with solar products or through specifically designed exemption policies.
Distribution & After-Sales Support	• Storage and warehousing for larger products, such as televisions and refrigerators, present difficulty. • Because of the skills required for more complicated technology repairs, after-sales support for refrigerators and televisions is more difficult than for fans.	• Costs for distribution are generally more significant for countries, where the off-grid population is physically spread out, such as India	• As off-grid appliances become more popular, and traditional distributors and retailers gain confidence in stocking and selling these products, distribution costs are likely to decrease.

manufacturers have deeper engagements with the off-grid market in Asia and Sub-Saharan Africa, mostly for vaccine storage and commercial usage (e.g., Sundanzer). Multinationals and local conglomerates, attracted to the sector by commercial and corporate social responsibility rationale, are new to the off-grid appliance market. For example, Samsung designed 23" and 32" off-grid TVs that can operate both on AC and DC power, which were recognized by the Global LEAP Awards in 2014.[119] LG partnered with World Vision Kenya to manufacture and donate 20 solar refrigerators for vaccination and food storage.[120] However, these initiatives have not yet been coupled with viable go-to-market strategies.

Manufacturers often partner with regional companies to assemble parts in-country. Two factors drive this. First, lower import duties on individual parts means that local assembly reduces the overall cost of the product to the consumer. Second, this approach can support improvements to both performance and affordability. Regional companies have greater quality control in a market that is sensitive to spoilage. SHS enterprises are emerging as the most important player in this component of the value chain (discussed in greater detail below).

Given the nascent stage of the market, companies are experimenting with various channels for last-mile distribution. Currently, there are four main distribution channels: (i) institutional partners; (ii) integrated distribution (iii) traditional dealer–distributor networks; and (iv) franchising (Figure 35). The decision to adopt a particular channel depends on several factors, including, but not limited to, manufacturers' pre-existing local presence and established relationships, population density, and local infrastructure. To date, institutional partnerships tend to be the most popular, since they unlock extensive rural networks and community-level understanding of different terrains. As the market continues to grow, like it did with solar products, manufacturers will be able to tap into traditional distributor–retailer networks.

Quotes on distribution

"We moved from a franchise model to a branch model to increase control and improve local staff development.... we wanted more control over product quality and customer care."

— Distributor in Uganda

"NGOs distribute these products as well, but at a relatively higher price....in the next five years, commercial ventures for distribution are likely to gain popularity."

— Distributor in Bangladesh

"Marketing and distribution are two sides of the same coin, if the proper channels for distribution do not exist, then the requisite products will also not be developed...we reach low-income consumers through post office and NGOs."

— Manufacturer in India

119 Nic Healey, "Samsung amonst winners in "off-grid" super energy efficient TV design awards," CNET May 13 2014, http://cnet.co/1KFXDgm.

120 Ephraim Batambuze III, "LG Donates Solar Powered Refrigerators to support Rural Communities in Africa," PC Tech Magazine, Nov. 27, 2014, http://bit.ly/1V4jpdW.

Distribution models have significant implications for marketing, sales and installation, and after-sales support. The level of manufacturer involvement is highest with the integrated distribution approach, requiring significant financial investment, local contextual understanding, and continued follow-up with consumers through a dedicated sales force. Franchising, while allowing manufacturers to link with individuals and companies on the ground, still requires a significant amount of investment to ensure quality control and appropriate representation of the brand. Engaging with local institutional partners, on the other hand, allows manufacturers to tap into pre-existing networks and pass on the burden of customer acquisition and after-sales support to partner institutions. Institutional partnerships tend to be the most economical for manufacturers, while traditional distributor–retailer networks require individual profit margins up to or exceeding 10 percent at each step in the distribution chain.

SHS distributors are key stakeholders in the off-grid appliance value chain. SHS customers also represent potential customers for fans, TVs, and refrigerators. Success in the SHS market increasingly implies being able to fulfill these expanding customer needs, and prominent SHS players have already started adding

FIGURE 35: Overview of distribution channels used by off-grid appliance enterprises

	Overview	Examples	Prevalence
Institutional partnership	• Partnership with third party organizations, such as MFIs, NGOs, government, and corporations, to capitalize on their reach and local networks	• Rural Services Foundation • Barefoot Power • Sola Home Appliances	
Integrated distribution	• Manufacturers employ a dedicated sales force to distribute product in off-grid regions	• SELCO • Solar Now • Simpa Networks	
Traditional dealer-distributor network	• Products reach end consumers through the traditional wholesaler–distributor–retailer chain	• Superstar Solar • MAKS BD • REMI	
Franchising / Micro-franchising	• Manufacturers permit other parties, including rural entrepreneurs, to distribute products in their trade name	• BBOXX • Barefoot Power • Onergy	

Source: Interview with Manufacturers and Distributors; Dalberg analysis

appliances to their suite of product offerings. Upselling higher-margin appliance products using existing SHS sales channels can also make up for the comparatively low margins seen on SHS sales (approximately 1-4 percent), helping SHS distributors transition into more general appliance companies.[121] Some SHS companies are exploring the viability of designing and manufacturing their own appliances, especially those with relatively robust in-house R&D capabilities. However, most SHS companies lack the capital, sales volumes, and technical knowledge to launch and sustain appliance production. As an alternative to manufacturing their own appliances, some SHS companies maintain a presence in manufacturing bases like China to enforce their own production quality standards with third party manufacturing partners.

Quotes on participation in value chain by SHS enterprises

"We carry out our own assembly [of off-grid appliances]. We source and certify products from China, have a presence there to ensure quality control."

— Global SHS Supplier

"We source [TV and fan] components from China and assemble them locally here, this helps control the price."

— Bangladesh SHS Supplier

"We have a hub in China, which helps select the right manufacturers, products are certified before they are brought in."

— East African SHS Supplie

Photo Credit: PeerPoint / Alamy Stock Photo

Assembly line at a low-voltage electrical appliance factory in Taizhou, China.

121 The Climate Group, 2015.


Photo Credit: T. Kopecny / Alamy Stock Phot

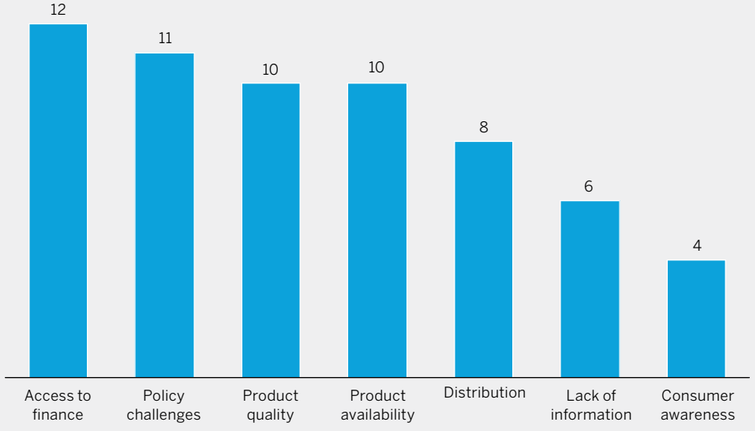
VII. KEY BARRIERS TO THE DEVELOPMENT OF THE OFF-GRID APPLIANCE MARKET[122]

Access to finance is a significant barrier facing the off-grid market, but critical other barriers exist. Financing challenges affect all players in the off-grid market, from manufacturers to consumers. Capital investment in R&D to manufacture appropriate appliances for the segment, debt and working capital for enterprises further down the value chain, and consumer financing all pose significant challenges. In addition to finance, off-grid appliance market stakeholders cite policy challenges and concerns about product quality and availability as the biggest barriers to growth (Figure 37). Throughout the global market ecosystem, deep information asymmetries and gaps in market intelligence also inhibit growth. These barriers resemble those experienced by many emerging markets, including the off-grid energy and lighting sectors.[123]

A. Access to finance

Enterprise financing is a challenge for both manufacturers and distributors. On the manufacturing front, R&D to develop appliances that are appropriate for the off-grid segment requires significant capital investment. Off-grid manufacturers also struggle to access working capital, and a lack of formal financing infrastructure makes it challenging to raise equity—few investment groups are targeting the appliance segment at present, despite its critical importance to the future of the off-grid market. For distributors, the need to invest in consumer awareness and marketing, build maintenance and after-sales support capacity, and retain enough liquidity to procure large volumes of appliance products necessitates significant working capital. However, distributors often have a limited trading history and lack collateral and therefore struggle to overcome high interest rates and reluctance from traditional financial institutions to offer credit. While market growth requires greater private sector participation in enterprise financing, traditional financial institutions remain reluctant to invest in enterprise financing for off-grid companies due to the relatively few successful examples of functional business models, lack of internal expertise to evaluate the strength and sustainability of off-grid business models, and the general perception of low profitability of the sector. Recent trends suggest increased interest in provision of financing for off-grid energy companies, but financing for off-grid appliance manufacturers and distributors remains challenging.[124]

FIGURE 37: Ranking of barriers to growth of the off-grid appliance market by manufacturers, distributors, and energy service providers
Number of respondents; N = 20



Note: Multiple responses allowed
Source: Interviews with manufacturers, distributors, and energy service providers; Dalberg analysis

FIGURE 38: Off-grid appliance market financing needs

	Manufacturers	Distributors	Retailers	Consumers
Uses of financing	• Capital investment for R&D • Working capital to sustain production • Brand building and marketing	• Trade finance to enable procurement activity • Working capital for marketing, after-sales support, and maintenance	• Loans for bulk purchases of off-grid appliances • Loans or equity investment to support consumer financing	• PAYG or other consumer financing mechanisms to enable product purchases

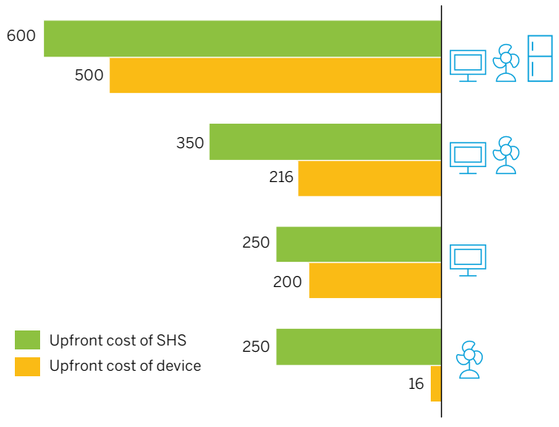
Source: Interviews with manufacturers and distributors; Dalberg analysis

122 Interviews with experts, manufacturers, and distributors, 2015; Dalberg analysis.
123 "Investment and Finance Study for Off-Grid Lighting," A.T. Kearney and GOGLA, June 2014.
124 Eric Wesoff, "Off Grid Electric Raises $45M in Debt for African Micro-Solar Leasing Platform," December 17, 2015 (http://bit.ly/20LVirt); Ian Clover, "BBOXX and Oikocredit bring securitization to off-grid African solar," January 12, 2015 (http://bit.ly/1T87Gw0)

In recognition of the challenges manufacturers face, Global LEAP is introducing an incentive program that aims to accelerate the growth of the market, by reducing risks across the supply chain and demonstrating scale. The program will provide incentives to off-grid solar and appliances companies that partner to market appliances that have been identified as high-quality and energy efficient through the Global LEAP Awards. One goal of this program is to demonstrate the viability of off-grid appliance sales to commercial lenders and appliance manufacturers who are not yet engaged in the market.[125]

Limited consumer financing options are available in some areas, but this remains a significant barrier to growth. Similar to challenges faced by the broader energy access market, off-grid consumers are often unable to afford the full price of an off-grid appliance product upfront. To address this issue, some market players have begun to offer consumer financing. Barefoot Power and Fosera, for example, offer financing through commercial lending partners as well as in-house financing programs. Their commercial lending programs involve direct partnerships with banks and micro-finance institutions (MFIs). The financing institutions provide a loan to cover some portion of the product's cost (e.g. 25 percent), which the customer repays via installments over the course of months (e.g. 3 to 6 months). SolarNow, a prominent SHS and off-grid appliance distributor, provides financing without interacting with a third party, and does not integrate the cost of the appliance with that of the energy supply. It conducts an in-house assessment of consumer credit worthiness, and approved customers make an upfront payment of 20–25 percent and repay the remaining amount over the next 18 months. However, about 90 percent of these customers take loans from a bank or MFI to make the upfront payment, so financing institutions remain a part of the process. For companies interested in selling an SHS bundled with appliance products, consumer financing is often the only way to enable the transaction.

FIGURE 39: Average costs of target off-grid appliances and relevant energy sources, 2015 (USD)



Source: Interviews with leading off-grid appliance manufacturers and distributors; Dalberg analysis

125 See: http://bit.ly/1PNWnb7

Challenges with off-grid consumer financing include weak recovery systems, customer limitations, and lack of interest from commercial lenders. At present, there is a high risk of default in off-grid markets, particularly for more expensive off-grid solutions, and the physical remoteness of many areas pose challenges to ensuring repayment. Many customers in the target segment do not pass credit worthiness tests. Some of the early consumer financing programs for off-grid appliances were not profitable for commercial financing enterprises, which depresses their interest in continued exploration of this type of lending. Increasing lender awareness about the high demand for off-grid solutions will help overcome this barrier. Evolving payment recovery technologies and systems, and reducing risk of default through improved appliance quality, have a role to play as well.

Pay-as-you-go (PAYG) financing solutions provide a new opportunity. A number of energy access providers, specifically enterprises providing lighting and energy solutions, are leveraging digital consumer financing to enhance the affordability of their products and services. PAYG customers typically make payments via mobile money or an agent-based energy credit model (e.g., scratch cards). Monitoring of payments and system use occurs through Machine-to-Machine (M2M) technologies that send information via GSM networks to system management centers. The overall PAYG model can be structured either as an ownership or rent-based model. Companies like Simpa Networks and M-KOPA structure the ongoing payments such that after a specified period, the customer owns the product. Off-Grid Electric and others offer solutions where consumers pay for the product as a fee-for-service, and the enterprise always retains the ownership of the product.

The PAYG model has several risks in the off-grid appliance market. First, the structure of the financing package requires customers to pay more money over the life of the term than an upfront cash transaction, which increases risk of customer default. Second, any failures in the product before the repayment of the loan can affect financial recovery and encourage customers to move to a different provider. Product failure in one area may also affect demand for additional appliance types from a particular distributor, restricting its ability to scale past initial

Feedback from off-grid appliance distributors on financing for off-grid appliances

"The price of the TV or any other off-grid appliance cannot be looked at in isolation; it always needs an integrated system to provide the entire solution."

"Off-grid appliances are just not at a price point where they can be adopted by the low-income customer segment. Market financing solutions that provide an end-consumer with the means to purchase these products will be crucial in developing and stimulating the market."

"Solar devices are more expensive and [customers] want to be sure of the quality of the product. One way is to catalyze demand by offering innovative financing."

product offerings.[126] Third, some customers may find even 10–30 percent of the full price a prohibitive upfront cost.

Continued evolution in PAYG models may reduce risk of default. Improved mechanisms for initial assessment of customer risk profiles could support lower down payments for the target off-grid appliances, which would expand the pool of potential customers while minimizing additional risk of default.[127] Increasing the recovery period for appliances from 12-18 months to 2–3 years may also support repayment by reducing monthly customer outlays. However, these evolutions may require improved quality assurance guarantees and/or longer warranties from manufacturers.

B. Policy challenges

The proliferation of low quality, cheap products currently inhibits the market for off-grid appliances; well designed and enforced quality control frameworks will support growth. The market for off-grid appliances is highly price sensitive. A large number of low-cost generic products and limited market differentiation for higher quality alternatives (specifically in the fan and TV markets) sustains a dynamic where off-grid consumers make choices almost exclusively based on price. To address this challenge and reward producers and distributors of high quality, energy efficient off-grid appliances, governments should implement stringent quality control standards to help improve overall product quality and performance and make it harder for producers of low quality inefficient products to spoil the market. Ideally, these policies should be harmonized and aligned with international best practices to enable trade. A new program from Global LEAP to test and share product performance could facilitate such policies.[128]

High import duties and tariffs on off-grid appliances depress market growth. In markets like India and Bangladesh, import duties imposed on off-grid appliances can be as high as 100 percent. Tariff and tax rates differ significantly across countries and regions as well, which results in wide disparities in the pricing of off-grid appliances and country-to-country market distortions.

A general lack of supporting policy frameworks results in missed opportunities. Few governments proactively pursue tax breaks and financial incentives for manufacturers of off-grid appliances or promotion of public–private partnerships to facilitate financing, targeted bulk procurement, technology transfers, and knowledge sharing. Consumer awareness and education programs that promote the use of energy-efficient appliances also receive insufficient support. The Super Efficient Equipment Program (SEEP), which aims to catalyze the market for energy efficient appliances in India through incentives for manufacturers, is an example such efforts.[129]

C. Distribution and after-sales support

Safe and effective last-mile distribution remains difficult and costly. Customer awareness of off-grid appliances is low, requiring distributors to invest in capital-intensive marketing efforts. It is also difficult to find reliable local distribution partners for manufacturers and distributors located in off-grid areas. For off-grid appliances like TVs and refrigerators, another major challenge is the need for after-sales technical support. The products themselves, as well as the accompanying battery systems, require frequent maintenance. Unregulated, unsafe, and expensive transportation and warehousing in developing countries, specifically in rural areas, can add substantially to costs. Companies seriously pursuing the off-grid appliance market will need to account for these challenges—doing so effectively could result in business model innovations with lasting impacts.

D. Product quality

Lack of adequate investment in R&D and an excessive focus on price negatively impact product quality. Innovation could be stifled through a race-to-the-bottom mindset, where companies focus almost exclusively on decreasing costs to drive uptake, which often results in low-quality components and products. The key driver in the off-grid appliance market is *value*, not *price*—particularly when considering evolving consumer financing, shifting demographics, and the role of energy efficiency in reducing upfront and total cost. The majority of technological innovation in household appliances focuses on premium markets, where consumer needs, preferences, and price sensitivity differs. There has been little investigation into the real or specific usage patterns of off-grid consumers, leaving manufacturers unsure of consumer preferences and quality requirements.

Energy efficiency, while crucial for the off-grid appliance market, should form only one of the major considerations toward ensuring quality. For example, it is currently technically feasible for a 19" TV to consume less than 10W. However, a significant reduction in illumination can accompany this level of energy efficiency, thus compromising the picture quality of the TV. Some off-grid appliance enterprises are investing in R&D and design to address the trade-offs in energy consumption and performance. Energy efficiency is important, and cost is important—but appliances must deliver value to off-grid consumers to ensure the long-run viability of the market.

Photo Credit: Rajesh Kumar Singh /AP Images

126 Peter Alstone, Dimitry Gershenson, Nick Turman-Bryant, Daniel M. Kammen, and Arne Jacobson, "Off-Grid Power and Connectivity: Pay-As-You-Go Financing and Digital Supply Chains for Pico-Solar" Lighting Global Market Research Report, May 18, 2015, http://bit.ly/23Xopaw .

127 Ibid.

128 See: http://bit.ly/1RqxsLW

129 "Super-Efficient Equipment Program (SEEP)," Climate Investment Funds, accessed Oct. 8, 2015, http://bit.ly/23XooTS.

E. Information gap

The early stage of the off-grid appliance market lends itself to information asymmetries. Significant investigations into the heterogeneous and evolving needs of off-grid consumers are needed to inform investments in innovation and design of off-grid appliances. Lack of robust ground-level consumer data, including demand for off-grid appliances, customer preferences, affordability, and willingness to pay make it difficult for manufacturers to determine the size of the opportunity. Furthermore, limited information on off-grid appliance products themselves, including product performance, design, and availability, make it difficult for manufacturers to assess the competitive landscape. Global LEAP is currently leading efforts to fill in many of these information asymmetries – including consumer research and a program that will test a wide cross-section of off-grid appliances and share the resulting data with market stakeholders – but much more investment in this area is needed.

F. Consumer awareness

Consumer awareness of the benefits and importance of quality and energy efficiency in off-grid appliance products is low. Increasing awareness and marketing efforts can generate and sustain consumer demand. Since this is a nascent market, many suppliers still focus the majority of their marketing efforts on solar lighting and energy devices. As off-grid consumers demonstrate willingness to purchase appliances, concerted efforts to improve customer awareness will be essential to increase uptake of these products.

Photo Credit: Prashanth Vishwanathan /IWMI

VIII. CONSIDERATIONS FOR THE FUTURE OF THE OFF-GRID APPLIANCE MARKET

A high-impact off-grid appliance market will accelerate the global clean energy access market, but a variety of cross-cutting evolutions and interventions will be required to achieve this. Industry players, governments, investors, development organizations, philanthropies, and civil society all must play an important role in overcoming barriers to growth. The following changes will help to catalyze the off-grid appliance market:[130]

Technology innovation specific to the off-grid market. An understanding of the specific needs of the off-grid segment and systemic support for innovation in designing appropriate products will drive uptake. While energy efficiency and affordability are important, other issues like product performance, usage patterns, novel form factors, and customized technological specifications are also significant. Currently, most of the innovation in the appliance market suits the needs and relatively fixed patterns of developed-world consumer segments; new investments in innovation must shift this focus to the off-grid market.

Access to enterprise finance. Enterprise finance, both for manufacturers and distributors, is a challenge that requires increased support from donors, governments, and private sector participants. Increased access to financing will enable R&D investment, provide essential working capital, and enable greater in-house provision of consumer credit.

New consumer financing solutions. Product affordability is a challenge, given the relatively larger ticket size and the cost of additional power required to operate off-grid appliances. Development organizations and traditional finance providers are often reluctant to invest in consumer financing mechanisms for these products, given the higher upfront price and an outdated and prescriptive thinking regarding the development merits of non-lighting appliances. Further exploration into, and uptake of, PAYG and similar models will be critical to increasing access to these products.

Increased exploration of distribution partnerships. Given the nascent state of the market and the relatively complicated technological configurations of SHSs, manufacturers should tap into the distribution networks of energy service providers that have effective last-mile distribution networks, financing schemes, and requisite after-sales and support systems. This can help provide a one-stop, integrated solution.

Bundled product offerings. Bundling off-grid appliances with SHSs reduces the fear of compatibility issues given that the products are tested and sold together and allows the SHS company to "right size" the solar system with the energy load, reducing overall package cost. Depending on the technical capabilities of the SHS distributor it can also provide rich data on consumer patterns and preferences, opening new frontiers for off-grid appliance R&D.

130 Interviews with experts, manufacturers, and distributors, 2015.

Improved consumer awareness. Despite general awareness of household appliances like fans, TVs, and refrigerators, a lack of understanding about the importance of high-quality, energy-efficient appliances inhibits consumer willingness to buy these appliances, which can be more expensive than mainstream counterparts. It is crucial to sensitize customers to the benefits of high-quality, energy-efficient appliances. This can include door-to-door marketing, product trials, exhibitions, and information dissemination through grassroots partner organizations. That said, robustly implemented policy may be the most elegant and effective solution.

Increased market intelligence. Additional market research is required to better understand the off-grid appliance market. Areas of interest include usage patterns of off-grid consumers, current availability of and access to super-efficient off-grid appliances, the economics of manufacturing off-grid appliances, and opportunities for cost reductions along the off-grid appliance value chain.

Product quality assurance frameworks. Increased confidence by consumers, distributors and investors in the reliability and longevity of the product plays a crucial role in accelerating growth. Uniform quality and performance standards, adopted by key national governments and backed by internationally-accepted test methods such as those being developed by Global LEAP, will help make progress in this area.

Tariff reform. Taxes and tariffs should be reduced in key markets like India and Bangladesh and structured to provide an advantage – or at least even footing – to high-quality and efficient products. Import policy should be harmonized across countries and regions to encourage trade and reduce price disparities. Finally, tax policies for off-grid appliances should be structured in concert with those relevant to solar products, or distortions will emerge and both markets will face limited growth.

Targeted incentives for manufacturers. Governments should create incentives for global manufacturers to enter the off-grid market, and to enable current market players to scale up. Some governments have begun to put in place programs offering financial incentives to mainstream manufacturers; SEEP in India, for example, provides financial incentives to ceiling fan manufacturers to produce and sell highly efficient fans that consume less than half of the energy consumed by fans typically sold on the Indian market. Such programs should be imitated and expanded. Tax rebates for manufacturers producing qualifying appliances would also support growth.

Performance standards. Low-cost, low-quality products make it difficult for large-scale, high-quality players to enter the market, primarily because consumers often extrapolate their experience with poor products to all appliances in that category (and all companies selling those categories). Government programs that prevent bad-quality products from entering the market would further incentivize manufacturers to engage. Several mainstream markets already have energy efficiency and quality standards in place for household markets. Bangladesh's IDCOL program has established standards in the off-grid space, and has indicated plans to develop quality and energy efficiency standards for off-grid TVs and fans. Other countries should follow suit, ideally modeling such efforts after IDCOL's to minimize market distortions.

IX. CONCLUSION

This report suggests that a typical under-electrified BoP household will likely be able to afford high-quality lighting, a point for mobile phone charging, a table fan for cooling, a small LED television, and a 50L refrigerator in 2020. Thus, the off-grid market for TVs, fans, and refrigerators is in a similar place to where the solar lighting market was several years ago. The demand signals are there, and early movers are seeing robust opportunities for growth. What remains is the need to move existing activity beyond niche markets and onto the agenda of all off-grid energy players, innovators, distributors, and manufacturers. With expected growth in rural incomes in the majority of developing markets, the parallel rise of clean energy supply through SHS and mini-grid solutions, and increased grid electrification, the market fundamentals are strong.

Entrepreneurs and innovators in this sector stand to capitalize on a multi-billion dollar opportunity while also forging new brands, distribution networks, and direct customer relationships that will help them compete with mainstream incumbents. Global companies should take note that the next global consumer appliance brand could very well emerge from the off-grid market. The more than 2 billion people living in energy-poor environments represent a substantial market that is projected to grow, in spite of efforts to increase and improve grid electricity service worldwide.

In enabling breadth and scale in the global distributed renewable energy market, the growth of the off-grid appliance market will have significant positive social and environmental impacts, marrying public, private, and corporate interest. Careful support for conditions that encourage strong private sector engagement, including non-distortionary regulations and taxes, better information flows, and financing that takes into account true risk and values, is important. Through these measures, and with the support of market forces, NGOs, mutli-laterals, philanthropies, and governments have the opportunity to fundamentally transform the lives and livelihoods of the world's poorest people.

Photo Credit: epa european pressphoto agency b.v. / Alamy Stock Photo

About Global LEAP

The Global Lighting and Energy Access Partnership (Global LEAP) – the Clean Energy Ministerial's energy access initiative, which is led by the U.S. Department of Energy – catalyzes markets for clean energy access products and services through efforts focused on quality assurance, promotion of demand-side super-efficiency, and partner collaboration.

Global LEAP launched as a commitment to the United Nations' Sustainable Energy for All campaign, and its programs and initiatives support the growth of sustainable commercial markets for clean energy products and services throughout the developing world. Global LEAP is currently spearheading several activities to develop the off-grid appliance market.

- **Driving innovation and scale.** The Global LEAP Awards identify and promote the world's highest quality, most energy-efficient and affordable off-grid appliances. A program launched in 2015 will provide incentives to off-grid companies that partner to sell large quantities of high-quality, super-efficient Global LEAP Awards appliances. As a first step, the program will have a geographic focus on Bangladesh and focus on companies that supply televisions that were either the winners or the finalists in the Global LEAP Awards announced in May 2014.
- **Building technical infrastructure and capacity.** An interactive off-grid appliance data platform will provide a clearinghouse of off-grid appliances that have been tested according to international best practice, and giving different market stakeholders – including distributors, policymakers, investors, and manufacturers – the opportunity to evaluate and compare off-grid appliances based on different parameters, including energy efficiency, market availability and off-grid appropriate design. Global LEAP has also developed, or supported the development of, the world's first test methods for off-grid LED appliances, televisions, and fans.
- **Creating and sharing market intelligence.** Studies like this one inform market stakeholders and equip them to act. Global LEAP is supporting a variety of market intelligence efforts, including techno-economic analysis, practitioner surveys, country-market analyses, and more.
- **Developing the market.** Through a variety of efforts, Global LEAP is supporting the companies, investors, and policymakers navigating the off-grid appliance market. Global LEAP hosts business-to-business networking events, educates investors on the off-grid appliance market, and provides technical assistance to policymakers and other institutions working to break ground on public and private policy.
- **Partnership & collaboration.** There are more than 140 private sector and civil society supporters of the Global LEAP Guiding Principles. Global LEAP and Sustainable Energy for All are leading a global campaign, the Efficiency for Access (E4A) Coalition, to harness the untapped potential of super-efficient end-use technologies to expand the human and economic benefits of energy access.

About the Clean Energy Ministerial

The Clean Energy Ministerial (CEM) is a forum of the world's largest and most forward-leaning countries working together to accelerate the global transition to clean energy. Launched in 2010, the CEM pairs the high-level engagement of energy ministers with year-round technical initiatives and campaigns to drive faster deployment of clean energy policy and technology worldwide.

About Dalberg

Dalberg Global Development Advisors is a strategy and policy advisory firm exclusively dedicated to global development and innovation. Dalberg's core advisory services include: (i) developing innovative strategies, approaches, and market mechanisms; (ii) analyzing global markets and developing market-entry and M&E strategies; (iii) reforming internal organizational processes and structures; and (iv) coordinating and facilitating large, multi-stakeholder initiatives. Energy is one of Dalberg's 13 sectors of expertise; led from the Mumbai office, Dalberg has worked on more than 100 engagements in the energy access space globally.

About CLASP

CLASP is an non-profit organization with over 15 years of experience in appliance energy efficiency and market transformation. CLASP's Clean Energy Access program focuses on using energy efficiency to accelerate the affordability—and social and environmental benefits—of access to clean energy throughout the developing world. CLASP is responsible for the Clean Energy Ministerial's Global LEAP Awards program, and it has developed and manages several Global LEAP off-grid appliance market development initiatives on behalf of the U.S. Department of Energy, Energising Development, ClimateWorks Foundation and other partners.

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