

A Tale of Two Sensors: Measuring accuracy and ease-of-use through human-centered design

A 5-household user test in urban Uganda reveals new insights on how best to design an offline PAYG LPG product

EXECUTIVE SUMMARY

With support from FCDO's Modern Energy Cooking Services, M-KOPA Labs has examined the suitability of pay-as-you-go (PAYG) financing to enable East African homes to affordably purchase LPG cooking fuel to displace traditional charcoal fuel.



Figure 1: M-KOPA staff member and test user cooking with her offline PAYG LPG prototype cookstove

In the past two years, it has explored a suite of off-line technologies to test accurate, remote monitoring of customers' LPG usage without requiring IoT functionality, thus challenging the need for a 'smart valve' solution which remains unproven as a market viable product. Following months of testing various low-cost gas monitoring solutions (see M-KOPA's A Comparative Analysis of Enabling Technology for PAYG LPG report), Labs sought to test the highest potential offline sensors in a real household application.

This paper summarises the findings following a 5-household trial over the course of six weeks in Kampala, Uganda. Labs selected households of M-KOPA Uganda staff members who indicated a willingness to participate in this trial gave daily readings of bottom-mounted ultrasonic sensors and handheld weighing scales via SMS to gauge LPG usage. They subscribed to PAYG payment plan, requiring a micro-payment sent

via mobile money to assimilate the PAYG experience, understanding that they would not pay if they did not like the service. At the end of the trial, the five test users participated in focus group discussion to relay their experiences shifting from predominately electric and charcoal use to wholly LPG use, as well as impart recommendations to further shape M-KOPA's PAYG LPG concept.

TEST OBJECTIVE & APPROACH

The purpose of this trial was to investigate the effectiveness of low-cost sensors to gather customer usage data when administering a PAYG LPG service model. The primary questions we intended to answer through this trial are as follows:

- Which sensor holds the most potential, in terms of accuracy, if a PAYG LPG proposition is scaled?

- What is the superior customer experience with administering PAYG LPG, in terms of simplicity for customers?

To answer these fundamental questions, Labs designed an experiment to assimilate a PAYG LPG experience for target customers eager to displace charcoal use with this modern cooking fuel.

The remainder of this section outlines the key components of the PAYG LPG prototype, and how Labs designed a user trial to understand the degree of ease and accuracy of offline gas monitoring to underpin a pay-as-you-cook business model.

Prototype

The intent of an offline PAYG LPG negates the need to attach an IoT-enabled 'smart' valve on the LPG canister to monitor daily usage and synchronise payments to customers' accounts, thus unlocking continued use of LPG gas. The challenge with this technology, however, is that the added hardware, telemetry, and other material costs for a locking valve amount to \$43 - although some industry experts note it is closer to \$200. Therefore, the smart locking valve's high cost relative to that of the LPG cylinder erodes affordability for customers and scalability for providers.

Instead, the M-KOPA solution looks to collateralise customers' existing PAYG assets (smartphones) to secure a line of credit to enable a pay-as-you-cook micro-payment model with simple, low-cost monitoring technologies. These technologies – illustrated in Figure 1 below – were selected following a series of lab testing in Labs' Woking, UK facility and its Kenya-based Large Appliance Testing Station.

The various components, as outlined below, enabled Labs to evaluate the degree of measurement accuracy for the ultrasonic sensors and the handheld scale, as well as the degree of ease for the customer to report daily usage. Thus, Labs could validate the hypothesis that lower cost bottom-mounted ultrasonic sensors can capture more accurate market information via a smartphone app to underpin a PAYG LPG business model.



Four sensor brand tests to further examine their ease and accuracy:

- Truma
- Gas watcher
- Mopeka
- Smart Propane

Figure 2: Diagram of components comprising the PAYG LPG prototype for user testing

Payment Plan

The experiment was designed to ensure customers remained active in the trial by having ‘skin in the game’ and a clear incentive to purchase a second cannister on a PAYG basis, if needed. Therefore, users were asked to send a nominal daily payment to M-KOPA, thus assimilating the PAYG repayment experience. Recognising the price sensitivity of Ugandans and the competitiveness of charcoal fuel, Labs selected an attractive daily payment that would ensure customers did not revert to charcoal use – expected to cost Kampala households £0.35 daily.

Payment Plan	Daily Rate
Deposit	UGX 20,000 / £4.00
Daily payment	UGX 800 / £0.16
Days	28
Total	UGX 42,400 / £8.42

Table 1: Test PAYG LPG Payment Plan

This payment plan was uploaded onto M-KOPA’s proprietary PAYG platform to verify and monitor customers’ micro-payments for continued LPG use and participation in the trial.

Engagement & Data Collection

Upon delivery the 6kg canisters and standard meko grill to customers’ homes, customers received a tutorial on proper lighting of their LPG grill and a safety demonstration from the TOTAL Gas representative. Users were also briefed on the requirements of the pilot by their M-KOPA Engagement Officer, entailing daily response to an SMS survey to gather the following: meals cooked each day and readings from both the bottom-mounted ultrasonic sensor and hand-held weighing scale. Users were also informed that an Engagement Officer is available, should they run into any issues or need a new canister.

At the end of the study, Labs held a focus group discussion with test users to hear and collect honest feedback on the ease of use and issues arising from the sensors and scales, which is outlined below.

User Profiles and Pre-trial Cooking Norms

Test users are all M-KOPA Uganda junior staff members and representative of the target Kampala urbanite, who aspires to cook with LPG yet predominately cooks with electricity when it is available yet relies on charcoal as a low-cost and accessible substitute. We saw a mix of participants living solo or in households with up to 12 members, with an average of 5.6 members per household. Users were instructed to cook as they normally would, yet account for any adjustments required to accommodate for LPG’s fast cooking ability.

When asked what cooking fuels they cook with most, all users noted they cook with charcoal – on average 6 times per week. One respondent notes he cooks with kerosene daily, while three users cited cooking with electricity daily, if the grid is available. Only one participants cooked with LPG on a regular basis prior to this trial,

yet noted it is very expensive. On a scale of “very unsatisfied” to “satisfied”, only one participant rated their normal cooking experience as “satisfied” – unsurprisingly, the user who mostly cooks with electricity and LPG. The remainder rated their experience as “very unsatisfied” or “unsatisfied” – for reasons relating to cost and inability to cook when the grid is down or charcoal is wet from the rains.

It should not come as a surprise then that staff members who feel the pinch of cooking with charcoal on wallets would self-select to participate in trial that would allow for a break from this consumptive spending, while upgrading to a premium cooking fuel.

RESULTS OF THE PAYG LPG COOKING TRIAL

This section contextualises the user experience relative to the measurement accuracy for a range of offline measurement devices to monitor LPG use.

Degree of Technology Accurateness & Ease of Use

Handheld weighing scales:

Of the two solutions, our test users preferred the handheld weighing scale for its simplicity. As an analog device, users were never troubled if they were not home and needed to know the current gas level, as anyone in the household could take the measurement.

“If someone is home, they can read the scale for me to input. Whereas I couldn’t input the sensor reading if I’m not home because my phone must be close. That’s a challenge if you’re away.”

- M-KOPA Test user

Of course, M-KOPA, or any PAYG provider, could scale an analog device and confidently rely on user-reported data to finance a PAYG LPG cannister. In the future, this technology must be a ‘smart’, i.e. able to digitally collect and report readings via Bluetooth, which negates the key benefit customers illustrated above.

Moreover, one user noted the handheld sensor became increasingly inaccurate, providing irregular measurements. After a couple of weeks, the handheld scale provided a measurement that was higher than previous day. Even when weighing it multiple times, he would see different readings – leading to confusion and frustration. We suspect his scale had low batteries, which were replaced during the trial which corrected the issues.

Bluetooth ultrasonic sensors:

Two-out-of-five test users erred more toward our digital solution – an ultrasonic sensor installed directly onto the canister that automatically synced and pushed gas level readings to a smartphone app. The real benefit to users was the ‘set it and forget it’ ease that didn’t require any human intervention to gauge gas levels, besides being within close proximity for short-range wireless communications. Interestingly, it was the single-person households that preferred this option – as they could not benefit from another household member weighing the cannisters, as mentioned above.

This method was not without its technical issues either. Multiple participants needed new batteries from constant use over the six-week course. The project Engagement Officer sent new cells once reported, but in a real-life situation, customers may take days or weeks to replace the specific cell battery – or may not realise that is the issue as there is no battery level reading – thus disrupting continued LPG use. This risk could be mitigated by designing or procuring a weighing scale that can be recharged via a standard USB port.

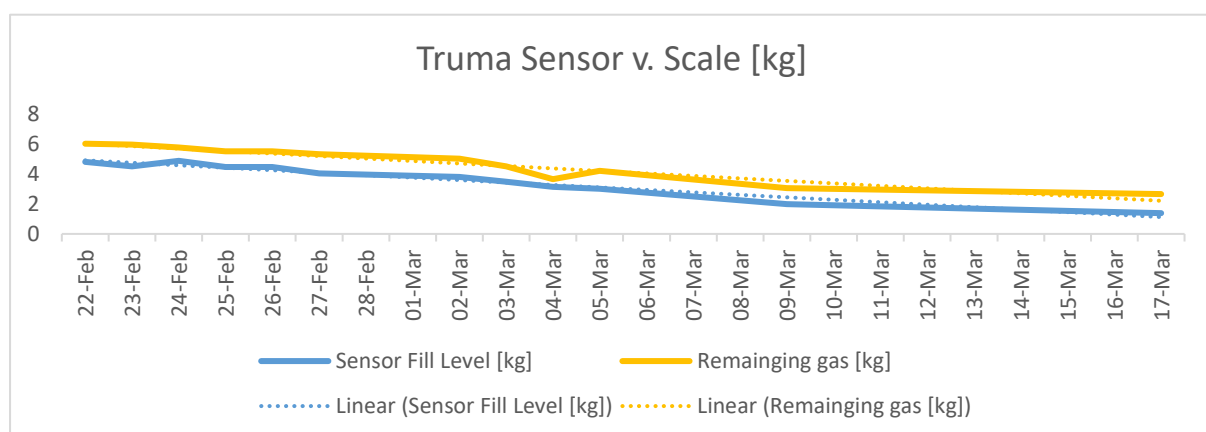
Additionally, the sensor readings themselves led to confusing amongst some users. Some sensors provided users with an estimate of remaining cook time, while others only saw the remaining gas level. The former was very much preferred as users because it leaves no guessing game as to whether or not users have sufficient gas to cook that day’s meals.

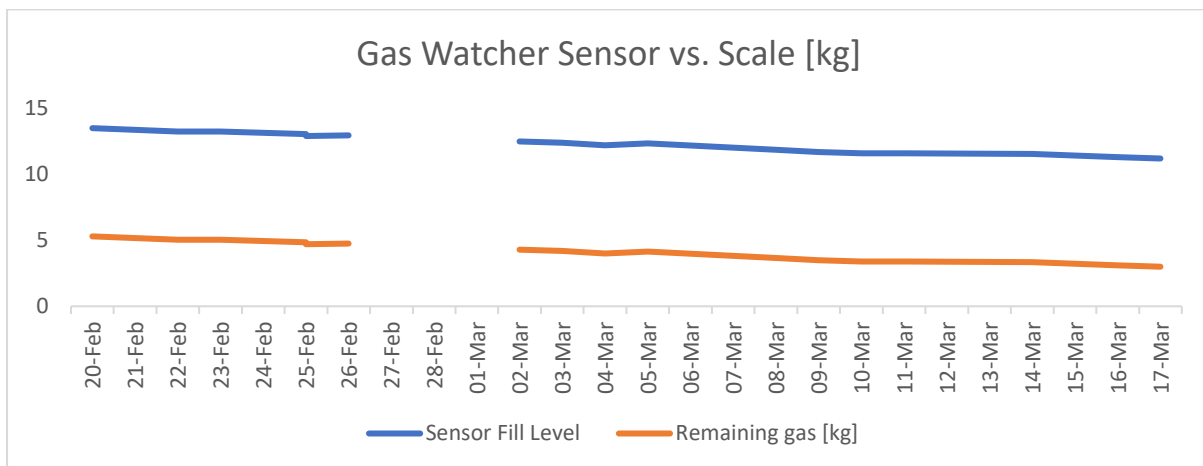
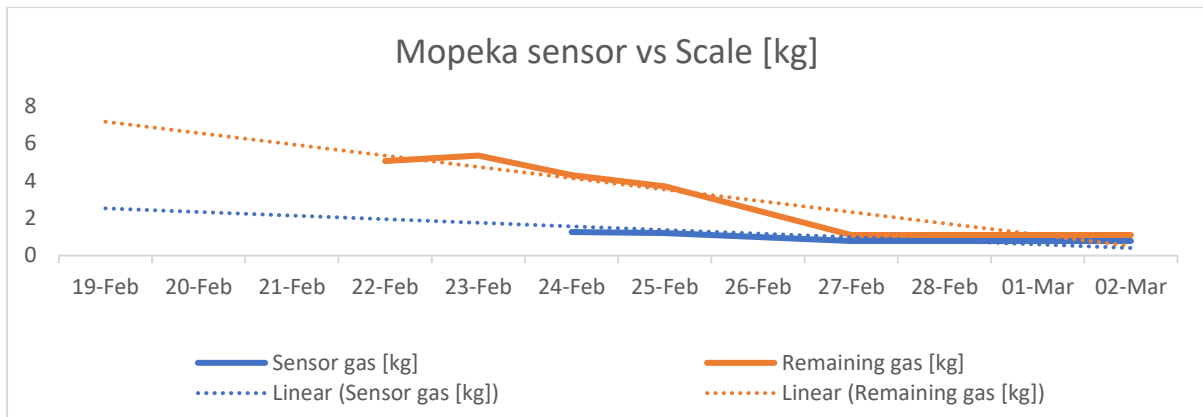
Accuracy Comparison:

It is important to remember that this trial was conducted with only five participants, which is too small of a sample to draw any causal conclusions. Even more, for unforeseen reasons, one participant (the Smart Propane user) was away from home too many days to conclusively use data to draw preliminary correlations.

Firstly, Truma proved to be most the reliable sensor in terms of precision and accuracy. The drawback of this sensor, though, is that it requires more battery power, which was evidenced in the pilot. Mopeka came in second for accuracy, however we have reason to believe the sensor’s calibration went awry prior to delivery, which led to its questionable results. (We will seek to re-test this in the future.) Lastly, the Gas Watcher sensors provided the largest error in measurement and did not prove to be easy to calibrate during lab tests.

Safe to say, these three sensors require more extensive testing before any can be eliminated or confirmed as the right fit for purpose.





That said, a review of these comparison analyses has deepened M-KOPA's Hardware Engineering team on the following technical necessities, especially as they relate to customer needs and behaviours with these measurement devices:

- Sensor calibration must be conducted and checked prior to installation as providers cannot rely on customers to perform the calibration at home due to complexity;
- Ultrasonic sensors show promise as an accurate measure of remaining gas; and
- Final solution must have multiple sensors to account for different positions of the canister to optimise measurement accuracy.

Before and After Comparison: Fuel Choice, Frequency of Use and Satisfaction

Unsurprisingly, prior to the trial, users used a diverse mix of cooking fuel and stack fuels on a daily basis, as is the norm in Uganda given the comparatively low prices of charcoal and availability of (albeit fragile) electric grid access.

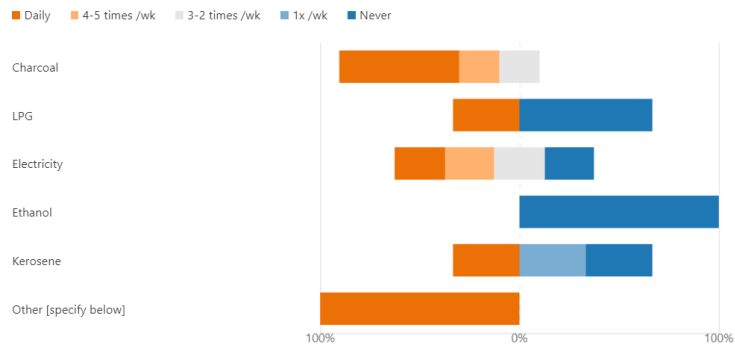
Given these users are located in urban and peri-urban settings, we saw a larger reliance on electricity for cooking, anecdotally evidenced as the primary source unless the grid is down in which case users resort to charcoal or an alternative. Users also noted a preference for using biogas in their individual fuel stack.

Additionally, users that rely mostly on electricity for cooking report higher levels of satisfaction with their current cooking stack, while those reporting a higher use of charcoal report a lower satisfaction score. They further contextualised that their poor

satisfaction relates to affordability and frustratingly slow cooking times, especially if the charcoal is unable to heat up from dampness or rainwater.

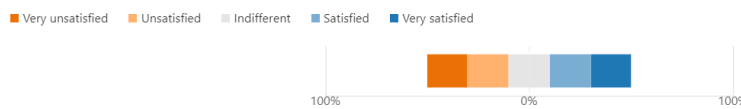
. Please indicate how often you used the following fuels on a **WEEKLY** basis **before** participating in this trial.

[More Details](#)



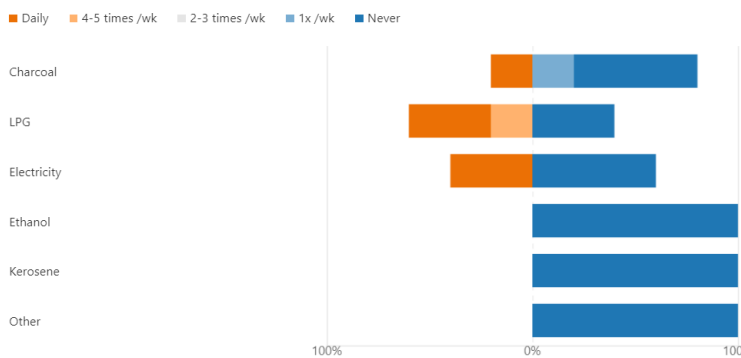
How would you characterize your enjoyment cooking with the mix of fuels you indicated above, on a scale of 'very unsatisfied' to 'very satisfied'?

[More Details](#)



Please indicate how much you used the following fuels **during the trial on a weekly basis**. If you only cooked with LPG, please select 'Never' for all other fuels.

[More Details](#)



How would you characterize your enjoyment cooking with the mix of fuels you indicated above, on a scale of 'very unsatisfied' to 'very satisfied'?

[More Details](#)

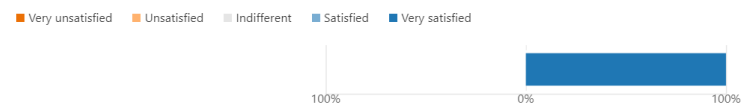


Figure 3: Before and after mix of commonly used fuels by frequency, and satisfaction rating with current fuel stack

Once users had access to LPG cooking, more than half of the participants maintained cooking with their previous primary cooking fuel. Why? Because those with larger families could not feed their families cooking on only one burner. Moreover, when probed further during the focus group, participants cited some difficulties regulating the heat and speed cooking with LPG, prompting some to

revert to their customary mix for greater control of the cooking experience and comfort knowing food would ruin from burning.

Bottomline:

While the sample size of this study was small, Labs uncovered important insights for to further shape the offline PAYG LPG concept, particularly we consider the user-friendliness of these devices and their match with lifestyles and tech/digital literacy.

What is clear is, customers value simplicity and the transparency that an app-enabled sensor provides to inform cooking expenses and fill level for cooking. Even more, customers want a predictability with: payments, refills, timeline of use, and even cooking temperatures (i.e., a more user-friendly dial to avoid burning). These user requirements will directly feed into the ultimate product design based on needs and wants (see Appendix) to promote adoption amongst target users.

Labs will be deepening this study in further lab tests through a collaboration with Clean Cooking Alliance, specifically working to further evaluate the technological and economic pros and cons of an online PAYG gas locking valve or offline alternative as the appropriate solution.

Appendix: Mapping Urban Uganda Needs and Wants to Product Requirements

Mapping the Needs & Wants of Urban Ugandans to a PAYG LPG Concept

More design needed to ensure a good experience and value proposition.

OFFLINE PAYG LPG

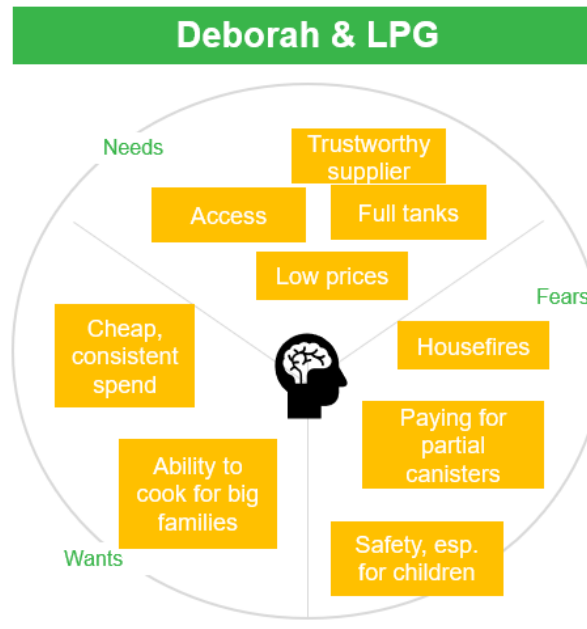
Features

Benefits

- Pay easy for fast-cooking LPG fuel, never need charcoal again
- Know exactly how much you use daily to control your finances
- Link with a reputable supplier to refill 100% when needed

Experience

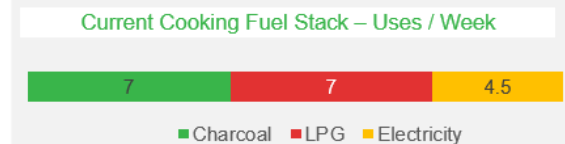
- 😊 Loved direct to home delivery
- 😞 Frustrated that handheld scale battery died early
- 😞 Liked ease of Bluetooth sensor – but troubled when they were away and couldn't sync
- 😊 Loved knowing exact fill level
- 😞 Displeased that it's too small for big families, burns easy
- 😞 Sensor has too many settings



Meet Deborah, a young, Kampala-based M-KOPA staff member, who lives with four other family members.

Concept Enhancements Needed

- ① Handheld scale w/ rechargeable battery, or sensor w/ 1 measurement for simplicity
- ② Double-burner grill to enable typical two pot cooking
- ③ Child-proof safety lock to mitigate children turning on gas



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