EFFICIENCY FOR ACCESS

TECH TRENDS IN ENERGY ACCESS:

ASSESSING THE OFF-GRID REFRIGERATOR MARKET



Part of the Efficiency for Access Appliance Tech Trends Series

SEPTEMBER 2023

Efficiency for Access Coalition

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CITATION AND COPYRIGHT

Efficiency for Access Coalition, Tech Trends in Energy Access: Assessing the Off-Grid Refrigerator Market, September 2023, https://efficiencyforaccess.org/publications/2023-tech-trends-in-energy-access

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Off-grid refrigeration plays a vital role in a warming world, but new research from Efficiency for Access shows that the sector is struggling. Additional investment is needed to help the technology scale.

Key findings:

- The off-grid refrigeration market has fallen behind projected reach, due in part to the linked challenges of low consumer demand, high upfront cost, and inadequate post-sale service.
- To grow the market, policymakers and financing institutions should provide financial support for manufacturers and consumers.
- Half of all manufacturers continue to use refrigerants with high global warming potential.
- Consumer preferences for off-grid refrigerator technology are changing, with notable trends in different regions.

In a world experiencing escalating global temperatures, refrigeration services have transitioned from a luxury to a crucial resource for households and businesses alike. However, 1.12 billion people currently lack access to refrigeration, according to SEforAll.[1] Extending the technology's reach can significantly advance multiple Sustainable Development Goals, from strengthening resilience and adaptation within communities to stimulating economic growth.

So how can the global community increase access to refrigeration? This report, which is part of an ongoing series, offers valuable insight into the evolving market for off-grid refrigerators and provides recommendations for strengthening the sector. In particular, it examines trends among manufacturers and consumers of refrigerators designed for domestic and light commercial use; identifies opportunities for enhancing performance and affordability; assesses barriers to scale; and offers actionable advice for sector actors like policymakers.

In a companion report published as part of the Efficiency for Access 2021 Solar Appliance Technology briefs, we celebrated the notable success of increased refrigerator efficiency. But our recent analysis shows that in spite of this significant improvement, off-grid refrigeration market growth is falling short of projections.

OFF-GRID REFRIGERATOR MARKET AT A GLANCE

The sector is struggling with substantial initial costs and subdued consumer demand: GOGLA affiliates selling refrigeration units in late 2021 and early 2022 reported sales figures nearly half of what they had achieved in previous reporting periods. In the absence of additional investment aimed at supporting companies throughout their maturity journey, enabling them to provide products at affordable prices to their customers while maintaining profitability, the off-grid refrigeration market is unlikely to attain global scale.

This report calls attention to important trends in the off-grid refrigeration market:

- We observe a notable shift in technology adoption, with DC refrigerators facing near non-existence in numerous markets due to both minimal demand and prohibitive pricing.
- Changing consumer preferences are also evident, with freezers and multi-temperature refrigerators gaining widespread popularity over traditional refrigerator-freezer combinations, allowing more flexibility in small shop settings.
- While challenges are impeding growth sector-wide, regional differences are creating diverse market landscapes in South Asia, East Africa, and West Africa.
- Consumers' trust and satisfaction in off-grid refrigerating products rely on after-sales service, repairability, and comprehensive warranty offerings, which are inadequately provided for most products.
- Perhaps most alarmingly, our analysis underscores environmental concerns, with half of all manufacturers continuing to use refrigerants with a high global warming potential.

Addressing these unique challenges and opportunities while paying close attention to regional nuances and evolving trends is imperative for the success of this pivotal sector.



MARKET TRENDS AND INSIGHTS

MARKET DYNAMICS AND CONSUMER CHOICES

In our 2021 appliance market assessment, we estimated a 10% annual growth in the cumulative global market potential for refrigerators - projecting a tripling from US$4.4 billion in 2018 to US$14.3 billion by 2030[1], with greater affordability and increased efficiency.

However, refrigerator ownership in distributed energy settings is yet to reflect the predicted growth. GOGLA affiliates selling refrigeration units in late 2021 and early 2022 reported sales of nearly half what they had been during previous reporting periods. By late 2022, sales were reported for around 4,600 units, marking a return to the volume sold in earlier reporting rounds.[2]

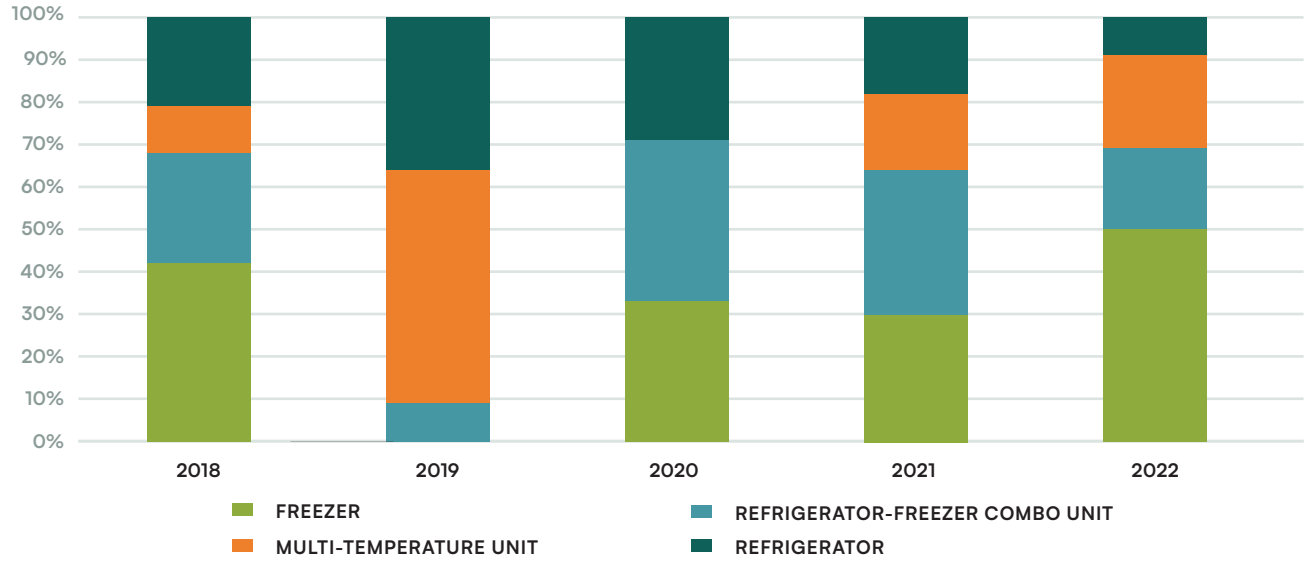
GOGLA cited supply chain uncertainties, lingering pandemic effects, and customers' inability to pay as possible indicators for the period of decreasing sales. The surge in pay-as-you-go sales, particularly towards the end of 2022, suggests that this payment option might be enabling access to refrigerators for previously untapped customers. However, due to the early stage of the commercial solar refrigerator market and GOGLA affiliates representing just a portion of this crucial market, comprehending all the contributing factors remains challenging.

The refrigerator landscape has not evolved significantly since we developed the 2021 Solar Appliance Technology Briefs, but different technologies and use cases are becoming more prevalent. DC refrigerators are nearly non-existent for purchase in numerous markets within our purview, stemming from extremely low market demand and prohibitive pricing.

India[3] and Pakistan[4] offer a scant selection of DC models on the market, leading consumers to depend on AC models coupled with inverters instead. This inclination has also been observed by VeraSol stakeholders, who note that consumers tend to shy away from the more costly DC refrigerators that require a smaller PV module. Instead, many opt to invest in a medium-sized PV module or kit to power a highly efficient AC refrigerator using an inverter.[i] This is an example of market flexibility and highlights trade-offs consumers face when choosing how to invest in off-grid technologies. Other technologies, such as solar direct drive models, remain available in the market but are often more expensive and not in high demand.

Our market scoping efforts show that freezers and multi-temperature refrigerators — those with one compartment that can act as either a refrigerator or a freezer — have become the most widespread in the market, edging out refrigerator-freezer combinations units (Figure 1). GOGLA affiliates and the VeraSol Product Database[ii] also note the rise in multi-temperature units in the market, highlighting the popularity of these flexible models. This trend might suggest reduced refrigerator adoption within household settings, marked by a decline in combination units. On the other hand, there appears to be an uptick in usage within small shop environments that bolster local food chains or in health centers where glass-fronted multitemperature units and large deep freezers could prove more advantageous.

Figure 1. Percentage of refrigerator types sold in markets from 2018 to 2022, as reported by EforA market scoping surveys.



i Based on an internal VeraSol stakeholder survey.
ii VeraSol tests and generates consistent and comparable performance data to support scalable markets for durable, high-performing, and affordable off-grid appliances and productive use equipment.

AFFORDABILITY ASSESSMENT

Predictably, enhancing affordability continues to pose a significant challenge in boosting the uptake of refrigerators in distributed energy sector markets.[5] 50% of survey respondents in Kenya, Tanzania, and Uganda report having to make unacceptable sacrifices to make refrigerator payments, while 20% reported having to cut back on other consumption to make these payments.[6] A survey of VeraSol stakeholders reveals that manufacturers and distributors of off-grid refrigerators grapple with substantial initial costs, import duties and restrictions, varying national regulations and quality enforcement, as well as diminished consumer demand. These factors collectively impede the facilitation of refrigerator sales while striving to maintain prices that are attainable for off-grid end-users.[i]

However, over the last few years, it has been encouraging to observe the continued drive towards growing the off-grid refrigerator market through funding and technical support schemes. These schemes aim to help companies make cooling products more affordable to consumers. Examples include:

- The Efficiency for Access Research and Development (R&D) Fund[7]
- Ashden and K-CEP Fair Cooling Fund
- United States African Development Foundation's Off-Grid Energy Challenge[8]
- Beyond the Grid Fund for Africa[9]
- The Basel Agency for Sustainable Energy (BASE) and the Clean Cooling Cooperative's Cooling as a Service (CaaS) incubator programme[10]
- Novastar Ventures Africa Fund II[11]
- Engineers Without Borders USA's "Chill Challenge"

Several of these initiatives pair support for household and small-business refrigeration with larger cold storage, investing in the full, integrated supply chain that keeps produce, meat, and fish fresh. Collectively, these initiatives have provided programmatic support, development resources, and over US$ 63.6 million[ii] in financial assistance to cooling companies in the distributed energy sector. This support enables them to develop innovative technologies, implement creative business models, and expand their reach to underserved markets.

Policy programs remain essential in improving affordability. Aligning policy frameworks with the specific needs of communities, governments, and regulatory bodies can foster market growth, encourage investment, and facilitate the widespread availability of cost-effective refrigeration options. Policy programs like the ECOWAS Refrigerators and Air Conditioners Initiative (ECOFRIDGES)[12] in Senegal and Ghana, along with the R-COOL with Green On-wage financing initiative in Rwanda[13] leverage green on-wage financing[iii] and on-bill financing[iv] to make cooling products, including refrigerators, more affordable to consumers. Similar programs designed for off-grid refrigerator products and communities have the potential to stimulate their adoption.

QUALITY ASSURANCE AND PRODUCT MAINTENANCE SUPPORT

Given that purchasing a refrigerator constitutes a significant investment for consumers, ensuring quality is key. VeraSol continues to test and report the performance of refrigerators submitted by development programs, manufacturers, and distributors, and sourced from retail markets.

In response to requests for the inclusion of refrigerators in its established solar lighting product certification scheme, VeraSol has drafted and incorporated stakeholder feedback[14] on the draft policy, Requirements for VeraSol Certification of Refrigerators.[15] This policy outlines the pathways to refrigerator certification as part of a solar home system and a standalone appliance while addressing four core elements of product quality: **truth in advertising, health and safety, durability, and consumer protection**.

VeraSol continues to work with the International Electrotechnical Commission (IEC) to develop and adopt test methods for off- and weak-grid refrigerators, aiming to assure refrigerator quality internationally, and expanding on current certification work. These methods build on the Global LEAP Off-Grid Refrigerator Test Method[16] to simulate real-world conditions, from fluctuating voltage in areas that experience frequent brownouts to solar irradiance patterns that affect solar direct drive refrigerating performance. Product testing and quality assurance remain an important pathway toward improving affordability by protecting consumer investments and helping unlock preferential tax treatments.

i Based on an internal VeraSol stakeholder survey.
ii Estimate based on EforA calculations and desk research.
iii **Green on-wage financing** allows local financial institutions to provide a zero-interest loan to eligible salaried employees, where the repayment is deducted from their paycheck each month during the repayment period.
iv **On-bill financing** allows the utility to incur the cost of the clean energy upgrade, which is then repaid in installments on the utility bill.

CASE STUDY 1



REGIONAL VARIATIONS IN OFF-GRID REFRIGERATOR MARKETS

NIGERIA, PAKISTAN & UGANDA

While some obstacles to refrigerator market growth are shared across the sector, nuanced regional differences make for diverse market landscapes in South Asia, East and West Africa.

In Pakistan, the market for DC refrigerators remains notably limited, as numerous distributors point to high costs and minimal customer demand as primary factors contributing to their limited availability in the market. While Pakistan's extensive grid connectivity reinforces the prevalence of AC-dominated appliances in the market, the frequent voltage fluctuations and power outages caused by load-shedding can exert an impact on connected devices. Therefore, labels and marketing for models that can withstand voltage fluctuations are popular. Finally, Pakistani consumers prefer larger refrigerator models, with 70% of units surveyed in 2022 having a volume greater than 250L.

Similar trends were observed in market surveys in neighbouring India, indicating wider regional market preferences.

Nigeria has a nascent but growing off-grid refrigerator market, which has reported the highest sales of refrigeration units by GOGLA affiliates since the second half of 2021, though the market remains dominated by AC models. Medium units with volumes between 150L and 250L are preferred. In contrast, Uganda, when surveyed by EforA, reported a developed DC market and a preference for models smaller than 150L, indicating even more localised market patterns. Refrigerators, their use cases, and user preferences vary greatly, indicating that a one-size-fits-all approach to growing this sector will likely fall short of that goal.

CASE STUDY 2

ENVIRONMENTAL SUSTAINABILITY IN OFF-GRID REFRIGERATION

Beyond assuring quality for consumer health and safety, minimising environmental impacts of refrigerating appliances is essential and predominantly revolves around the evaluation of refrigerants used for cooling. Off-grid refrigerator manufacturers primarily rely on three types of refrigerants for refrigerators under 600 litres in size: propane (R290) and isobutane (R600a), both of which are natural refrigerants, and 1,1,1,2-tetrafluoromethane (R134a), classified as a hydrofluorocarbon. While R290 and R600a exhibit a low global warming potential (GWP), R134a is a potent greenhouse gas possessing a high GWP of 1430 over a 100-year timescale.

Our study[18] found that among the analysed refrigerator models, 40% used R600a, and 47% hydrocarbons (R600a or R290), while over 50% of manufacturers continued to use R134a. Based on VeraSol Product Database data since that study, 7 of 9 tested refrigerator models used R600a, noting that the problem continues. This trend is different from on-grid markets in high-income countries where many manufacturers are transitioning to using an intermediate refrigerant technology — hydrofluoroolefins (HFOs) — before adopting natural refrigerants. This indicates that the off-grid refrigerator market, with the right guidance, could follow trends in Europe, where R600a has replaced R134a as the dominant refrigerant in the domestic refrigerator and freezer market.

The Global LEAP test method for refrigerators[19] includes an environmental rating scale, underlining the importance of this aspect in assessing overall quality and safety. Encouraging manufacturers to transition to natural refrigerants is vital for sustainable and environmentally friendly refrigeration systems. While some may consider transitioning to HFOs (hydrofluoroolefins) a temporary solution, it is crucial to recognise that it only postpones the inevitable shift towards natural refrigerants.

Figure 1. Percentage of refrigerator types sold in markets from 2018 to 2022, as reported by EforA market scoping surveys.

TYPE	REFRIGERANT CODE	CHEMICAL NAME	GLOBAL WARMING POTENTIAL (100 YR.)
Natural	R-744	Carbon dioxide	1
	R-290	Propane	3
	R-600a	Isobutane	3
Hydrofluorocarbon (HFC)	R-134a	1,1,1,2-tetrafluoroethane	1430
Hydrofluoroolefins (HFOs)	R-1234yf	2,3,3,3 Tetrafluoropropene	4
	R-1234ze(E)	1,3,3,3 Tetrafluoropropene	7

After products reach last-mile users, safeguarding that investment to ensure a prolonged product lifespan is important and currently represents a gap in the off- and weak-grid refrigerating market. Survey respondents indicated that 48% experienced issues with product parts or the battery, and many noted that an improved customer experience would encourage them to recommend the product to friends, family, and neighbors.[17] The required product support to address these challenges is two-pronged: building local capacity for technical support and maintenance and providing robust product warranties.

CASE STUDY 3

STRENGTHENING ACCESS AND AFFORDABILITY THROUGH MAINTENANCE, REPAIR, AND WARRANTIES

INDIA, NIGERIA & SOUTH AFRICA

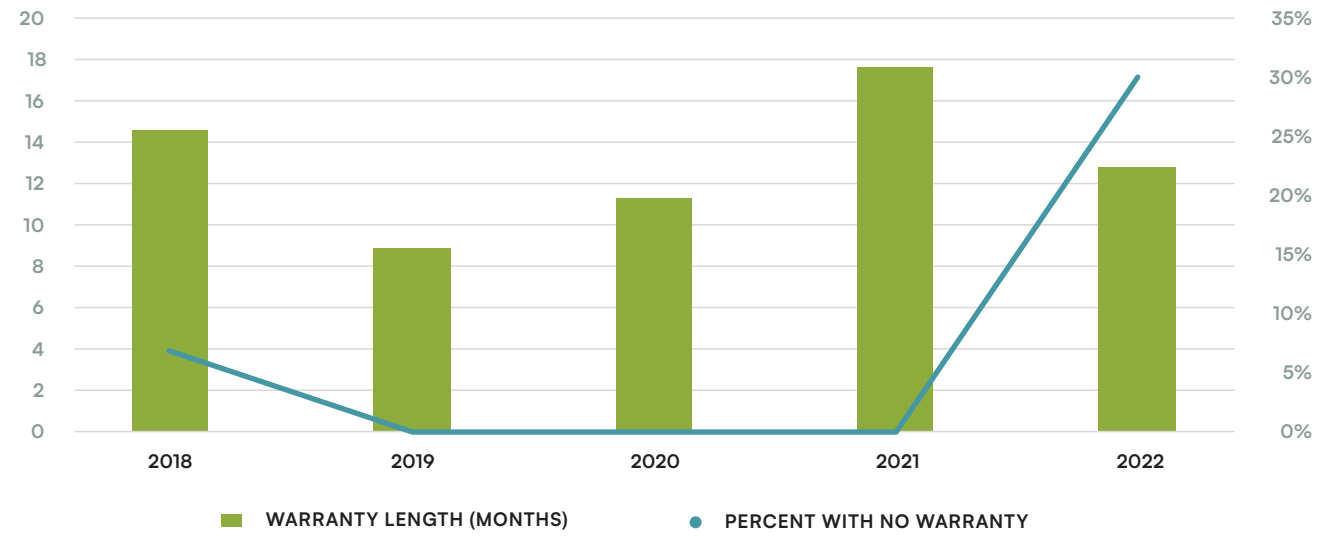
Ensuring access to reliable maintenance and repair services for distributed energy refrigeration solutions is another pathway toward better affordability. Training programs and vocational courses for assembly, installation, and maintenance can help create jobs and boost local assembly. The Solar Power Naija (SPN) scheme in Nigeria is designed to create 250,000 new jobs and support the financing of upstream companies dealing with manufacturing and assembly of off-grid value chain components, such as solar panels, inverters, and batteries.[20] India's Production Linked Incentive (PLI) scheme offers an incentive for establishing manufacturing facilities in the country. The scheme provides a direct payment, amounting to a 4—6% subsidy on the incremental sales of goods manufactured in India, and includes a dedicated budget for the solar manufacturing sector.[21]

South Africa's Air Conditioning and Refrigeration, Infrastructure, Apprenticeships, and Skills Development Project allocated EUR 3 million to address the lack of specialised skills in the heating, ventilation, air-conditioning, refrigeration, and natural refrigerants sector. It aims to benefit 2,500 trainees, 30 percent of whom are women, 90 percent of youth aged 15 to 30, and 80 percent coming from low-income and vulnerable groups.[22] Finally, the Africa Centre of Excellence for Sustainable Cooling and Cold-chain (ACES) has also made commitments to develop capacity by building after-sales capability.

Flexibility on product order quantities, reduced production lead times, and customisation of products help meet community-specific needs enabled by local manufacturing, assembly, installation, and repair services. This can empower communities to become self-sufficient in meeting their refrigeration needs while generating economic benefits and local technical expertise.

Strengthening warranties is the key piece in providing after-sales service, and ultimately builds consumer trust in emerging technologies. Surveys conducted in local markets reveal that warranties generally have not improved for refrigerating appliances since collection began in 2018 (Figure 2). In addition, though we had not observed models sold without a warranty from 2019 to 2021, a survey in 2022 in Pakistan[23] highlights that not all distributors provide warranties. This can dissuade consumers from making purchases, as they perceive a lack of assistance in case the product fails. Improving warranty offerings will be vital to building trust in end-users, especially for more nascent DC models.

Figure 2. Market scoping data collected by EforA from 2018 through 2022, examining refrigerator warranty length and percentage sold without a warranty.





FUTURE OUTLOOK

An off- and weak-grid refrigerator can be transformative for a household, small business, or fresh food supply chain.

The increasing demand for these products is underscored by requests for greater refrigerator capacity, better affordability, quality assurance via certification, and improved consumer and product support. Some of the strongest and most recent evidence for this demand comes from CLASP and Nithio's Productive Use Appliance Financing Facility public auction for procurement subsidies. Submissions by last-mile distributors indicate a sustained demand for refrigerators while highlighting the massive investment gap in the way of affordability and driving scale in markets. Of six technologies within the scope of the Facility, refrigerators were the second most sought-after product for subsidies, amounting to over **US$ 5.1 million**. When distributed across the projected sales of 24,000 units, this equates to approximately US$ 212 in subsidies for each refrigeration unit. This insight indicates that unless the necessary investment is provided to support companies through their maturity journey — where they can provide products at affordable levels to their customers and profitable terms for their operations — the refrigeration market will not take off anytime soon.

ADDRESSING AFFORDABILITY REQUIRES A HOLISTIC APPROACH

The off-grid refrigeration market grapples with steep initial expenses and subdued consumer demand. Consequently, consumers encounter steep prices and limited market availability, fostering a stagnant cycle that can prove challenging to overcome. To propel the market towards its optimal potential, it will be essential to channel increased investment into innovative and blended finance instruments tailored to the economic circumstances of communities within energy-constrained environments. Combined with investments aimed at improving the efficiency of refrigeration technologies through research and development, more companies can enter the market, offer competitive pricing, and scale up the production and distribution of affordable refrigerators.



Building economies of scale, where refrigerator manufacturers can utilise the same key components across different brands and refrigerator types, can also increase affordability.

RECOGNISE AND SUPPORT QUALITY PRODUCTS THROUGHOUT THEIR LIFETIME

Upcoming mechanisms in the form of VeraSol certification of refrigerators and international test methods offer key initial steps toward a global quality assurance framework for off- and weak-grid refrigerators. However, this framework can only be rounded out by local assembly and installation, after-sales support and repairability, and strong warranty coverage to help consumers alleviate repair costs. When a refrigerator constitutes a potentially significant expenditure for a household, business, or health center, ensuring the availability of only high-quality models to consumers becomes essential. Additionally, guaranteeing that their investment remains well-preserved over an extended duration is crucial for enhancing their quality of life and augmenting their income.

FOSTERING THE PATH TOWARDS MARKET MATURITY REQUIRES A HARMONIOUS COLLABORATION BETWEEN PUBLIC AND PRIVATE SUPPORT

Establishing policy regulations that foster an environment conducive to facilitating the sales and distribution of refrigerators in energy-constrained communities is imperative, despite existing challenges. For instance, the initiative to unlock local manufacturing urgently demands solutions for issues such as import tariffs that diminish the economic advantages of local assembly, the absence of quality standards for domestically assembled products, suboptimal or inefficient execution of incentives, and uncertainties surrounding the demand for off-grid products, as highlighted in the 2021 ACE TAF report.[24] Applying lessons learned from the innovative initiatives explored in this publication will help establish appropriately and effectively designed financing mechanisms, incentives, subsidies, and training programs to propel the growth of local manufacturing and other obstacles to growth.

It also requires the public and private sectors to engage and collaboratively work together to advance the market.

Empowering homeowners, shopkeepers, farmers, and fishermen to invest in these technologies will build cold storage networks and get fresh produce, meat, and vital medicines directly to last-mile communities, improving livelihoods, health, and economic growth.



FURTHER READING



TECHNOLOGY-SPECIFIC RESOURCES:

Uses and Impacts of Off-Grid Refrigerators — A summary of the benefits and challenges experienced by off-grid refrigerator users in Kenya, Tanzania, and Uganda over several years.

Designing and Implementing Field Testing for Off- and Weak-Grid Refrigerators – A practical guide on monitoring refrigerator performance and efficiency in the field to inform decisions about product design, financing, business models and more.

Evaluating Appliance Performance in the Field: Results from Refrigerator Testing – An April 2023 follow-up to the above guide for field testing refrigerators to present data and observations from field tests carried out in Rwanda and India. These tests were conducted to assess how various usage scenarios and user practices influence the operational efficiency of direct current refrigerators.



MARKET-SPECIFIC RESOURCES:

Efficiency for Access Country Profiles — Off- and weak-grid sector and appliance performance data, including for refrigerators, for key markets, including India, Sierra Leone, Nigeria, Uganda, Ethiopia, and Pakistan.

Kenya Consumer Experience Study — A market snapshot providing insights into the ownership of and consumer experience with off-grid solar appliances, including refrigerators, in Kenya.



APPLIANCE-INCLUSIVE RESOURCES:

Appliance Impacts Over Time — A longitudinal study exploring how customers' relationship with their off-grid appliances, including refrigerators, changes over time. Over 4,000 off-grid customers were interviewed to track product quality, durability, satisfaction, impact, and uptake.

Appliances for All — This report examines how well solar lighting and appliances, including refrigerators, are reaching key populations, and assesses inclusion across solar company employment practices and product offerings.

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