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Insight

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How innovation in off-grid refrigeration impacts lives in Kenya

Practical thinking on investing for development

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Foreword

The proliferation of affordable access to off-grid solar home systems has played a vital role in helping to improve the lives of millions of households across Africa. Rural households in particular stand to gain the most from access to these products and services, where energy and other household appliances can transform the way they work, live and connect with communities. Furthermore, women stand to disproportionately gain from better access and engagement with off-grid solar home systems, given that they hold primary responsibility for collecting food, water and firewood and running the household activities.

Both CDC and M-KOPA are firmly committed to using our investment capital, and products and services to advance gender equality and women's economic empowerment. We recognise the role we must play to help reduce the economic gender gap across the world, which at current rates will take a further 202 years to close. Women are fundamental to achieving the Sustainable Development Goals – cutting across all aspects of poverty reduction and sustainable economic growth. Not only is investing in women the right thing to do, it's the smart thing to do – evidence makes it clear that gender equality leads to better corporate decision making, customer engagement, innovation and expansion into new markets and services. It makes strong commercial sense to consider the impact of women across all aspects of business activities.

M-KOPA's innovation for solar-powered refrigeration for the off-grid market builds on this conviction, by intentionally engaging both male and female consumers equally throughout the product development and user testing period in Kenya. The results have proven our hypothesis to be true – the impact case for off-grid refrigeration is real, and these impacts predominantly accrue to women in terms of freeing up their time spent on household activities, saving costs from bulk purchases, reducing stress and bringing the opportunity to generate income through fridge-based businesses. These all contribute to women's economic empowerment.

While we are excited about the potential of this new product, as with any form of innovation, challenges remain. Despite the positive impacts, the production costs of the current product mean that the price, coupled with the novelty, of this new technology makes customers at the base of the economic pyramid reticent to adopt, especially without fully understanding its benefits. More research and understanding how to appropriately design, price and sell off-grid refrigeration will help scale the market. We're determined to keep trying and delighted to be able to share this journey with you.



Nick O' Donohoe
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Executive summary

M-KOPA, a CDC investee, has a mission to make high-quality solutions affordable to everyone. It has done so by scaling the world's most advanced pay-as-you-go platform that links the solar energy services with flexible financing for over 800,000 homes and businesses across Africa.

This Insight study explores the impact of off-grid refrigeration (an emerging product in the M-KOPA portfolio), and M-KOPA Labs' (the dedicated R&D unit) product innovation in this space, on rural households in Kenya. It focuses on time and cost savings, income generation, broader social and lifestyle benefits and its potential to benefit women.

The study was conducted by Dalberg in partnership with CDC Group and M-KOPA. Through interviews and focus groups with over 1,100 households across five Kenyan counties combined with other data sources, our research explores how M-KOPA serves the needs of rural households and pursues product innovation to make previously out of reach products affordable for these households.

Globally, 840 million people live without electricity, and a further 1 billion people live with unreliable or insufficient electricity. Private off-grid solar companies aim to provide one part of the solution (alongside, for example, utility scale power generation, mini-grids, commercial and industrial solar, improved transmission and distribution) by providing energy supply for rural households through solar home systems. Solar appliance systems have been made affordable for low-income consumers through pay-as-you-go (PAYG) financing. This method, pioneered by M-KOPA, enables cash-constrained customers to pay in small increments daily or weekly through mobile money, thus eliminating the upfront affordability hurdle. However, energy supply needs to be coupled with meaningful opportunities to use this energy in order to make a difference. Access to affordable, efficient off-grid appliances (including refrigeration) will be a key part of helping low income consumers climb the energy ladder and see improvements in their lives.

Beyond mature appliances (lighting, mobile-charging, TVs), low-energy appliances designed for off-grid applications remain unexplored and are still in the R&D stage. Frontier products that are brought to market face substantial headwinds: few know those are available and each product bears the full weight of R&D costs which must be recouped through pricing. This poses two barriers to adoption for rural, low-income households: awareness and affordability. As such, these appliances will need to provide sufficient value in the short-term to motivate target customers to purchase. This paper examines M-KOPA's off-grid refrigeration as a prime example of these innovation and commercial challenges and identifies the ways that off-grid refrigeration provides benefits to households and identifies which households are most likely to gain sufficient enough benefits to justify the costs. Even at the current economics, it is estimated that more than 1.5 million off-grid households in Kenya could realize a direct net economic benefit from refrigerator ownership. Within households too, it is important to understand to whom benefits accrue.

840 million

people globally live without electricity

1.5 million

off-grid households in Kenya could realize a direct net economic benefit from refrigerator ownership

Key insights from our study are:

- The impact case for having a refrigerator in the home is real and these impacts predominantly accrue to women on all dimensions, with time and cost savings, plus business opportunities.
- Illustrating the value proposition for a frontier product is critical to achieving adoption, and most low-income households are cautious to make a purchase until the technology is proven by early adopters (who are difficult to find in rural settings).
- To achieve viability, over the long term, market-based and technological solutions are needed, including:
 1. Exploring economies of scale in manufacturing and building out local supply chains to bring down production costs and prices
 2. Improving positioning of this technology as a productive use asset and communicating its value proposition to micro-enterprises
 3. Developing technological solutions to bring down costs and improve performance of the product and therefore economic viability
- The path to commercial viability and positive impact for a broader set of households for off-grid refrigeration will rely on building awareness and improving affordability.



01

Context

1.1 The off-grid refrigeration market

The scale of the energy challenge is well-known – with 840 million people living without electricity globally, and a further 1 billion people living with unreliable or insufficient electricity. Off-grid energy presents an opportunity to deliver the benefits of reliable electricity to these underserved individuals and, therefore, enable a higher quality of life, without the hazards of toxic kerosene lanterns or diesel generators. Off-grid solutions, including solar lighting, solar home systems, and increasingly mini-grids are crucial to enable people to study in the evenings, watch television or charge mobile phones, and generally improve their living conditions¹. So far, off-grid solutions reach only an estimated 17 per cent of the global market potential². A key reason for this is that most people living without electricity are among the poorest and hardest to reach.

Furthermore, women stand to gain the most from reducing energy poverty - women experience energy poverty differently as they spend three to five times as long as men do on domestic activities, and energy collection³. Women and girls often travel long distances to collect firewood, water and hold primary responsibility for the use of energy resources. Women are therefore central to reducing poverty through access to energy bringing potential time savings, opportunities for converting saved time to productivity, and better health and education outcomes. As primary users of energy, it is essential that women are engaged to adopt and employ new technologies⁴.

To address this challenge, many private off-grid solar companies have brought to market a range of solar solutions, and are actively supported by impact investors and development finance institutions, like CDC. This cadre of private solar companies, however, are still in early stages of development, with many of the most prominent players being established within the last decade. The development of a commercial off-grid solar market for low-income customers has been driven by technological developments including improvements in efficient light emitting diode (LED) technology – with the price of off-grid solar lighting systems dropping by 27 per cent over the last 5 years⁵.

Meaningful energy supply needs to be coupled with meaningful opportunities to use this energy, only then can consumers improve their living standards. The top-ranked benefits of energy appliances found in an experiment in rural



Off-grid solutions reach only an estimated 17 per cent of the global market potential.

- 1 World Bank (2019). Energy overview. <https://www.worldbank.org/en/topic/energy/overview>
- 2 World Bank (2018). Off-grid bringing power to millions. <https://blogs.worldbank.org/energy/grid-bringing-power-millions>
- 3 African Development Bank (2016). Empowering Women in Africa through Access to Sustainable Energy. www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/AfDB-Gender_and_Energy_Desk_Review-EN-2016.pdf
- 4 World Bank (2017). Energy access and gender: getting the right balance. <http://documents.worldbank.org/curated/en/463071494925985630/pdf/115066-BRI-P148200-PUBLIC-FINALSEARSFGenderweb.pdf>
- 5 Abagi, N. et al (2019). State of play and innovations in off-grid refrigeration technology: lessons learned from current initiatives. <https://link.springer.com/content/pdf/10.1007%2F978-981-10-9783-1.pdf> and Lighting Global. (2018). Off-Grid Solar Market Trends Report. www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report

Uganda were: business opportunities, elimination of labour intensive tasks, preservation of health, ability to acquire knowledge, feeling comfortable, information access, time savings, and productivity improvement⁶.

Accordingly, access to affordable, efficient off-grid appliances (including refrigeration) will be key to the continued development of this market and to achieving important social outcomes. Commercially, these appliances also form a crucial part of the product portfolio of off-grid solar companies and are central to driving demand for energy from consumers⁷. There are many different types of off-grid appliances, including: lighting appliances, televisions, radios, refrigeration units, cookstoves, washing machines / dryers, water pumps / irrigation, grinding / milling / husking and others, such as mobile phones⁸. Many solar companies follow a pay-as-you-go model.

From an economic outcomes and development perspective, these appliances are generally divided imperfectly between consumptive and productive appliances – that is, those primarily for consumptive purposes (such as television and radio) and those primarily for productive purposes (for example, water pumps/ irrigation and grinding/milling/husking).

Off-grid refrigeration requires more investment to make it accessible to consumers. The highly intensive power requirements of refrigerators are unlike those of LED and TVs, which has historically made it an ill-fit appliance for solar. M-KOPA Labs and Embraco's innovation in this space overcomes those technological hurdles, making a solar refrigeration available and accessible to low-income, off-grid households and micro-enterprises.

Refrigeration falls somewhere in between both categories and will – at least in rural settings – simultaneously satisfy consumptive and productive use. This makes a fridge a popular product. A recent survey highlighted refrigeration units as the fourth most in demand (of 18) for households behind lighting, televisions and mobile / smart phones⁹. The same survey also highlighted refrigeration units as the third most in demand (of 20) business / productive use appliances behind solar water pumps and refrigeration for agriculture cold chain.

Competition to capture this large market opportunity is low but entry is tough. Development of an affordable, fit-for-market solar fridge took two years and high investment in R&D, production and distribution. It was supported by the Shell Foundation in partnership with UKAID and USAID, nonetheless it represented a substantial risk for M-KOPA. As a first-mover, M-KOPA and Embraco will need to continue to invest in customer education and market development.

The benefits of access to off-grid refrigeration are intuitive in theory – including: time savings (such as from enhanced ability to preserve food), reduced spending (such as from the potential for bulk buying), improved incomes (such as from micro and small businesses), and broader social benefits (such as enhanced nutrition and leisure time).

The potential impacts of off-grid refrigeration will also vary widely depending on use cases – from household use (depending on the socio-economic and geographic profile of households), to commercial retail (drinks, foodstuffs, pharmaceuticals); and agricultural value chains (input retailers, dairy, fisheries). This study focuses on households and household-run businesses. Since launching in market, M-KOPA has found households are challenged to monetise the aggregated savings, whereas businesses can see a clear route to revenues and are, consequently, much more accepting of current pricing.

Yet the evidence to support these impacts remains untested given how nascent the off-grid refrigeration market is – for instance, it is unclear the extent to which households save time, or use time saved on more productive activities. Studies in high income contexts,¹⁰ conclude that owning household technology rarely reduces unpaid household work (the Cowan paradox); it is unclear if the impact hypothesis holds true in the Kenyan context. Particular assumptions around money saved through bulk-buying and income generation through business activities may change with smaller refrigerator sizes. Furthermore, simply buying a refrigerator may not necessarily lead to changes in food preparation and consumption habits, at least not in the short-term.



Off-grid refrigeration requires more investment to make it accessible to consumers.

6 Hirmer, S. and Guthrie, P. The benefits of energy appliances in the off-grid energy sector based on seven off-grid initiatives in rural Uganda. 2017, 79, 924–934. www.sciencedirect.com/science/article/pii/S1364032117307797

67 Global Leap (2016). The state of the off-grid appliance market. www.gogla.org/sites/default/files/resource_docs/global_leap_-_the_state_of_the_global_off-grid_appliance_market_2016.pdf

7 Hirmer, S. and Guthrie, P. (2017)

8 Hirmer, S. and Guthrie, P. (2017)

9 Efficiency for Access Coalition (2018). Off-grid appliance market survey 2018: <https://assets.publishing.service.gov.uk/media/5bb77fcoed915d23ad91fcb3/Market-Survey-2018.pdf>

10 Ramey, V. A. (2009). Time spent in home production in the twentieth-century United States: New estimates from old data. *The Journal of Economic History*, 69(1), 1-47. and Bittman, M., Rice, J. M., and Wajcman, J. (2004). Appliances and their impact: The ownership of domestic technology and time spent on household work. *The British Journal of Sociology*, 55(3), 425-431

Few studies have systematically quantified the benefits that household refrigeration brings to men and women. Yet, spending for off-grid refrigeration could increase to \$1.1 billion. Research from 2018 estimates that annual spending on refrigerators by off- and weak-grid households is around \$75 million. If efficient products become accessible to all households with the purchasing power to buy a refrigerator, the spending could increase to \$1.1 billion by 2020¹¹. Given this large market size, evidencing the differential benefits actually accrued to men and women becomes a worthwhile undertaking from a developmental as well as a commercial perspective.

For refrigeration, as with most other appliances, efficiency and economics present challenges to viability:

- 1. Energy efficiency** – conventional appliances consume a huge amount of energy supply, which has historically prevented their use with solar systems. Even in areas with weak electrical systems, the combined energy demand from inefficient appliances has led to overloading of these systems, contributing to power outages.
- 2. Economics** – the high prices of off-grid appliances makes affordability (see CDC's note on affordability¹²) a critical barrier to adoption – especially for larger appliances that represent capital expenditure. Off-grid refrigeration prices range between around \$300 and \$2,200 (significant compared with a gross national income of £1,620 per person in Kenya) which is beyond what many off-grid households' can afford¹³. Where markets for individual appliances are relatively mature (such as televisions) we see prices trending down as volumes grow, research and development (R&D) improves and manufacturing costs decline. This will very likely be the case as solar refrigeration advances.

Figure 1 below maps household appliances against their energy demand and required income level (excluding primarily productive appliances).

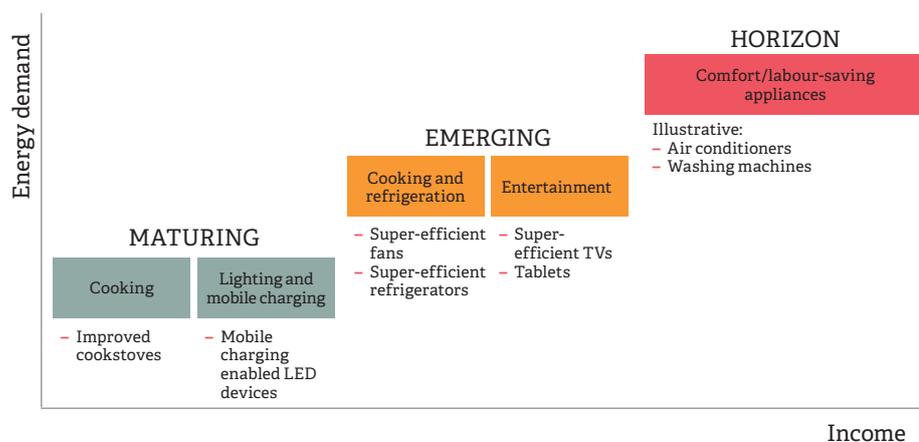


Figure 1: Stylised mapping of off-grid household appliances by energy demand and income (source: Dalberg analysis)

» *If efficient products become accessible to all households with the purchasing power to buy a refrigerator, spending could increase to \$1.1 billion by 2020.*

11 Appliance data trends, 2018: <https://assets.publishing.service.gov.uk/media/5bb3492bed915d25b68f6b87/Data-Trends-Report-Sept7-Final.pdf>
 12 CDC Group (2018). Affordability. Beyond the buzzword. <https://www.cdcgroup.com/en/sustainable-investing/affordability-beyond-the-buzzword/>
 13 Efficiency for Access Coalition (2018). Appliance data trends. <https://assets.publishing.service.gov.uk/media/5bb3492bed915d25b68f6b87/Data-Trends-Report-Sept7-Final.pdf>

1.2 M-KOPA's off-grid refrigeration journey

M-KOPA is Africa's leading off-grid technology company – and a pioneer of pay-as-you-go for low income homes. Since its foundation in 2010, the company has been giving customers a path to owning items that are at the heart of the home, connecting lights, charging, radios, televisions - and now fridges. M-KOPA subscribers chose a payment plan that suits them, and then can upgrade to more.

The company operates across the value chain, from R&D and product design to manufacturing, sales/distribution, servicing, underwriting and financing of customers. M-KOPA pioneered the pay-as-you-go solar industry and has grown rapidly over the last 8 years – and now provides off-grid solar home systems (SHS) to over 800,000 low-income households across East Africa, providing over 3 million individuals with clean, safe lighting solutions.

M-KOPA's off-grid refrigerator has been in development with its R&D team, M-KOPA Labs, and partner, Embraco, since June 2016 with the aim of bringing to market an affordable cooling solution to off-grid customers across Africa. In July 2016, M-KOPA Labs and Embraco agreed a development plan for the refrigerator and secured funding from the Shell Foundation to develop large power solar systems and grid-enabled devices.

Embraco is a world-leading player in cooling technology, and the partnership with M-KOPA Labs has led to a hyper-efficient refrigerator capable of running solely on solar power with the same cooling power at 6 degrees Celsius as a regular fridge. Such partnerships signal welcome interest from legacy hardware companies to innovate solutions for previously overlooked low-income, off-grid markets.

Throughout 2017 M-KOPA Labs conducted a series of customer research and product tests to support this innovation – customer research focused on usage patterns and hypothesised financial benefits related to refrigerator ownership. A subsequent SMS survey was also launched to validate willingness to pay among customers. Results from this research showed early indications that women stand to disproportionately benefit from the product in terms of time saved from fewer trips to far-off markets and reduced cooking time.

In 2018 M-KOPA Labs began sales pilots of two refrigerator models: a 47 litre and 100 litre versions – primarily in Kenya and, at a smaller scale, in Uganda. These pilots were an opportunity to validate customers' reported preferences against their actual behaviour when given the opportunity to purchase the product in a commercial setting.

Armed with this insight, M-KOPA has now launched a 100-litre refrigerator as a commercial product throughout Kenya and Uganda. The need for continued customer testing remains central though, particularly to better understand the shape of the demand curve for off-grid refrigerators.

1.3 Understanding the impact of off-grid refrigeration

This study, in partnership with M-KOPA, CDC and Dalberg, sought to examine real and perceived impacts of off-grid refrigeration on households (and, in particular, women) in Kenya. Little credible research exists on the impact of many off-grid appliances in the sub-Saharan African context – in large part due to the limited availability of these technologies (a call for additional R&D investment). The study provided an opportunity to inform product innovation, market size and to bolster the knowledge for the wider development community on this new product class.

Our research explores the positive impacts of owning a fridge from users and quantify the benefits in areas such as time savings (from reduced trips to markets and medical centres and reduced time spent preparing meals), cost savings (from reduced trips to town, reduced food waste, reduced cooking fuel use, and bulk buying), income gains (from sales of cold drinks, specialized use cases such as storing dairy products or veterinary medicine, or from the monetisation of time savings on household chores) and broader social benefits.

800,000+

low-income households across East Africa are provided with off-grid solar home systems by M-KOPA

It is important to note that M-KOPA's Solar Fridge system powers more than the refrigerator itself. The full system provided to customers entails the solar panel, a battery capable of 36-hours of continuous power in the event of a very cloudy day, 2 LED strip bulbs and phone charging capability, and financing to make the system available on a flexible, PAY-AS-YOU-GO basis. Therefore, the full stack of benefits provided to customers extend far beyond cold storage, but for the purposes of research we have chosen to narrow the focus to those tied to refrigeration.

The research also prioritises understanding who the impact accrues to – between households, and within households with a focus on women. To understand differences between households, a broad geographic coverage was targeted for primary research. To understand differences within households – all primary research ensured an equal representation across men and women – with a range of methods used to understand not only *what* the impacts were but also *why* and *how* they were accrued.

Three research methods were used to triangulate the impacts of off-grid refrigeration:

1. A large-scale survey of potential refrigerator customers of 1,023 M-KOPA Kenya customers (515 female, 508 male) to explore buying decisions, expected impact, demand drivers, and potential use cases. These customers were chosen by simple random stratified sampling over a range of climatic zones (to control for climatic variations across regions) to ensure representativeness (Figure 2). Importantly, M-KOPA TV customers were over-sampled as those most likely to purchase the Fridge as their next product choice and demonstrate willingness to finance solar assets set at a \$1 / per day PAY-AS-YOU-GO daily payment amount. As the price point for refrigerators declines, it is more likely that these findings will be generalisable.
2. Six focus group discussions with potential refrigerator customers – gender balanced with a mix of single-gender and mixed groups of customers – as well as a sales agent focus group. These discussions allowed us to dig deeper into the drivers of off-grid refrigeration ownership, better understand the social and economic drivers, and nuance the findings by gender.
3. In-depth interviews with 43 owners of M-KOPA's off-grid refrigerator drawn from customers who had purchased the product during piloting. These interviews allowed us to understand the real experiences of consumers who had acquired the refrigerator and triangulate with the expected impacts articulated by the larger samples above.

» Little credible research exists on the impact of many off-grid appliances in the sub-Saharan African context.

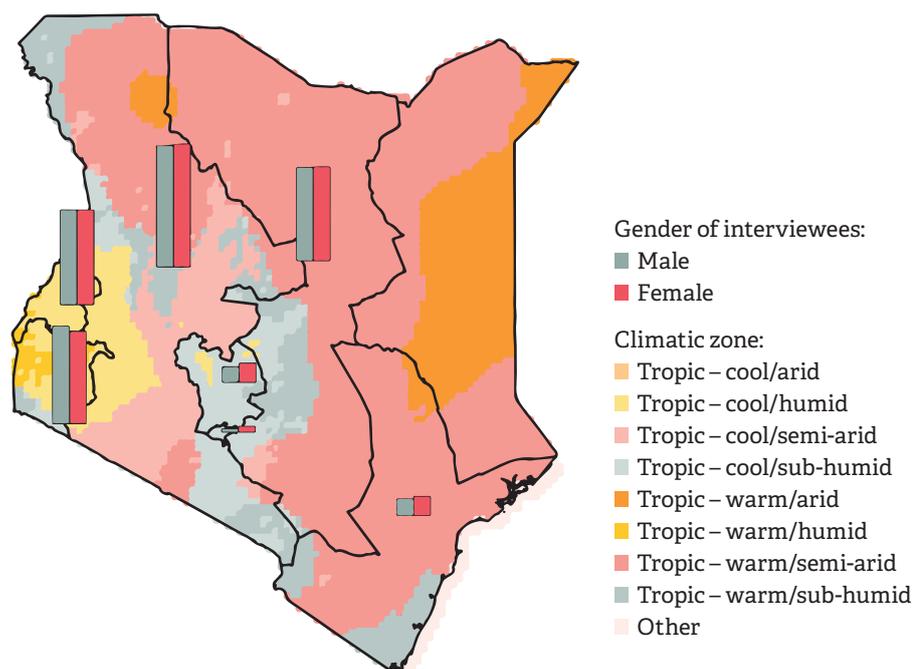


Figure 2: Map of Kenya by climatic zone and spread of survey samples



02

Key findings

2.1 Understanding and quantifying the benefits of owning a refrigerator (and for who)

Our study explores the impacts of owning an off-grid refrigerator along several dimensions:

1. Cost and time savings
2. Income generation (commercial use)
3. Broader social and lifestyle benefits

Cost and time savings

The M-KOPA refrigerator was perceived to save households around \$4.82 per week from fewer trips to the market; less spending on cooking fuel, and less food waste due to spoilage; with female respondents estimating higher savings on all three accounts. (Figure 3) Outside potential income generation, M-KOPA refrigerator users see additional benefits from increased variety in diets reduced dependency on unreliable electricity, lower stress resulting from the ability to store raw food, and increased convenience from the ability to store cooked food. Refrigerator ownership was associated with increased social capital through signalling wealth and economic stability to the community, and having the ability to help and host neighbours.

» *The M-KOPA refrigerator was perceived to save households around \$4.82 per week.*

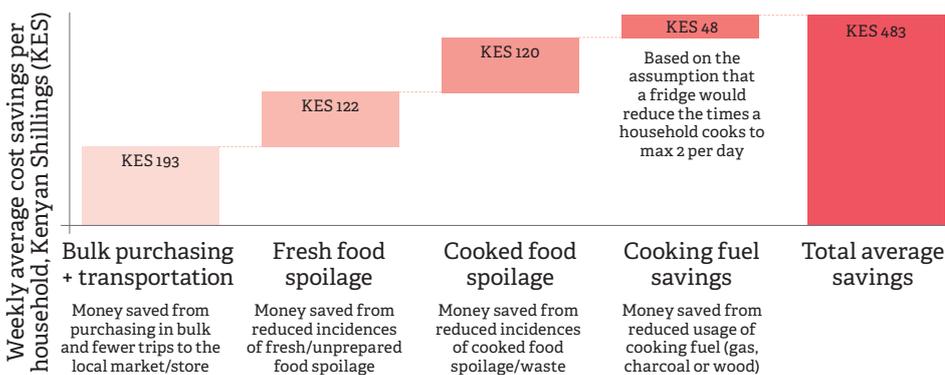


Figure 3: Household estimated cost savings by source

Results from in-depth interviews of refrigerator owners are consistent with these expected savings. The key impacts highlighted by those who already owned a refrigerator included:

- **Expected time savings equate to roughly 2 hours a week per household – which accrue primarily to women.** More broadly, the main savings come from reducing fresh and cooked food spoilage and time/cost savings associated with food purchasing. Female respondents tend, on average, to estimate higher savings across all three of these sources (+6 per cent against male respondents)
- **Lower stress**, primarily for women: having a refrigerator was noted to relieve women from rushing to the market and then back home to prepare dinner at a certain hour; many noted that they felt assured that their food is “safe” and “alright”
- **Varied diets:** diet changes were noted by most households as a result of using the refrigerator – this was based on adding more variety to food consumption, including fruit, vegetable, meat and fish.
- **Increased reliability:** the refrigerator’s key advantages included increased reliability of cooling due to constant solar power (compared with unreliable alternate electricity sources) and no separate electricity bills.
- **Increased convenience:** a number of respondents, predominantly men, noted that they appreciated not having to worry about food when getting home late as it can be preserved now.

2 hours

Expected weekly time savings per household with a refrigerator, which primarily benefit women

Total perceived average cost savings alone from owning an off-grid refrigerator currently represent 60 per cent of the weekly payments for the product. This confirms that for households who dually use the product for income generating activities or accrue significant social benefits, the price point will need to come down if the product is to deliver net benefits to the mass low-income market. Over the lifetime of the refrigerator system, customers will see a positive return on their investment, especially for households that will displace current expenditure for expensive, poor-form lighting, e.g., kerosene lanterns and diesel generators with the LED lights provided with M-KOPA’s fridge system.

Some households are more likely to accrue outsized time and costs savings than others. These include those with higher incomes (\$3-4 per day daily earnings), those most likely to start or already operate businesses, those where the female head of household has higher levels of education, those formally employed and those between 20 and 39 (likely linked to child-rearing).

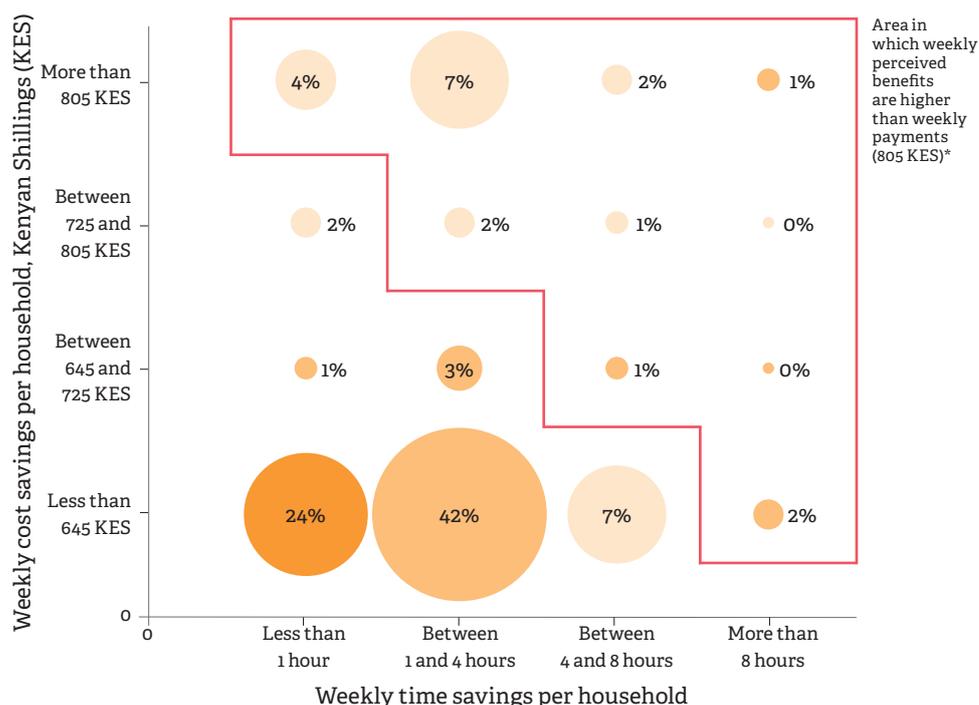


Figure 4: Distribution of household time and cost savings – identifying people estimated to receive positive net benefits

Broader social benefits

Around 60 per cent of the informant interviewees saw the main beneficiary as the female head of the household – with time benefits disproportionately accruing to women, who are the primary shoppers in 91 per cent of households in this survey. Majority of respondents in the focus groups also stated that the women of the household would be able to use the fridge to start a business, such as selling vegetable and fruits, ice or beverages (cold water, soda, juices, drinks and milk).

Buying a fridge is generally a joint decision between men and women within Kenyan households – most women said they had to consult their husbands, and men usually consulted with their wives too, as they considered the fridge a product being mainly used by women. This was particularly the case among more educated households.

Focus group discussions with potential customers revealed that owning a refrigerator is perceived to be associated with important ‘social capital’ benefits – these included high status (representing “wealth” and “happy life”) and the ability to host (many participants noted the ability to have guests over for drinks). Households that already owned refrigerators validated the same social benefits – with some also mentioning a key benefit as the ability to store food for their neighbours.

2.2 Better understanding the business uses of a refrigerator

Income generation

Income generation from micro businesses linked with refrigerators would more likely to accrue to women- most respondents (53 per cent) noted that they have someone in their household who engages in business – with women, on average, more likely to be involved with business than men (71 per cent female participation, against 47 per cent for males) out of which 73 per cent indicated that they would use a fridge in their business.

Primary business activities for owners of off-grid refrigerators were people who sold or would sell perishable goods and pharmacies – as well as those selling general merchandise. Households that sold perishable goods (vegetables, fruits, milk, eggs, animal proteins) or ran pharmacies, but did not yet own a refrigerator, noted that they would be “interested” in a refrigerator in more than 85 per cent of cases.

Number of respondents by category is shown below the column

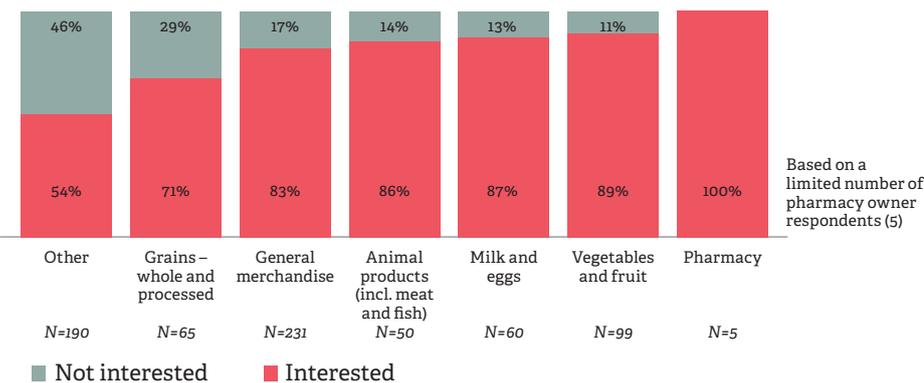


Figure 5: Stated level of interest in using a refrigerator for business by use case

Results from focus groups also validated the commercial opportunity, particularly for women to be able to start a business. The results noted that businesses primarily focussed on perishable goods (milk vegetables, fruits and fish) and cold water would be likely to get more customers if they could store more commodities in a refrigerator. The focus groups also confirmed that many respondents saw a refrigerator as an income-generating asset to scale up their current business or create a new one for another family member.

60%

of interviewees saw the main beneficiary as the female head of the household



As a business person if I get a fridge I can put in sodas, water, juice and other things to sell and make profit out of it.

Focus group participant

During in-depth interviews, business owners reported that, on average, a refrigerator increased weekly income by \$1-\$40 (100-3,750 Kenyan Shilling)¹⁴. More generally, respondents interested in starting a business would mainly sell cold water and drinks (33 per cent), milk and eggs (28 per cent) and vegetables and fruits (20 per cent). There was limited interest around selling other animal products, ice and other products. These business uses are naturally tied to refrigerators with capacities between 47 and 100 litres and would likely shift if different sizes, models and functionality of refrigeration were tested.

\$1-\$40

Average increase in weekly income for business owners with a refrigerator

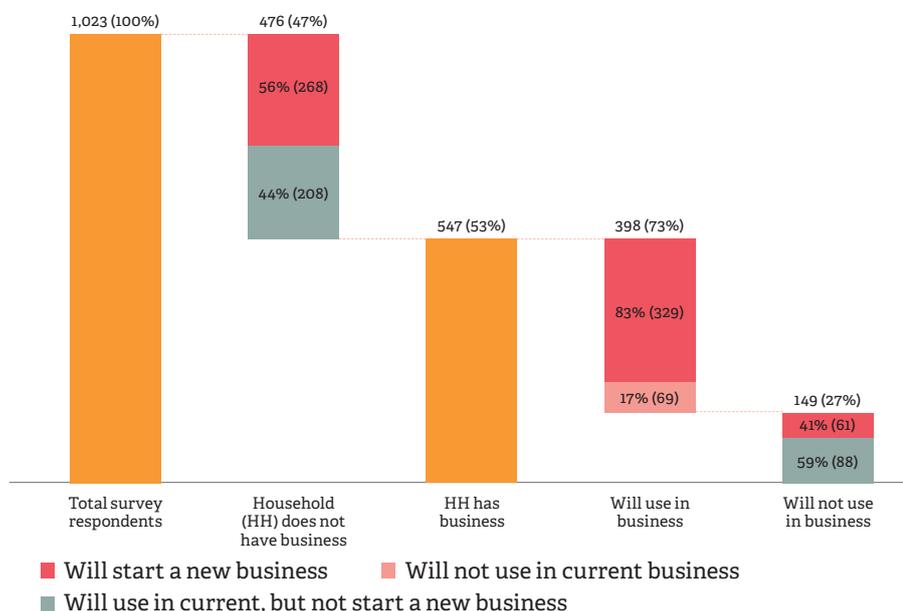


Figure 6: Respondents who aim to use a refrigerator for business (business and non-business owners)

2.3 Sizing the addressable market for off-grid refrigeration

Despite the positive impacts, a clear majority of refrigerator owners (83 per cent) in Kenya say the refrigerator is currently too expensive and more than half say that they have had trouble making payments, including those who used the refrigerator for commercial activity. Much more work is needed to bring down the price of the product to become attractive for low-income adopters using the fridge for household purposes only. Sales agents also validated the need for the price of the refrigerator for rural households to come down to drive net benefits and demand from households.

Even so, when shown the product and pricing, most households surveyed remained interested in buying the product. On average, around 60 per cent of the respondents would be interested or very interested in buying off-grid refrigerator, with 10 per cent very interested – likely the best reflection of conversion rates. Excluding the lower-income third of the population, it is estimated that as many as 1.8 million off-grid households in Kenya would be interested in buying an off-grid refrigerator even at current prices.

Even at the current economics, it is estimated that 3.4 million off-grid households in Kenya could realize a direct net economic benefits from owning a fridge (an even larger number than the estimated 1.8 million households that would be interested in purchasing) – and this number does not include potential income gains from small business ownership, or the value of time savings from cooking less often.

1.8 million

off-grid households in Kenya would be interested in buying an off-grid refrigerator even at current prices



I feel like I should have it but maybe I cannot afford it.

Focus group participant

¹⁴ Noting small size of respondents of 11 business owners.



03

The way forward

The impact case for the refrigerator is real and these impacts predominantly accrue to women on all dimensions, with substantial cost savings for large portions of survey respondents, plus substantial business opportunities. Yet, current economics is a barrier for the sector to deliver these benefits in the near term, and many customers and sales agents are concerned about pricing creating financial burdens for households. Through market-based and technological approaches the challenge ahead will be to understand how to appropriately design, price and market off-grid (or weak-grid) refrigeration on the path to commercial viability.

To achieve viability over the long term, market-based and technological solutions are needed. These paths are briefly signposted here – a more detailed analysis can be found in the ‘Off-Grid Refrigeration Technology Roadmap’ by the Department for International Development¹⁵.

- 1. Exploring economies of scale in manufacturing to bring down production costs and prices.** A growing market could result in economies of scale, especially when exploiting synergies with refrigeration for motorhome and recreation markets. Cost reduction could also be explored through material substitution and cheaper components. However, before putting the focus on cost reduction, it is important to increase confidence that the design is well-specified and meets the needs of the target populations. Practical first steps include designing for robustness, reparability, simplification and with fewer material types (especially plastics).
- 2. Building out the entire supply chain and reducing costs.** This could include building repair capability in rural communities, reducing last-mile transportation costs and working with technological input suppliers to reduce the cost of component parts to bring down overall product cost.

¹⁵ Efficiency for Access Coalition (2019). Off-Grid Refrigeration: Technology Roadmap. https://assets.publishing.service.gov.uk/media/5d31c1e6ed915d2fed340c4f/Refrigeration-Roadmap_FINAL.pdf

3. **Targeted sales and marketing efforts for female users of the product.** This could include emphasising key messages about the benefits that could accrue to women such as the ability to free up time to spend with family and friends or run a business.
4. **Improving understanding of where income generation provides a robust case to cover ongoing running costs in productive use and then target this market.** This could include expanding distribution networks for large drinks manufacturers or collaborating with local and regional farming organisations in relation to cold storage for agricultural value chains or with pharmacies for safe storage of medicine and vaccines.
5. **Developing more technological solutions to bring down costs and improve performance of the product and therefore economic viability.** These can range from a wider choice of DC compressors to conversion kits that allows mass produced AC refrigerators to be used with DC power supply.

The path to commercial viability and positive impact for a broader set of households for off-grid refrigeration will rely centrally on the ability to maintain efficiency while dramatically improving affordability – which goes beyond just pricing and into cost of access as well as broader considerations of opportunity cost¹⁶. Though even in those circumstances, some suggest that take-up of household refrigeration is more likely in mini-grid and weak grid areas than through solar home systems.

M-KOPA will therefore continue to innovate on its off-grid solar products, including fridges to help customers climb up the energy ladder and make more benefits available to more people.



The path to commercial viability and positive impact will rely on the ability to maintain efficiency while dramatically improving affordability.

¹⁶ CDC, 2018, Affordability – Beyond the Buzzword: <https://www.cdcgroup.com/en/sustainable-investing/affordability-beyond-the-buzzword/>

¹⁶ CDC, 2018, Affordability – Beyond the Buzzword: <https://www.cdcgroup.com/en/sustainable-investing/affordability-beyond-the-buzzword/>

Appendix

Large-scale survey notes

- Population spread based on World Bank survey in 2015¹⁷
- Large-scale sample assumed to be representative of similar households in the Kenyan market in terms of:
 - Interest level in purchasing the M-KOPA refrigerator
 - Time and cost savings estimated by the survey respondents
- Survey respondents categorised based on the Progress out of Poverty Index (PPI) of more than 50 per cent being below the national poverty line, then a PPI likelihood of more than 50 per cent below \$3.20, then a PPI likelihood of more than 50 per cent below \$5.50, and the remaining respondents allocated to the high-income bracket
- Percentage of population off-grid estimated based on an average Kenyan off-grid rate of 73 per cent of households from a 2012 off-grid solar country briefing in Kenya¹⁸ and a simplified spread over the four populations assuming lower grid penetration for lower incomes
- Average potential benefit for each income segment computed based on savings estimated by survey respondents in each segment reporting of:
 - Weekly savings on transport fare/fuel
 - Weekly savings on cooking fuel
 - Weekly savings through reduced spoilage
 - Weekly earning potential from decreased travel time (based on earnings rates of 20, 40, 60 and 80 Kenyan shillings for national poverty line, lower-middle income, upper-middle income and high-income brackets, respectively)

¹⁷ World Bank. Poverty and Equity Database: <http://povertydata.worldbank.org/poverty/country/KEN>

¹⁸ Overseas Development Institute (2016). Accelerating access to electricity in Africa with off-grid solar: www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/10249.pdf

Breakdown of large scale survey respondents by gender and district

District	Breakdown by gender and country					
	Male		Female		Total	
Mombasa	2	40.0%	3	60.0%	5	100.0%
Kwale	2	28.6%	5	71.4%	7	100.0%
Kilifi	10	52.6%	9	47.4%	19	100.0%
Lamu	1	100.0%	0	0.0%	1	100.0%
Taita Taveta	4	44.4%	5	55.6%	9	100.0%
Isiolo	2	66.7%	1	33.3%	3	100.0%
Meru	20	44.4%	25	55.6%	45	100.0%
Tharaka Nithi	4	44.4%	5	55.6%	9	100.0%
Embu	7	53.8%	6	46.2%	13	100.0%
Kitui	15	53.6%	13	46.4%	28	100.0%
Machakos	38	49.4%	39	50.6%	77	100.0%
Makueni	21	52.5%	19	47.5%	40	100.0%
Nyandarua	3	33.3%	6	66.7%	9	100.0%
Nyeri	5	55.6%	4	44.4%	9	100.0%

Kirinyaga	1	50.0%	1	50.0%	2	100.0%
Muranga	5	55.6%	4	44.4%	9	100.0%
Kiambu	4	36.4%	7	63.6%	11	100.0%
West Pokot	4	50.0%	4	50.0%	8	100.0%
Samburu	1	25.0%	3	75.0%	4	100.0%
Trans Nzoia	19	51.4%	18	48.6%	37	100.0%
Uasin Gishu	14	45.2%	17	54.8%	31	100.0%
Elgeyo Marakwet	6	60.0%	4	40.0%	10	100.0%
Nandi	9	50.0%	9	50.0%	18	100.0%
Baringo	12	44.4%	15	55.6%	27	100.0%
Laikipia	4	44.4%	5	55.6%	9	100.0%
Nakuru	24	52.2%	22	47.8%	46	100.0%
Narok	21	48.8%	22	51.2%	43	100.0%
Kajiado	16	53.3%	14	46.7%	30	100.0%
Kericho	6	60.0%	4	40.0%	10	100.0%
Bomet	3	42.9%	4	57.1%	7	100.0%
Kakamega	52	50.0%	52	50.0%	104	100.0%
Vihiga	9	47.4%	10	52.6%	19	100.0%
Bungoma	27	49.1%	28	50.9%	55	100.0%
Busia	21	52.5%	19	47.5%	40	100.0%
Siaya	41	51.3%	39	48.8%	80	100.0%
Kisumu	24	54.5%	20	45.5%	44	100.0%
Homa Bay	20	43.5%	26	56.5%	46	100.0%
Migori	17	53.1%	15	46.9%	32	100.0%
Kisii	7	63.6%	4	36.4%	11	100.0%
Nyamira	3	60.0%	2	40.0%	5	100.0%
Nairobi	4	36.4%	7	63.6%	11	100.0%
Total	508	49.7%	515	50.3%	1023	100.0%

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