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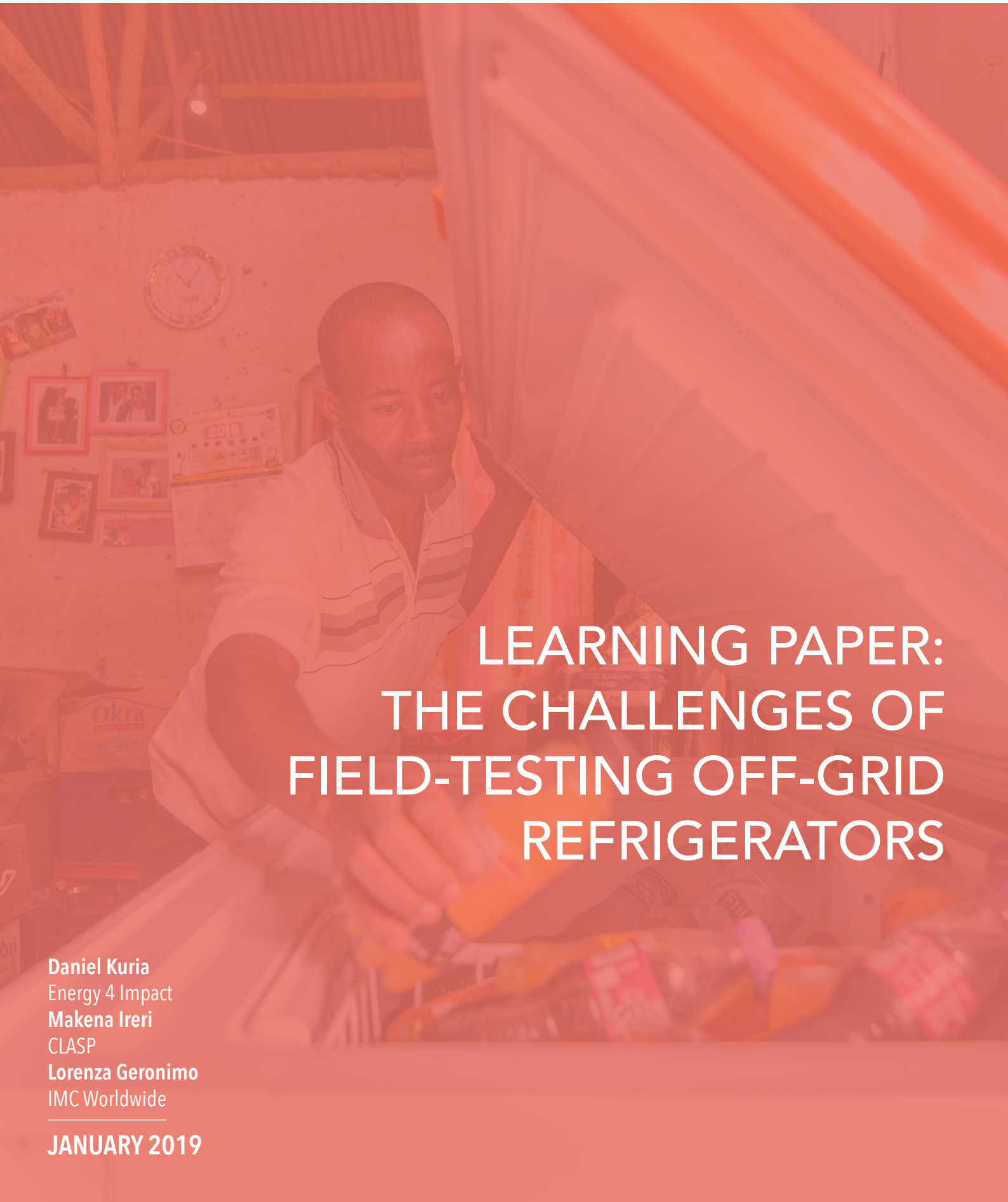

LEARNING PAPER: THE CHALLENGES OF FIELD-TESTING OFF-GRID REFRIGERATORS

Daniel Kuria
Energy 4 Impact
Makena Ireri
CLASP
Lorenza Geronimo
IMC Worldwide

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CONTEXT

The Ideas to Impact programme, funded by the UK Department for International Development (DFID), is testing whether prizes can stimulate innovative solutions to longstanding development challenges for low-income households. Target areas include climate change adaptation and access to energy, water and sanitation.

Within the energy access theme, the 2017 Global LEAP Awards Off-Grid Refrigerator Competition aimed to encourage the development of off-grid energy-efficient refrigerators that are affordable and suitable for communities in areas without access to electricity. The competition was supported by the Scaling Off-Grid Energy Grand Challenge for Development, the US Agency for International Development, DFID through Ideas to Impact, and Power Africa's Beyond the Grid initiative.

As part of the competition, in 2017-2018, IMC Worldwide, Energy 4 Impact and CLASP tested off-grid refrigerators submitted by global manufacturers to determine efficiency, reliability and design appropriateness for off-grid users. The competition shortlisted 24 models from 57 submissions, based on energy and performance efficiency.

The submitted products with a capacity range of 50L-212L were grouped into three categories: refrigerators, refrigerators-freezer combinations and freezers. Most products are already commercially available but the competition also accepted those at development stage. To have a comprehensive evaluation of the products, the tests were conducted in two stages:

- **Laboratory (lab) tests in the Netherlands** – testing innovation and general performance (two prizes were awarded, each worth US$ 200,000, one for demonstrated market-leading advancement in energy efficiency and the other for overall value).
- **Field tests in Uganda** – testing user experience and design appropriateness (prize US$ 200,000).

The competition presented a good opportunity to compare available products and provide feedback to manufacturers on areas of improvement from a technical and design perspective. Running the competition involved multiple experts, countries, products and technologies.

The results will guide the industry towards better designed off-grid refrigerators and the prize will serve as catalytic fund for further research and development of the winning product.

The laboratory tests in the Netherlands were straightforward as similar tests had already been conducted. The standards, protocols and parameters are readily available in the industry, while the controlled environment reduces shortfalls. The parameters included stabilisation levels at steady-state operation, product autonomy, pull down, and freezing capacity among others.

The second leg of the competition, however, was conducted in a non-controlled environment. Moreover, it involved global and local logistical coordination, use of advanced technologies in rural settings and identification of unique parameters to evaluate fridge performance, user experience and design appropriateness.

This paper summarises some of the challenges faced during the second stage, and how the team worked around them, ensuring the competition remained fair and relevant.

The main challenges were concentrated in three areas:

- **Testing Methodology**: With little precedent for off-grid refrigerator testing available, we had to both develop a vanguard methodology from scratch and continually improve its protocol[1] and evaluation criteria to account for new insights gained through learning.
- **Data Collection**: Finding suitable shop owners to test the fridges and sourcing appropriate remote sensing technologies that could capture the data required without failure proved difficult.
- **Logistics**: Compliance with Ugandan shipping and labelling proved difficult, particularly when information on proper labelling procedure was not made available to the public. The team also experienced challenges transporting the fridges to their remote testing locations.

1. The protocol includes the objectives, requirements, activities, resources, documentation and methodology used in the refrigerators field tests.

Nabukenya Resty likes that her solar refrigerator does not consume too much energy compared to traditional fridges. Credit: Efficiency for Access/CLASP.

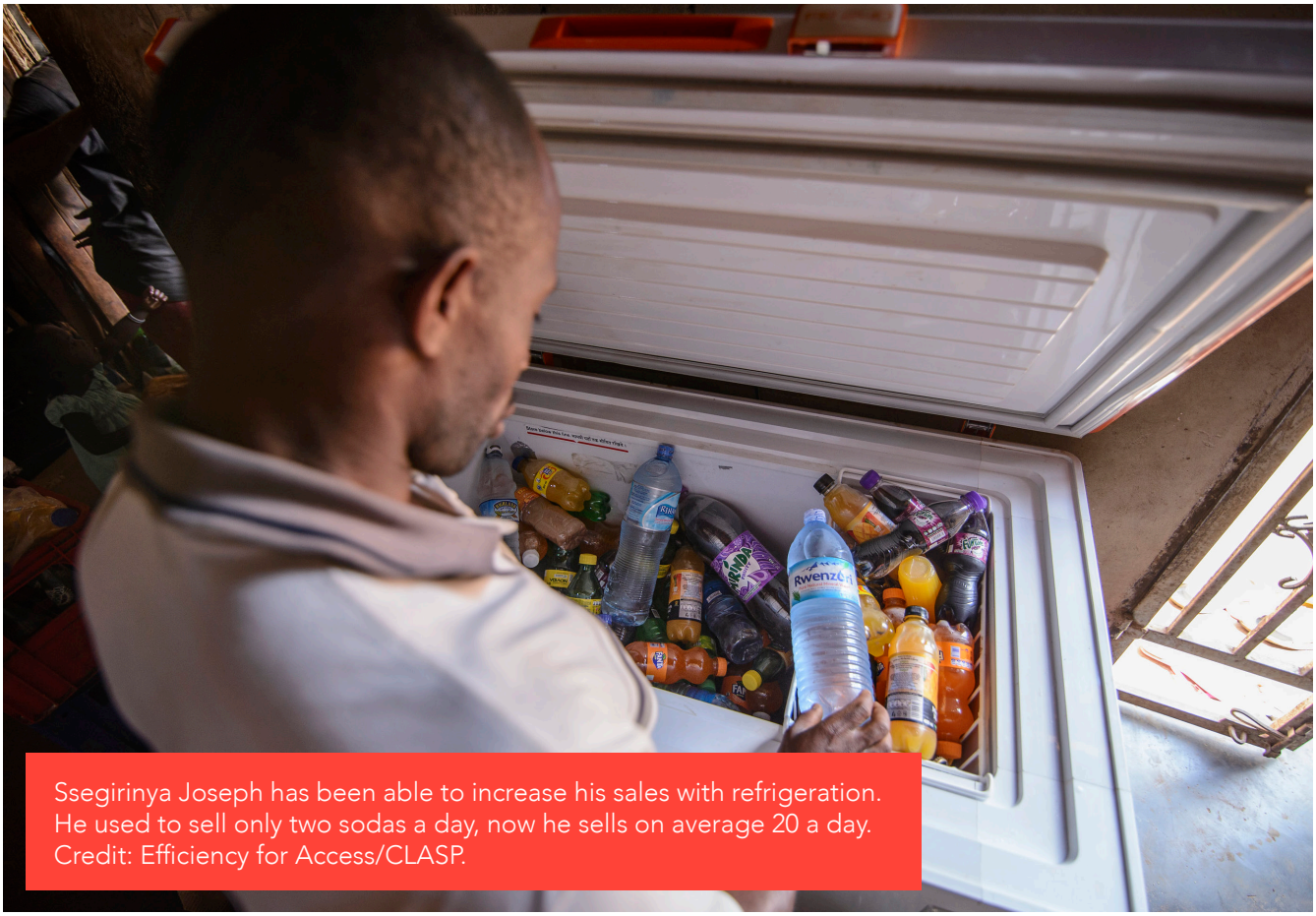
METHODOLOGY – A STEEP LEARNING CURVE

The off-grid refrigeration market is nascent while the practice of lab and field-testing these appliances is expensive and rarely attempted. To our knowledge, outside the vaccine refrigeration industry, there has been no field-testing at this scale that crosschecks lab test results in a comparable 'non-commercial' context. Consequently, the team had to develop a vanguard testing methodology which would answer questions such as what to measure, how, when, with what, and who to collaborate with.

The team drafted a standard testing protocol capturing user experience, design appropriateness, value to user and energy efficiency. The test subjects were 36 home-based general shop owners (entrepreneurs) in rural off-grid locations[2] who had no access to a refrigerator. Unlike lab tests, testing in off-grid areas is not a case of plug and play, given zero access to electricity. As such, the competition installed customised solar photovoltaic systems in the shops which could generate enough power to run refrigerators and provide lighting.

The refrigerators were provided to the entrepreneurs as a grant on condition that they would give feedback over two weeks. Providing free power systems and a refrigerator had an implication on the feedback as most users would only provide praise comments. This meant the test had to use proxy information and combine multiple questions during surveys to get a true perception. Data from the users were collected in six bi-weekly rounds, each time asking the same questions and recording any shift, positive or negative, in opinion. The protocol was improved several times during the test period when better indicators were observed following interactions with entrepreneurs.

In the end, four indicators were used to evaluate the refrigerators performance: user experience and design appropriateness, product costs, truth in advertising and energy performance. Having no precedence on off-grid refrigerator testing meant the protocol and evaluation criteria had to be dynamic to allow for improvement through continuous learning.



Ssegirinya Joseph has been able to increase his sales with refrigeration. He used to sell only two sodas a day, now he sells on average 20 a day. Credit: Efficiency for Access/CLASP.

2. Uganda was selected as the country for field-testing due to partner presence on the ground and the fact that it was a virgin market for this technology.

Before her solar refrigerator, Nanabirwa Maria was making losses on pineapple and passion juice. She is happy now because she can store the juices for much longer. Credit: Efficiency for Access/CLASP.

COLLECTING DATA – FROM THEORY TO PRACTICE

The evaluations comprised both technical and user experience data. Technical data was intended to be collected via remote sensors and meters capable of monitoring live ambient temperature and humidity, compartment temperature, and energy parameters (power production, consumption, and battery levels).

Remote monitoring technology played an important role in collecting technical data as shops' locations were too spread out for manual data recording. However, widely available meters only have energy performance sensors, use mobile networks to upload data, do not have local data storage and come at a considerable cost. Therefore, we had to continuously innovate to be able to capture intended data.

At the start of the field test, we worked with a start-up metering company to augment their meters to capture non-energy data (temperature and humidity data). However, meters failed after a few weeks in the field as they had previously not been subjected to rigorous off-grid testing.

To compensate for meters' inability to capture non-energy indicators, the team tried employing temperature guns. However, credibility of the data received was questionable as the process involved researchers manually recording data. Human error and varying times of temperature recording did not provide credible data for evaluation. As a result, the protocol was redesigned to allow heavy weighting in user experience. It also helped that the technical data had been evaluated in the labs.

Mobile network connectivity was another challenge as shops were located in remote areas without coverage. Meters upload data instantaneously, which meant that any second of downtime would lead to loss of data. To work around the issue, the team had to procure global SIM cards capable of roaming. This option is expensive but ensures maximum data upload as the SIMs use the strongest network available at any time.

Smart and remote metering is still a developing concept, which makes it an expensive method of capturing data, with prices averaging US$ 800 per meter. Although the growth in solar home systems is advancing the technologies available and reducing the cost per unit, prices for stand-alone meters are still high as competitive costs are realised through economies of scale. The team approached a couple of metering manufactures who indicated they only sold meters at minimum orders of 200.

Despite all the difficulty, there are local companies in East Africa that manufacture meters for solar systems at competitive prices. We worked with one such company to access competitively priced ordinary meters that we ultimately used, which only had energy sensors.

Finding suitable shop owners was also complex because we discovered that the majority of those with the largest need for refrigeration (located in town centres with high foot traffic and larger customer base) were already grid-connected. In other cases, the grid was just right around the corner. In fact, in the intervening period between entrepreneur selection and fridge delivery (three months), the grid had reached two of our chosen shop owners. Meanwhile, off-grid entrepreneurs were very remote and serviced very few customers. This reality of grid proximity was unexpected and called into question the general assumption of the prevalence and characteristics of off-grid businesses in East Africa.

The user experience data was collected by field researchers who visited the shops every two weeks. Part of the experience was on recording the business value of the fridges. This was done by observing customer and revenue trends and other parameters before and after acquiring the refrigerator. However, many of the small shops do not keep any records. The response was from memory or gut feel, which did not provide credible empirical evidence.

Therefore, field researchers had to work with the entrepreneurs to help them with record keeping methods, at least for the duration of the data collection. They visited each entrepreneur twice a month for at least two hours to record activities in that timeframe and estimate sales related to the previous two weeks. Data were gathered through the Kobo survey app and uploaded to an online platform to limit data loss.

Evaluation of the refrigerators is data sensitive. The team had to put in place a number of safeguards e.g. excluding outliers on temperature data, enhancing metering technologies and training the researchers on how to ask question that avoid biased answers.

Nansubuga Agnes runs the only business in her village that has a refrigerator. She is seeing an increase in sales as the whole village now comes to her shop for cold drinks. Credit: Efficiency for Access/CLASP.

THE LOGISTICS CHALLENGE – MOVING FRIDGES TO AND WITHIN UGANDA

After the lab tests were concluded in December 2017, the 19 shortlisted models (36 products in total) were shipped. The whole process from initiating shipping in the Netherlands to delivery of the refrigerators to 36 locations in Uganda took six months, from January to June 2018. Requirements and processes in multiple stages caused some delays – the team had planned for the refrigerators to be distributed in Uganda within three months.

Rules on shipping fridges are specific and stringent. In the Netherlands, companies specialise in providing inspection services before shipping. In Uganda, the process is not as straightforward. We encountered difficulties in finding a firm that could determine fridges' compliance with the requirements set by the Uganda National Bureau of Standards. The rules of the Bureau of Standards assumed that the fridges would be sold in Uganda, and therefore demanded inclusion of documents such as details of seller and buyer and invoices.

In order to pass the inspection, accessories such as specific labelling on safety and performance and instruction manuals needed to be included. As a minimum, manuals had to be in English and preferably also in the Luganda language. While retail consumer appliances generally include these accessories, some of the fridges did not have these documents as they were shipped to the test lab in the Netherlands directly by the manufacturers and these criteria had not been required earlier.

When we realised that the fridges could not be successfully inspected before being shipped, we explored the Bureau of Standards exemptions which could have applied to our appliances while complying with the law. This resulted in a month and a half's delay, but allowed us to learn that fridges below a pre-determined retail price are not required to comply with excessive sampling requirements as long as they comply with safety standards. We had to rethink logistics and send fridges in separate lots, for a total of 11 packages. Moreover, our fridges were destined for intensive research purposes which would provide instruction for both performance and safety above and beyond a written manual.

Once in Uganda, the fridges were not labelled or packaged properly according to the authorities. Information on how they could have been labelled properly was not publicly available so once they reached Kampala, they were retained by the Uganda Revenue Authority until detailed inspection was conducted. Transporting the fridges to the 36 shops was fraught with difficulties, because of the sites' remote locations and poor condition of roads and bridges. Special care had to be incorporated to mitigate damage and this resulted in a slower pace of delivery.

USER EXPERIENCE

In spite of training shop owners on proper usage, care and maintenance of products, some still did not use the refrigerators properly. One of them damaged a fridge he was testing with a knife while trying to get ice from the freezer component. Some entrepreneurs, especially those who were testing fridges with 50L capacity, wanted to return the products because they did not meet their business needs.

Others did not appreciate the research field team visiting them several times to troubleshoot the faulty system of some appliances. The test team was therefore very keen to manage the relationship with the users to ensure credible feedback.

Some of the refrigerators experienced technical or mechanical issues on arrival. The team contacted the respective manufacturers who gave the go-ahead for refrigerator technicians to troubleshoot the products. The challenge, however, was that qualified refrigerator technicians, especially those who understand solar technologies, are very few in Uganda. It took a week to find one who had extensive knowledge of refrigerator technologies, even though he had not worked with solar products. Fixing the fridges on the ground was not included in the original budget and was therefore an additional cost to the test.

MAIN TAKEAWAYS

To our knowledge, the Global LEAP Off-Grid Refrigerator Competition team has been the first to conduct this type of test in the field, which entailed a number of unknowns and challenges. These range from developing a methodology from scratch through to grappling with an underdeveloped market. Some of the issues we faced could have been prevented, while others would have been too hard to plan and budget for as these were not anticipated. Moreover, foreseeing the amount of time needed to solve them was impossible.

Challenges include:

Finding suitable entrepreneurs to test the fridges. We knew that the market for off-grid energy-efficient fridges was not well developed, which is why we ran this competition. What we did not know though, contrary to the current assumption, is that the appropriate consumer for an off-grid refrigeration business use case is not prevalent. While the number of people off the grid is high, we found out that the number of Ugandan entrepreneurs who own relatively large shops, need fridges to store their products and are still off the grid is lower than expected. This reality made it challenging for us to find suitable entrepreneurs to test the fridges.

Selecting appropriate remote monitoring systems capable of capturing important data. We also encountered issues related to the underdevelopment of this market, especially finding remote monitoring systems suitable for off-grid areas that were able to collect all the technical data we required and did not fail in the field. After various attempts looking for the most suitable meter and even working with manufacturers to improve their functionalities, we had to scale down our ambitions.

An adaptive and flexible approach has been vital. It has allowed us to rethink the field-testing methodology based on the lessons learned in real time to ensure the competition proceeded in the best possible way. We decided for example to reduce the data set we would collect, omitting humidity and external temperature.

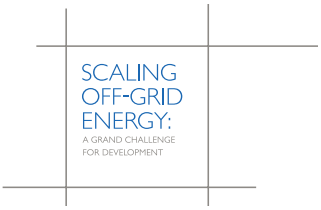
It is important to anticipate problems which might arise at any stage during the project implementation.

To address this, **a deeper understanding of the local context is necessary.** This includes awareness of local regulations or requirements for imported products in a specific country. Furthermore, it is key to detecting issues as soon as possible and rectifying them before they escalate and risk endangering a whole project. Where they cannot be anticipated, **creativity and flexibility are crucial** to redress situations. Shipping the fridges from the Netherlands to Uganda in separate lots below US$ 2,000 each in value, for a total of 11 packages, allowed us to successfully bring the appliances to their destination.

Finally, **being able to rely on a local team of credible partners is key.** Their support is invaluable to help address challenges that ranged from reaching remote locations through to helping managing relationships with fridges users.

Ideas to Impact is an action-research programme with a strong learning mandate. It is our hope that these lessons will help inform future initiatives that aim to catalyse innovation to improve the lives of poor households.

All entrepreneurs agree that the solar fridges are good for business. They are appreciative of being selected to participate in the field-testing exercise as it has allowed them to test out a new technology while also seeing practical benefits to their businesses. Credit: Efficiency for Access/CLASP.



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