AN INVESTIGATION INTO THE POTENTIAL OF DC SOLAR-POWERED COOK STOVES WITH TANZANIAN FOOD VENDORS

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Contents

1. Executive Summary 4
2. Methodology 6
2.1 Baseline Survey 6
2.2 Baseline Cooking Diaries 7
2.2.1 Case Study Vendors 9
2.3 Prototype Testing 11
3. Baseline Data 13
3.1 Cooking Fuels 13
3.2 Cooking Equipment 16
3.3 Foods/Meals Cooked 18
3.4 Cooking/Sales Volume 20
3.5 Opening/Busy Times 22
3.6 Group Differences 24
3.6.1 Grid vs Off-grid Vendors 24
3.6.2 Community Comparisons 25
3.6.3 Gender 26
4 Market Potential of Solar Cooking 27
4.1 Interest of and Barriers to Electric Cooking 27
4.2 Interest of and Barriers to Solar Cooking 28
4.3 Preferred Solar Stove 29
4.4 Desired Features of Solar Stove 30
5. Prototype Testing 33
5.1 Preliminary Testing 33
5.2 Solar Water Heater 34
5.3 Solar Pressure Cooker 35
6. Target Customer Profiles 37
6.1 Chips Mayai Vendors 37
6.2 Rice/Bean Vendors 38
6.3 Chicken/Meat Stew Vendors 39
6.4 Dagaa Fryers 40
7. Proposed Second Generation Prototypes (G2) 41
7.1 Rice/Bean Cooker 41
7.2 Enlarged Pressure Cooker 42

7.3 Insulated Pressure Cooker 42
7.4 Hybrid Dagaa Wok 43
7.5 Chips Mayai Set 44
7.6 Ugali Pot 45
7.7 Summary of Second-Generation Prototypes (G2) 45
8. Recommended Next Steps 46
9. Conclusion 48
10. Appendices 49

1. Executive Summary

This working paper details the results of a feasibility study investigating the potential of DC solar-powered cooking with food vendors in Mwanza Region, Tanzania. It was the product of a three-month work placement, sponsored by the Engineering and Physical Sciences Research Council (EPSRC), that enabled Anthony Perrett from Loughborough University's Geography Department to lead a research project on behalf of Africa Power Ltd. Three prototypes of DC solar-powered stoves were supplied by KuyereOrg, a Malawian social enterprise specialising in domestic solar electric systems: a water heater (rice/bean cooker), pressure cooker and wok. The prototypes were tested with vendors and data was collected through cooking diaries and semi-structured interviews. Additionally, a baseline survey was conducted in ten communities across Mwanza Region and baseline cooking diaries were also conducted for in-depth analyses of four specific vendors' cooking practices: chips mayai, rice/beans, chicken stew and dagaa.

All fieldwork was conducted by Anthony Perrett and a team of four research assistants between Monday 24th February and Tuesday 11th March 2020 in Mwanza Region, Tanzania. Supplementary staff was also provided by the local branch of Africa Power Ltd., Kua Solar Ltd., a domestic solar home systems supplier. The overall aim of the study was to examine if DC solar cooking is commercially viable in Mwanza Region and if so, determine what is required, especially regarding the product development of the prototypes, for this emerging clean cooking technology to be a feasible alternative to biomass energy i.e. how can the current prototypes be redesigned and improved so that they specifically meet the needs of Tanzanian food vendors and are compatible with local cooking practices. To achieve this, four research questions were developed and answered:

1) What are the current cooking practices of food vendors in Mwanza?

122 surveys were conducted with food vendors across the region to evaluate the specific details and diversity of Tanzanian food vendors' cooking practices. We sought answers to key questions such as: What was being cooked? How, where, and when? What fuels were used? How much was being spent? What differences were there between communities, gender, vendor type and choice of fuel?

These surveys provided a comprehensive overall assessment but lacked the depth required for thorough analyses of specific day-to-day cooking practices. Therefore, cooking diaries were conducted with the four aforementioned vendors to analyse their daily cooking routines and determine if, and how, they can be compatible with DC solar-powered cooking, as these same vendors tested the prototypes later in the study. This data can mostly be found in Chapter 3.

2) Is DC solar cooking compatible with existing cooking practices?

This was primarily investigated through compatibility testing. The prototypes were given to vendors currently using similar cooking methods and compatibility was evaluated through cooking diaries. The testing period culminated with a semi-stricture interview with each of the vendors discussing at length the prototypes' compatibility and the potential of DC solar-powered cooking more broadly. There was a particular focus on how the prototypes can be redesigned to be as compatible as possible with the vendors' cooking practices. Most of this information can be found in Chapters 4 and 5.

Additionally, compatibility was assessed in a section of the survey, which recorded a strong interest from vendors in DC solar cooking and found that the primary barrier of access to was that there was nothing available on the market that met vendors' needs (4.2). Incidentally, there was also a strong interest in grid-electric cooking, but cost was identified as the primary barrier of access, or at least the perception of cost (4.1).

3) What changes to the prototypes are necessary to develop them into commercially viable products?

Feedback was collected from the vendors who tested the prototypes through cooking diaries each day and then semi-structured interviews at the end of the testing period, which gave the vendors an opportunity to discuss their experiences in detail. This feedback was then used, alongside the baseline data, to identify potential iterations to the prototypes that would inform product development. It was strongly emphasized throughout the testing period and interviews that we were seeking constructive feedback from the vendors on what needs to be done to the prototypes to make them as useful, beneficial and compatible with their current cooking practices as possible.

Generally, the water heater and pressure cooker both require enlarging to make them commercially viable with food vendors as they cook much larger quantities than the current prototypes were capable of, as they were more appropriate for household cooking. This may also require increasing the power, but more efficient and innovative insulation can significantly contribute (Chapter 5). It is recommended that the wok is redesigned into two separate models to be compatible with very distinct cooking practices - chips mayai and dagaa vendors (3.2) and then tested with vendors to evaluate compatibility and identify further iterations. In total, seven new designs are proposed; five are iterations to the existing three prototypes and two are new concepts (Chapter 7) - overall, increased size, power and versatility are key changes necessary to develop them into commercially viable products.

4) What is the best course of action from now?

This report concludes that the best course of action in the short term is to secure funding to upscale this feasibility study into a larger product development research project. The proposed project focuses on the product development of the seven prosed designs and expanding baseline data into potential new sectors and geographical markets. Full details of the recommended best course of action, including project outlines, commercializing strategies, and long-term business models, have been omitted from this working paper but were included in the original report for Africa Power Ltd.

Furthermore, as we could not determine the long-term durability of the current prototypes in this 3-month study, it was strongly recommended to do this now by allowing vendors to use them indefinitely, even without cooking diaries, so we can evaluate their long-term durability as soon as possible. The longevity of any DC solar-powered cooking products is paramount for commercial viability (Chapter 8).

I also recommend publishing at least one academic paper based on this research. One of the key elements required is a literature review and contextualizing this study's findings into wider academic debates and existing research. A literature review is now in progress and will be added to this working paper soon. The authors intend to submit an academic paper from this research by the end of 2020 and the current authors confirmed by the publication of this working paper (July 2020) will be Anthony Perrett, Jon Leary, Ed Brown and Alastair Livesey, although additional contributors are likely to be invited.

2. Methodology

2.1 Baseline Survey

Overall, 122 surveys were conducted in Mwanza Region across ten communities (Table 1). Most of the communities targeted were markets of some kind: urban, rural, residential or food markets, although a fishing community and a roadside cluster of vendors were also targeted as the former's cooking practices were particularly unique and the latter comprised a range of food vendors very common in and around Mwanza. 14 other surveys were conducted in locations other than these ten communities; sometimes the vendors were located in between communities or the surveyor did not record the location, but mostly they were in communities where very few surveys were conducted, so their representativeness would be severely limited. These included Dampo, Mabatini, Uhuru, Stesheni, Buzuzuruga Stendi and Nyamagana. No more than three surveys were conducted in any of these additional communities.

Table 1: Communities included in the survey (minimum of 8 surveys)

Community Name	Type	Number of Surveys
Nyamalango	Rural Market	16
Sahara	Urban Market	14
Kamanga	Fishing Community	13
Kisesa	Urban Market	12
Nyamhangolo	Residential Market	10
Kiseka	Urban Market	10
Buhongwa	Rural Market	9
Kiloleli	Urban Market	8
Malikusema	Food Market	8
Igoma	Roadside Vendors (main road)	8
Other	Mixed	14
Overall	***Mwanza Region***	***122***

The surveys were conducted using random sampling; all vendors that were encountered were approached except for those who only grilled foods directly on charcoal e.g. mishkaki (barbecue) and cooked no other foods. There were very few vendors who solely sold mishkaki; most cooked meat or bananas on the grill alongside one or more other dishes and were consequently included in the survey.

Overall, 23 questions were asked to each vendor by a member of the research team. The surveys were originally written in English (Appendix 1) and translated into Swahili, and then all surveys were conducted in Swahili. Once the surveys had been completed, they were translated into English and compiled directly onto Excel. The data was then converted into SPSS format and most of the graphs and tables in this report were made either in Excel or SPSS. There were some challenges that were encountered while conducting the surveys, most of which were resolved quickly with no or little impact on the results, but some were not (Table 2). These have been included in this report to inform and assist any future related surveys that are conducted.

Table 2: Challenges experienced with surveys

Challenge	Resolution	Future Action
Some of the English to Swahili translation resulted in some confusing questions. Had the translated surveys checked by native speaker but mistakes were missed	We identified these problems in two test surveys we initially conducted and then changed the wording of the Swahili to make it more understandable	Have translated surveys checked by a paid translator with sufficient time Review similar existing surveys in Swahili before drafting
Initial 1-5 ranking system for Q20 deemed unfamiliar by vendors and surveyors, so many unanswered or data collected was unreliable	Changed the 1-5 ranking to "important" "not important" and "very important", although one surveyor still had trouble understanding	Use the latter format from the beginning Review similar existing surveys in Swahili before drafting
Some questions e.g. Q10, the answers recorded did not specify if they were per day or week, or which food when many were sold, so accurate data difficult to determine	Surveyors confirmed that they were daily totals	Separate sections for day/week, different foods etc. Inform surveyors of potential confusion
Many open-ended questions led to lengthy data compilation	Categorised all open-ended answers into multiple choice to simplify data analysis	Only have open-ended questions when strictly necessary in future surveys
Translator incorrectly inputted the survey data into Excel so had to restart, resulting in delay with the write-up	Initially extended their employment for 3 days to complete the work but was still unable to finish. I had to translate them myself	Ensure that enough time is given in finding a committed, competent, and reliable translator
Rainy weather delayed some surveyors	During rainfall, the staff found shelter and waited. Did extra surveys the following days when weather was good	Instruct surveyors to find shelter in heavy rainfall and supply umbrellas/waterproof clothing for light rainfall

2.2 Baseline Cooking Diaries

Cooking diaries were conducted with four vendors: three for one week and a fourth for one day. The vendors were selected because they were not only four very common types of food vendors found in Mwanza, but they were also vendors whose cooking practices were most compatible with the solar-powered prototypes available; our preliminary research indicated that these vendors could feasibly utilize a prototype, so they were ideal vendors to select for an in-depth evaluation to inform us of their specific cooking practices which could assist in designing the next generation of prototypes. These four vendors were also ideal for testing the current prototypes with. The four vendors sold chips/chips mayai, rice/beans, chicken and dagaa.

An enumerator spent each day with each of the vendors, typically between 8am and 7pm which are the hours where sunlight was strong enough to sufficiently power a prototype. Two of the vendors continued to stay open beyond 7pm, but the cooking diaries stopped then because that is roughly the time the Sun is too weak to sufficiently power a prototype. The enumerators were responsible for collecting the following data over the course of their respective cooking diary (Appendix 2) –

- The times (to the nearest minute) when anything was cooked by the vendor
- How long it took for that food to be cooked
- What fuel was used in what stove and how much they paid for that fuel per day/meal

- What pots and pans were used, when, what for and for how long?
- Weigh how much charcoal/wood was used each day and in some cases per cook/meal
- Weigh how much raw food was being cooked each day and in some cases per cook/meal
- Weigh typical portions of the foods/meals cooked by the vendor
- Measure amount of oil being used for cooking, throughout whole day and/or per cook
- Measure dimensions of all pots and pans used by the vendor and take photos of them all
- Any other observations

The data collected from these diaries would provide this report with an in-depth evaluation of the typical cooking practices of these four key vendors. Combined with the survey data, profiles of each vendor were developed (Chapter 6) to identify key requirements a solar stove would need to meet.

Table 3: Challenges experienced with cooking diaries

Challenge	Resolution	Future Action
Our daily presence in one community attracted unwanted attention - someone reported us to the local municipality who requesting a permit from an enumerator	James spoke with the necessary people and resolved the situation. From then on, I significantly limited my presence in the communities and communicated with the enumerators via telephone	Pay for a permit, perhaps even if not 100% necessary, in future research to limit these challenges. Should easily be budgeted for
Enumerators recording incorrect information, so some data collected was not reliable	Went through the training again the following mornings to clarify any uncertainty. In one case, redone the day entirely (chip vendor)	Have a test day for cooking diaries. Before starting the week-long diaries, have a trial day or two
One vendor was inappropriate; there was a communication issue and the chip vendor we selected sold chips after 3pm only and other foods for lunch so not ideal for the study	Found a more appropriate chip vendor and began that cooking diary a day after the others. Also surveyed the inappropriate vendor so still got useful data	Give as much time possible to select vendors and limit translation issues by speaking to vendor ourselves through perhaps a pre-cooking diary interview or survey
Finding suitable vendors in the time frame was difficult because they had to be selected before we fully understood what the prototypes were capable of	Instead of testing each prototype with two vendors each for one week (alternating over two weeks), the first week we tested the prototypes ourselves while conducting baseline diaries with vendors, then the second week tested them with vendors	Give more time for testing prototypes in-house before taking them to the field However, time issues such as this were to be expected with such a limited time frame
Rainfall and bad weather meant that vendors did not open every day or significantly reduced opening hours	Noted on the diaries the times the vendors were open and their sales throughout the day – were still able to collect useful data on amount of charcoal used to cook amount of food	Conduct cooking diaries of more than one week – therefore averages can be calculated for specific days of the week
Rainfall and bad weather meant enumerators could not arrive at the vendors on time or not at all	I conducted the cooking diary instead as I lived closer, but usually the vendor did not start their day until the rain had stopped and the enumerators were able to arrive in time for the start of cooking	Project manager and other staff should be prepared to do this on any days. Kua Solar staff could help, if not, can ask the vendors to do the diary themselves until staff arrive

2.2.1 Case Study Vendors

Images 1 & 2: Case study chips mayai vendor (above); typical portion of chips mayai (below)

Chips mayai vendor

Often referred to throughout this report as simply *chips vendor*, this stall was located close to Malikusema, an urban area in Mwanza town centre, and situated on a busy intersection in a relatively busy part of the town.

Like so many across Tanzania, this chips mayai vendor has a simple business model and daily routine - they deep fry potatoes, typically 1kg batches in 2-3 litres of cooking oil, store the chips in glass cabinets (Image 1), then cook chips mayai to order (Image 2). Chips mayai is basically a portion of chips (roughly 250-300g cooked) mixed with two eggs and sometimes vegetables, then fried like an omelette in a small frying pan. This vendor was going to test the solar wok prototype after the week-long baseline cooking diary, but we were unable to get the wok to work within the time frame.

They only use charcoal and are open seven days a week, from 9/10am until beyond 10pm, often past midnight, but the cooking diaries were only kept until 7pm, as that was generally the time when the sun wouldn't be strong enough to power a prototype. They also sell grilled chicken, mishkaki, but this is cooked on an open charcoal grill that DC solar power cannot currently replace, so was not included in as much depth as the chips frying or chips mayai cooking.

Rice/Bean vendor

This vendor was located in Sahara Market: a busy, urban market in the centre of town, very close to Kua Solar's office so was conveniently located. They sell a wide range of foods: rice, beans, ugali, chapatis, beef, liver, fish and tea, but rice and beans are two of their primary foods sold to customers.

Rather than cooking meals directly to order, they cook large batches of each of their foods once or twice a day (e.g. 5kg rice, 1kg beans), keep them warm until customers arrive and only portion it up to order, so service is very quick. They are open 5 days a week and only use chacoal as a cooking fuel, with four stoves and nine cooking pots, using different combinations together interchangeably. This vendor tested the water heater prototype, as they can use it for cooking both rice and beans, as well as preparing water for ugali.

Image 3: Case study rice/bean vendor using solar water heater alongside their usual charcoal stoves, Sahara Market

Image 4: Case study chicken stew vendor in Malikusema

Chicken vendor

The case study chicken vendor was located at Malikusema; a small food market that specialises in cooking chicken stew and soup. It is essentially a row of vendors all cooking chicken in slightly different ways, but the case study vendor specialized in chicken stew and only used charcoal in standard jiko stoves. They typically cook 4 or 5 chickens at a time, usually cut into 8 or 10 pieces per chicken, and cooked with water/stock, vegetables and seasoning. They also have a grill, so customers can choose to have their chickens either entirely grill-cooked or sometimes just finished off at the end directly on charcoal. They serve their chicken with ugali and vegetables, both cooked in separate pots, as well as banana which is grilled.

They are open from around 10am until late in the evening, but the cooking diaries were also only kept until 7pm. There is a drinks bar and chips mayai vendor in the market as well and they all share a communal seating area (Image 4). There are also breakfast vendors selling chapatis, tea, kitumbua etc. until around 11am so it is a popular area to get most foods at any hour of the day. They tested the solar pressure cooker prototype to cook their chicken stew or just chicken.

Dagaa fryer

Image 5: Case study dagaa fryer, Kamanga

This vendor is located in Kamanga, a fishing community on Lake Victoria on the outskirts of Mwanza. They bulk fry freshly caught dagaa 7 days a week, 8-10 hours a day using only firewood and is almost entirely surrounded by other dagaa or fish fryers (Image 5).

Dagaa fryers are rather unique among the vendors included in this study: rather than cooking meals to directly sell to customers, dagaa fryers fry fish all day and then sell the cooked fish all day and evening. This vendor cooks approximately 150kg of dagaa daily, in around 50 different batches of 3kg each, using 20-30 litres of cooking oil throughout the day.

Only a single day cooking diary was conducted for this vendor, compared to a week with the others. This is because initially, it was not believed that the solar wok prototype would be large or powerful enough to cook the sizes of the batches dagaa fryers usualy cook, not least because of the sheer sizes of the pans and volume of oil. However, the survey data and general observations indicated that these vendors could at least test the wok prototype and if compatible, dagaa fryers could potentially benefit greatly from a solar-powered equivalent to their firewood stoves. It was threfore very important to learn in more depth about their cooking practices and if they were compatible with DC solar power, but it was decided quite late so there was only time and resources for a single day baseline cooking diary.

2.3 Prototype Testing

Three prototypes of DC solar-powered cook stoves were supplied for this research project by KuyereOrg: a rice/bean cooker (water heater), a pressure cooker and a wok (for deep frying). Unfortunately, the latter was not able to be tested in the time period available. This is because we had problems getting the wok to heat the amount of oil necessary for chips mayai vendors or dagaa fryers, even as a hybrid (maintaining cooking temperature once biomass had started the cooking process). It is likely that with more power, more insulation, and repositioned heating elements, it will be able to be tested with vendors, but this was still being worked on at the time this paper was published (July 2020). Time restrictions were exacerbated by the spread of COVID-19 and bad weather. However, I believe that with more time to make the necessary alterations, the wok prototype can still be tested as a hybrid with both the chip vendor and dagaa fryer and subsequently included in this study.

There were similar issues with the other two prototypes, but we were able to make the alterations in time for testing, so we are optimistic about the wok. We made two major changes to the solar water heater and pressure cooker prototypes; first was switching from 275W 60-cell panels to 325W 72-cell panels, and second was insulating them both as much as possible with the materials available to us at the time (see Chapter 5). We also experimented with the prototypes by cooking a range of foods in various quantities and testing different insulating materials to identify the optimal conditions.

The two working prototypes were tested with the same case study vendors the baseline cooking diaries were conducted with (rice/bean vendor and chicken stew vendor) and the same enumerators were used to conduct the cooking diary (Appendix 3) with the vendors each day they tested the prototype. They recorded what the vendor cooked in the prototype, the cooking time and any feedback from the vendors, customers or anybody who made any comment them. They also recorded the weather changes throughout each day to evaluate how the weather affected the prototypes' performance. As we were not able to test the wok with the other two case study vendors, we found two new vendors to test each of the working prototypes, a pilau and beef vendor for the water heater, and for the pressure cooker another chicken vendor but who usually uses a charcoal-fuelled pressure cooker.

Image 6: The three prototypes (from left to right: water heater, wok and pressure cooker)

At the end of each testing period, one-on-one semi-structured interviews were conducted with each of the vendors for an in-depth discussion based around what changes/improvements to the prototypes were required that would make them more useful for their cooking needs. All interviews were conducted in Swahili using a translator and each interviewee gave their verbal permission to be recorded. The interviews were transcribed using oTranscribe – only the English was transcribed, but the whole interview including the Swahili remains on the recording - the interviews were then coded using Nvivo. The English-version interview guide is available in Appendix 4.

Table 4: Challenges experienced with prototype testing

Challenge	Resolution	Future Action
Working out the most efficient way to use each of the prototypes	Had assistance from Kua Solar staff and changed research plan to give us an extra week before testing them with vendors	Allocate a week or two for testing future prototypes before any fieldwork is scheduled
Prototypes were not always large enough to cook quantities vendors usually cooked, so could not accurately calculate specific charcoal savings when using the prototypes	Calculated the decreased charcoal use with current sized prototypes, and then estimated fuel savings based on future designs meeting certain criteria e.g. can cook 5kg of rice, or 5 chickens. Also, vendors estimated themselves how much charcoal can potentially be saved	Request larger prototypes from beginning, or ensure sufficient time to find most appropriate vendors for testing
Prototypes could not always cook food in comparable times to charcoal so vendors could not sell the food cooked in the prototypes to customers as it was too late	We provided the vendors who had this problem with the foods they cooked in the prototype e.g. we provided the chicken stew vendor with the first day's chicken to cook	Have funds available in case food needs to be bought for the vendors in these situations
To further insulate the prototypes, one material used was a blanket. However, it was observed that covering things in blankets was a cultural taboo, so vendors did not want to use a blanket-covered stove	Cut and hid blankets by taping them to specific parts, e.g. underside of lid, or cutting them into small pieces and covering them with something externally so blankets could not be seen (Chapter 5)	This problem is addressed in the proposed designs for second generation prototypes (Chapter 7)
Even with further insulation and increased power the wok still could not work properly	Kua Solar staff are working on it at the time this paper was published	This problem is addressed in the proposed designs for second generation prototypes (Chapter 7)
Calculating what solar panels were most effective and efficient to be used for the prototypes required trial and error – leading to increased project costs	Conducted three tests with least powerful panels and then slowly increased the power – limiting possibility of overheating	Ensure there is as much time and funds possible to test any new prototypes and make required changes

3. Baseline Data

The baseline data primarily comprises the survey results supplemented by the data from the baseline cooking diaries. As there is such diversity among vendors' cooking practices in Mwanza, forming conclusions based on averages across the entire sample was, although interesting, not very helpful when attempting to understand, or design prototypes for, specific vendors or particular cooking practices. Therefore, I grouped all 122 vendors into six groups by the foods they cooked. The first four groups reflect the four case study vendors: chips mayai, rice/beans, meat and dagaa. These four vendor groups would become the four ***key target customers*** because they are not only four of the most common vendor groups in Mwanza, but their cooking practices are also most compatible with the three solar-powered prototypes that were available for the project – the wok for the chip vendors and dagaa fryers, water heater for rice/beans, and pressure cooker for meat.

This left 42 other vendors, who were then split into two further groups. Breakfast vendors were those who did most of their cooking in the early mornings (therefore limiting potential of DC solar power), and the remaining 31 were too diverse so were grouped together simply as "other" and thus forming a control group. This was the most useful, effective and logical way to group the vendors, so this baseline data is categorized by these vendor groups in this paper. Other interesting categorizations: by gender, community, grid access etc. are found in 3.6.

Table 5: Vendors grouped by primary food(s) sold

Vendor	No. Surveys	Criteria
Chips Mayai	28	Only vendors who *primarily* sell chips/mayai; excluding vendors who only offer chips as a side
Rice and Beans	22	All vendors that sold *both* rice and beans
Meat	14	Vendors who *primarily* sold one or more type of meat stew or soup
Dagaa	11	*Only* vendors who bulk fried dagaa or other fishes and excluding vendors selling fish as a meal alongside sides
Breakfast	16	Vendors cooking *breakfast* foods such as chapati, kitumbua, porridge, tea, coffee etc. and who are predominantly open in mornings
Other	31	All other vendors

3.1 Cooking Fuels

Across Mwanza, the surveys clearly indicate that food vendors overwhelmingly rely on biomass fuels as their primary cooking energy. 107 out of 122 (87.7%) relied exclusively on biomass (charcoal and/or firewood) for their cooking. Charcoal was significantly the most common - 105 vendors (86.1%) surveyed across Mwanza used charcoal, 86 of which (70.5%) exclusively.

One exception to this prevalence of charcoal usage were the dagaa fryers, mostly located in fishing communities like Kamanga and Dampo. Only 2 of the 11 dagaa fryers, 18%, used charcoal at all, and this was usually for cooking ugali or chips as a side business. This compares to 100% of the rice and bean vendors (91% exclusively), 89% of chips mayai (75% exclusively) and 79% of meat stew vendors (57% exclusively).

Image 7: Charcoal is the most widespread cooking fuel in Mwanza

Table 6: Cooking fuels used by vendors

Vendor	Sample	Charcoal	Charcoal only	Wood	Wood only	Gas	Gas only
Chips Mayai	28	25	21	1	1	4	1
Rice and Beans	22	22	20	1	0	1	0
Meat	14	11	8	1	1	1	1
Dagaa	11	2	1	10	1	0	0
Breakfast	16	14	10	3	2	3	0
Other	31	31	24	5	0	2	0
Total	***122***	***105***	***86***	***21***	***13***	***11***	***2***
Total (%)	***100%***	***86.1%***	***70.5%***	***17.2%***	***10.7%***	***9.0%***	***1.6%***

Image 8: Firewood is the fuel of choice for frying dagaa in Mwanza

The second most prevalent cooking fuel in Mwanza was firewood, used by 21 vendors (17.2%), 13 of which (10.7%) exclusively. Just over half of all users used it for bulk fish frying, usually dagaa, so the number of vendors using firewood to cook and sell meals is relatively low - 11 out of 122 (9%).

Only 3 vendors (2.5%) surveyed did not use any form of biomass for their cooking business: two exclusively used gas and one exclusively electricity. 11 of the 13 vendors who used gas (10.7% of total sample) did so alongside other fuels, most commonly charcoal. This fuel stacking tended to be present with vendors of larger businesses - as they tended to sell more portions, employ more people and spend more on fuel overall. The single vendor cooking with electricity cooks chips in an electric deep fryer using the grid.

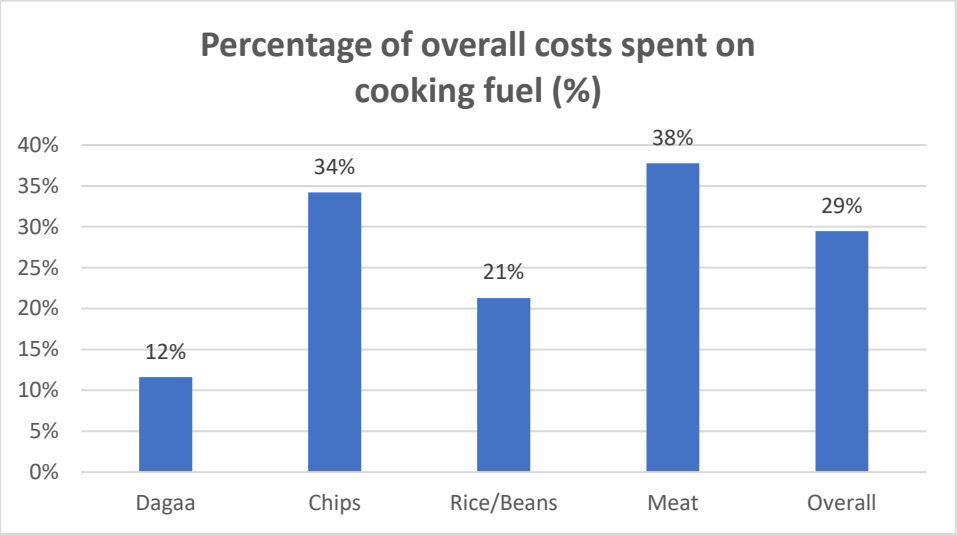
Physically accessibility was high across the sample. It is very easy and quick to access each of the cooking fuels in Mwanza, especially charcoal as it is ubiquitous and in places with no charcoal vendors, it gets delivered. Wood was generally delivered to wood-burning communities like Kamanga, and for gas users, the maximum distance they had to travel was 2km to refill their gas canisters.

Image 9: Gas tends to be used by larger businesses as upfront costs are relatively expensive

Physical accessibility may be consistently high among the vendor groups, but the amount of money spent on cooking fuels varied greatly, as did the percentage of income spent on cooking fuels. Overall, vendors spent an average of 17,000 TSh per day on cooking fuel, accounting for 29% of their overall costs.

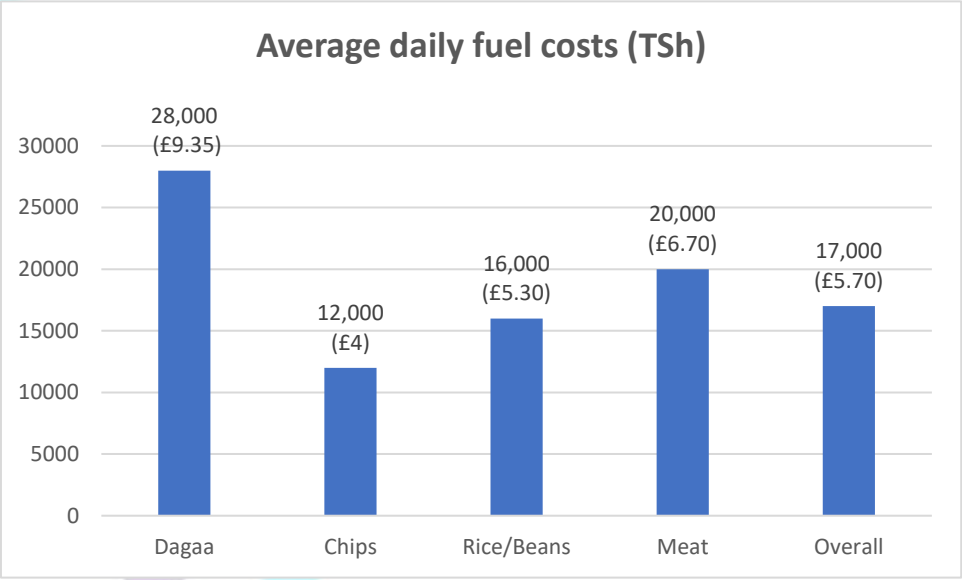
As seen in Figures 1 & 2, dagaa fryers spent the most money on fuel (predominately firewood) each day, 28,000 TSh (£9.35) but it accounted for the lowest percentage of overall costs, (12%). One reason this could be is because dagaa fryers' staff costs are comparatively high, the average number of workers for dagaa fryers was 19, significantly larger than the other three vendor groups and the overall average (Table 7). Unlike the other vendors who tend to buy the ingredients and cook them to sell directly to customers; dagaa fryers' business model differs greatly. Fishermen, often family members, would catch the fish, others would clean them, then the fish are dried, weighed and packaged before being transported to the fryer, who was the person we surveyed, so they likely included all of them in their responses, which is likely why the staff numbers were recorded as being so high when only one or a few people were present during the survey.

Figure 1: Percentage of overall costs spent on cooking fuel



Chips mayai vendors are the converse dagaa fryers, they tended to spend the least amount on their fuel (almost entirely charcoal), 12,000 TSh (£4), but it accounted for the second largest percentage of overall costs, 34%. There are likely two reasons for this. Firstly, chips mayai vendors tended to have the lowest number of workers, 2.5, so staff costs are low. Secondly, their only ingredients are essentially potato, eggs, and oil (sometimes vegetables), all of which are relatively cheap.

Figure 21: Average daily fuel costs



The rice/beans and meat vendor groups generally correlated with the overall average. The rice and beans vendors spent slightly less per day on fuel, 16,000 TSh (£5.30) compared to 17,000 TSh (£5.70), and fuel accounted for slightly less of their overall costs, 21% compared to 29% overall. On the other hand, meat stew vendors spent slightly more, 20,000 TSh (£6.70) compared to 17,000 TSh (£5.70), and 38% compared to 29%. As Table 7 displays, both had close to average staff numbers. Staff numbers are included in this section as apart from the actual foods vendor sell, cooking fuel, labour and rent are the three biggest expenses that account for vendors' overall costs, and no data was collected on rent as it was decided that this would be too personal/intrusive to ask.

Table 7: Average number of workers

Vendor	Sample	Average number of workers
Chips	28	2.5
Rice/Beans	22	3.2
Chicken/Meat	14	5.4
Dagaa	11	19
Breakfast	16	2.6
Other	31	3.6
Total	**122**	**4.8**
Total (excl. dagaa)	***111***	***3.3***

3.2 Cooking Equipment

Overall, each vendor owned an average of 9 cooking pots or pans that that on average cost 28,000 TSh (£9.35) and last around two and a half years each. Three-quarters of all vendors used at least one cooking pot and two-thirds used at least one frying pan, but the survey did not specify the size, shape or type of pot/pan they owned, nor which one they use more or less frequently. There were some notable differences among the four vendor groups.

Chip vendors tended to use the cheapest products, predominantly frying pans and woks, averaging 20,000 TSh (£6.70) each, and owned fewest of them overall, an average of 7. The case study chips vendor only had four altogether (two woks and two frying pans). The woks were used for deep frying the chips (Image 7), but one of them was not used at all throughout the week-long cooking diary. The two small frying pans (Image 11) were used interchangeably to fry the chips mayai.

Table 8: Cooking equipment

Vendor	Av. cost of pot/pan	Av. No. of pots/pans	How long they last (years)	Cooking pots	Frying pans	Av. time to light stove (mins)
Chips	20,000	7	2.3	42%	85%	18
Rice/Bean	40,000	11	2.2	100%	64%	11
Meat	31,000	13	1.5	92%	54%	17
Dagaa	32,000	n/a	2.9	14%	66%	20
Breakfast	18,000	7	3.3	88%	75%	11
Other	24,000	7	3.2	92%	48%	21
Overall	***28,000***	***9***	***2.6***	***75%***	***66%***	***13 mins***

Dagaa fryers only really used very large, flat-bottomed frying pans (Image 10) but they lasted the longest out of the four - almost 3 years. The also tended to have fewer of them. The case study dagaa fryer had four of these large frying pans, all almost the same sizes and used three of them interchangeably and one was used to only store the cooked dagaa on display for customers to buy.

Even though both chips mayai vendors and dagaa fryers reported high usage of frying pans, they differed greatly in size, strength and application. The chips mayai frying pan had a 20 - 23cm diameter and 1 - 3cm depth, and was made from relatively cheap, flimsy metal, compared to the dagaa fryer's 75 - 85cm x 15 - 20cm pan made of thick, sturdy metal that is built for durability and strength. This is noteworthy because when survey respondents said they had a "frying pan", there is considerable range of them used in Mwanza and it was not specified what sort of frying pan it was, what it was used for and what is was made from.

Image 11: Pans for bulk frying dagaa are very large and built to last (78 x 15cm)

Image 10: Chips mayai pans are small, light and cheap (20 x 3cm)

Rice/bean vendors had an average of 11 pots/pans per vendor, and 100% of them had a cooking pot. Like frying pans these varied greatly in size and use, but when it came to cooking rice and beans, they were generally very large products (Image 12). The case study rice/bean vendor used a 48 x 23cm cooking pot to cook 5kg of rice. For 1kg of beans, they used a 28 x 14cm cooking pot, but other vendors have larger one to cook larger quantities – 39x19 cm for 5kg and 50 x 22cm for 10kg (Image 29). When cooking vegetables or small portions of ugali, 18 x 9cm cooking pots were generally used (Image 13).

Meat stew vendors were similar to rice/bean vendors but had an even higher average number of pots/pans per vendor, 13 each. 92% of them had cooking pots, but their cooking equipment had the shortest lifespan of the four vendor groups, at an average of only 1.5 years. The case study chicken vendor used a cooking pot 30 x 14cm to cook up to 5 portions in one cook as well as soup and vegetables. They had two other cooking pots for cooking chicken and one other for ugali, which measured 18 x 9cm and could cook enough ugali for up to 5 customers. This pot was also used to cook a large batch of vegetables for up to 16 customers each day, but it was mostly used for ugali.

Image 12: : Large cooking pots are used to cook 5kg+ of rice (48 x 23cm)

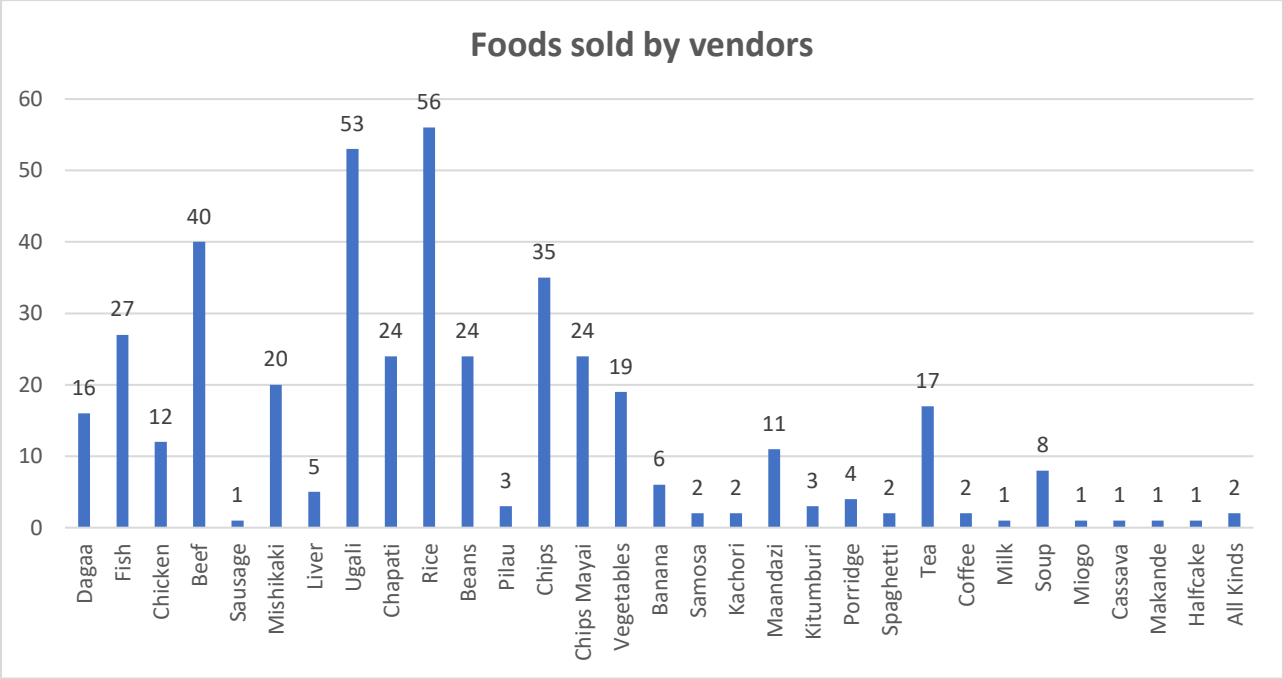
Image 12: Small cooking pots are used to cook vegetables and ugali (18 x 9cm)

3.3 Foods/Meals Cooked

There was a very diverse range of foods being cooked by the vendors surveyed. 120 out of the 122 surveys conducted gave definitive answers to what foods their businesses sold - "foods" include tea and coffee. Overall, the surveys identified 29 individual types of food and on average, each vendor cooked and sold four (mean of 3.875) different foods to their customers.

The most popular foods being cooked were rice and ugali with almost half of all vendors selling either of them, (47% and 44% respectively), and 37% cooking both. Beef was found to be the most popular meat sold in Mwanza with roughly a third of vendors and 60% of all vendors cooked at least one type of meat or fish to sell as meals (i.e. excluding dagaa) – out of beef, chicken, fish, liver, mishkaki or sausage. Chips is also a very common food sold: 29% of vendors cooked chips, the majority of which also offered chips mayai, but 11 vendors cooked chips but not chips mayai, and offered them as a side to other main foods/meals. Moreover, one-fifth of vendors sold beans, 14% sold tea and 7% sold soup, all three of which can potentially be cooked with the solar water heater, so are particularly noteworthy.

Figure 3: Total foods sold by all vendors



However, a limitation of the survey is that it did not specify how each food was cooked. Using chicken as an example, respondents simply responded chicken, as opposed to grilled chicken or chicken soup; both have very different compatibilities with DC solar cooking. Despite this, the data clearly shows that there are a wide range of foods being cooked by vendors in Mwanza, and we know from previous data that these are (with the exception of dagaa) predominately cooked with charcoal using cooking pots, frying pans or deep frying woks, and therefore potentially compatible with the prototypes.

Another limitation of the survey data is that due to the number of foods sold by each vendor (Table 9), it was difficult to discern what the primary foods sold were. For example, there were 4 vendors who sold 7 different foods each. There is no way of knowing if they sold all 7 equally or if and which two or three were sold primarily and the others only on occasion.

Almost two-thirds of vendors (65.8%) sold at least 3 different foods, and almost one-third (31.7%) sold at least 4. Only 11 vendors (9.2%) cooked just a single food - and 6 of these were dagaa fryers. On average, vendors typically cooked 3 or 4 different foods for its customers, but this varied among the different vendor groups. Expectedly, most dagaa fryers only sold dagaa wholesale, but a few also sold dagaa as a meal alongside one or two sides usually ugali, beans or chips (Image 15).

Table 9: Number of different foods sold

Vendor	1	2	3	4	5	6	7	Mean foods sold	Mode foods sold	Median foods sold
Chips		11	10	5	2			3	2	3
Rice/Bean			1	5	4	10	3	5	6	6
Meat		5	1	3	2	3		4	2	5
Dagaa	6	4	1					1.5	1	1
Breakfast	3	4	4	3	2			3	2, 4	3
Other	2	6	5	4	9	2	1	4	5	4
Overall	***11***	***30***	***22***	***19***	***20***	***14***	***4***	***3.5***	***2***	***3***
Cumulative	***11***	***41***	***63***	***82***	***102***	***116***	***120***			

Image 13: Vendor cooking (left to right): banana, soup, beans, rice. donuts, kitumbua and mishkaki

Image 14: Vendor cooking dagaa and ugali in Dampo

Chip vendors were similar in this respect as they typically only sold 2-3 foods: chips and chips mayai, with mishkaki for just under half the chip vendors. Rice/bean vendors cooked the highest number of foods on average at 6 per vendor (Image 14). If you look at what other foods rice/bean vendors cook, they are typically breakfast foods such as chapatis, kitumbua, porridge etc. which may have been cooked and sold before the rice and beans are ready, and sometimes even by different workers or family members i.e. even though 6 is the average, it does not necessarily mean that all 6 are sold at the same times, they could be spread between breakfast and dinner – this is evidenced when you view their opening hours (Figure 5).

The number of foods meat stew vendors sold were spread out relatively evenly, although the highest number sold two foods, most commonly ugali (86%) and rice (57%). The number of foods sold was recorded as high as 6, with three vendors cooking six different types of foods including their meat or fish. This range is why the mean, mode and median averages are all so disparate with meat stew vendors - 4, 2 and 5 respectively.

3.4 Cooking/Sales Volume

From the 110 surveys responses to the question "how many portions do you sell each day on average?" the average number of covers per day sold by vendors in Mwanza was 60 (59.2). Five vendors (19.2%) estimated they sold over 100 portions each day, with the highest recorded being 240. This data is relatively unreliable because only a single answer was given by the respondents and most of them cooked multiple foods (Table 9). There was also some ambiguity surrounding what constituted a "cover", for example, a cup of tea is technically a cover, so if the vendor cooks 5 different foods and one portion of each, but sells 100 cups of tea, their response could be 105, but there's no way of knowing how the covers are split between the foods that were sold by each vendor. Therefore, the survey data is quite limited so the case study vendors will be relied upon more for this baseline data, with the surveys still being drawn on.

According to the survey results, chip mayai vendors sold an average of 60 portions per day, the highest of the vendor groups. The case study chip vendor sold an average 59 portions of chips mayai per day over the course of the week-long cooking diary - all of which were cooked to order individually in the same two frying pans and sold directly to waiting customers. They had to cook the chips beforehand and did this by cooking an average of 16 batches each day, typically 1-2kg in 3litres of cooking oil. The vendor also sold mishkaki, but the cooking and sales of them were not recorded by the enumerator as barbecued meat was not compatible with the prototypes or proposed G2 models.

The rice/bean vendor group in the survey sold an average of 47 portions per day but it was not specified what the portions were of as they tended to cook several different foods. The case study rice/bean vendor showed that they were very consistent in the quantity of food cooked each day. Every day they cooked 5kg of rice, 1kg of beans, 2.25-2.5kg of ugali, 5kg chapati, 0.5-1kg liver, 2-2.5kg beef, 10 litres of tea and 10 fish. Using an average weight of a typical portion of each food and divided by its overall weight, it was calculated that the vendor sold 14 portions of rice, 12 of beans, 15 of beef, 62 chapatis, 5 portions of ugali and 10 fish, equalling 118 portions excluding tea.

Figure 4: Average number of covers sold per day

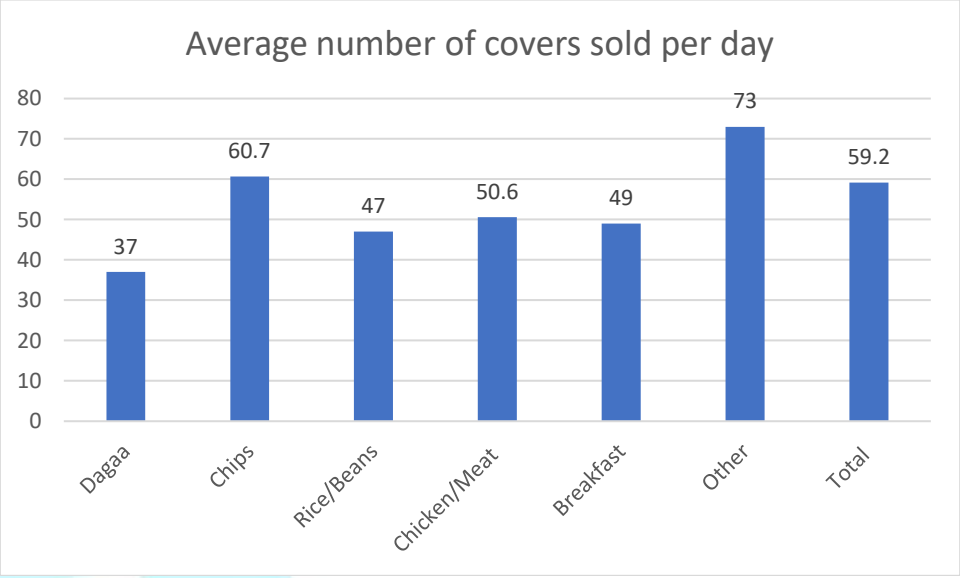


Image 15: Case study vendor cleaning chickens for the day's service

The survey indicated that meat stew vendors sold an average of 51 portions each day (50.6), but again, the ambiguity as to what constitutes a portion was problematic. For example, with the case study vendor, some customers have a quarter chicken as a portion (or two would share half a chicken), but most customers would have half a chicken, and some would order a whole chicken to themselves to take home and no knowing how many people it was for. Using the half chicken as a typical portion, the chicken vendor cooked an average of 12 chickens a day, 10 portions of ugali and 16 portions of vegetables: together totalling 32 "covers". Chickens were mostly cooked in saucepans to make the chicken soup/stew that the vendor specialises in, but an average of 4 were cooked on the grill at least partially.

According to the survey data, dagaa vendors sold the fewest portions of food per day, 37, but they were unique in the sense that they did not cook meals to sell like the others. The single-day cooking diary we conducted showed that the dagaa vendor cooked 49 batches of dagaa from 8am to 6pm, averaging approximately 3kg of dagaa per batch, which equals 147kg of dagaa cooked in one day. However, a separate estimation of the total fish cooked in one day was 156kg (weighing one debe and multiplying by the total) so 150kg of dagaa was selected as a compromise.

Image 16: Roughly 150kg of dagaa to be cooked in a day by case study vendor

To cook this quantity of dagaa, the case study dagaa fryer used two large frying pans (Image 34) and filled each with 9-11 litres of oil and then topped up with between 8-10 litres throughout the day to both. This was difficult to measure as oil was often taken out when it was close to overflowing and then returned to the pan sporadically. They also splashed some of the oil directly onto the fire to increase flames.

Image 17: Roughly 3kg of dagaa cooked in each of the 49 batches throughout typical day

At the end of the day, about 5-6pm, the fryer would stop cooking and then have a very large pile of cooked dagaa on display waiting to be sold to customers (Image 36). Customers would buy the dagaa in buckets, or debes, the bigger the bucket, the more dagaa they got per shilling, so discerning the number of covers for dagaa fryers is not very simple, rather, it is more useful to know that approximately 150kg of dagaa is cooked in a day with about 20-30 litres of oil in 49 batches of roughly 3kg.

3.5 Opening/Busy Times

Table 10: Average hours open

Vendor	Average hours open each day
Chips	12.6
Rice/Bean	13.1
Meat	12.3
Dagaa	7.2
Breakfast	9.2
Other	13.9
Overall	***11.9***

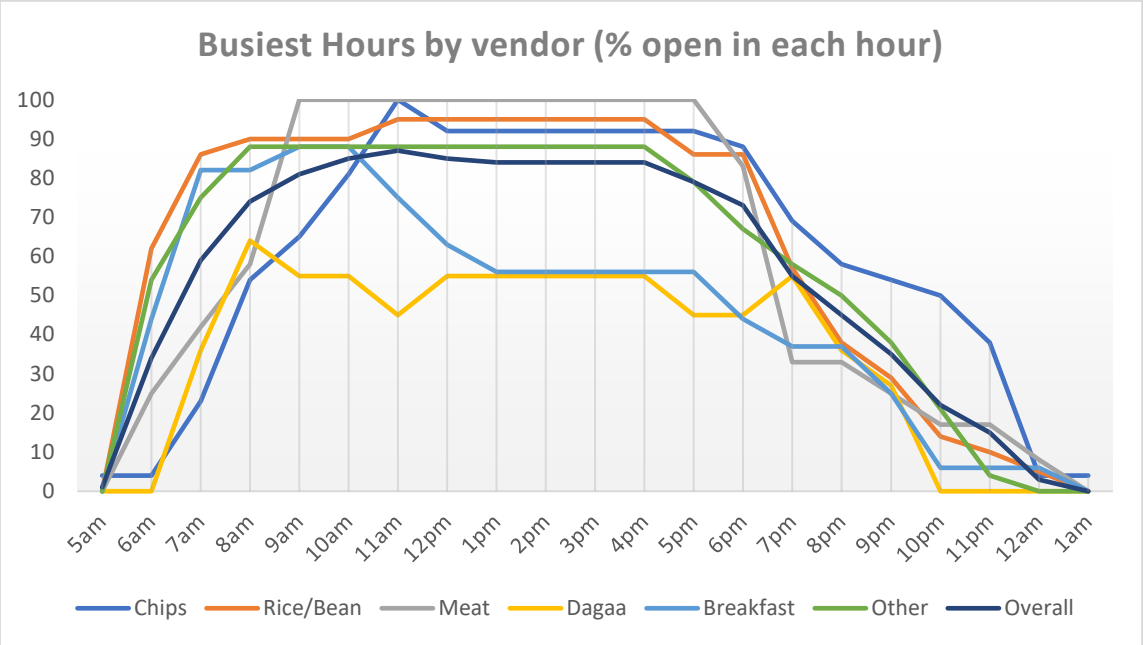
Vendors are generally open an average of 12 hours a day in Mwanza, usually the 12 hours of daylight, 8am until 8pm, but especially between 9am and 6pm, where 80% of vendors were open, and even more so between 10am and 4pm, with 85% of vendors open. What is unknown from this data is to what extent the vendors had started or finished cooking by these times; they could "open" at 9am and have all food already prepared and cooked by 9am. Conversely, they may "open" at 9am but not start cooking until 11am and spend the first two hours preparing food, lighting their stoves and buying ingredients or fuel.

Table 11 is colour coded to highlight the busiest hours of the day for each vendor, but Figure 5 has the same data in a line graph. This is important when evaluating the potential of DC solar-powered stoves because their usage and performance are directly linked to sunlight hours. The data supports the notion that solar-powered stoves can be utilised by the target vendors. The table clearly shows that, apart from dagaa fryers, food vendors' busiest hours are from 11am to 4pm – prime sunlight hours. Chip vendors began the day relatively late, with over 85% not opening until 11am, compared to 7am for rice/bean vendors, 9am for meat stew vendors and 10am for all vendors. All three ended their average workdays similarly, although rice/beans beginning to close from 4pm compared to the rest of the vendors more commonly at 6pm.

Table 11: Busiest hours – nearest percentage point

Hour	Chip	Rice/Bean	Meat	Dagaa	Breakfast	Other	Overall (%)
5	4	0	0	0	0	0	2
6	4	62	25	0	44	54	35
7	23	86	42	36	82	75	59
8	54	90	58	64	82	88	74
9	65	90	100	55	88	88	81
10	81	90	100	55	88	88	85
11	100	95	100	45	75	88	88
12	92	95	100	55	63	88	86
13	92	95	100	55	56	88	85
14	92	95	100	55	56	88	85
15	92	95	100	55	56	88	85
16	92	95	100	55	56	88	85
17	92	86	100	45	56	79	80
18	88	86	83	45	44	67	75
19	69	57	33	55	37	58	56
20	58	38	33	36	37	50	46
21	54	29	25	27	25	38	36
22	50	14	17	0	6	21	22
23	38	10	17	0	6	4	15
24	4	5	8	0	6	0	3

Figure 5: Busiest hours in line graph – nearest percentage point



Dagaa fryers were unique again with no more than 64% open at any hour. The hour most were open was 8am, perhaps because dagaa is usually fished at night so by 8am the fishermen have returned to shore and the dagaa has been cleaned, dried, and transported to the fryer, who begins frying immediately. Despite this early start, 55% were still open at 7pm, although it is very possible that many of these would have finished cooking already and only be open for selling dagaa.

Regarding busy days of the week, 87 out of the 122 vendors surveyed gave specific days which they believed to be their busiest; the other 35 providing answers such as “every day”, “none” or “it depends”. No distinction is made between these responses (n/a in Table 12). Overall, there were 188 responses and just over half (53%) were either Saturday or Sunday and almost two-third (65%) including Fridays. This varied between the vendor groups; meat and chip vendors’ busiest days were mostly weekends with 88% and 67% of their overall responses stating either Saturday or Sunday compared to just 31% of rice/bean vendors and 42% of breakfast vendors. This may be because the latter two primarily cater for local workers’ lunches, so weekdays would be busiest, whereas the former two cater to the general public so were busier at the weekends. Dagaa fryers also recorded a low percentage, likely because they bulk fry the same amount of fish whenever the fishermen go out the night before.

Table 12: Busiest days of the week

Vendor	n/a	Mon	Tue	Wed	Thu	Fri	Sat	Sun	% Weekend Busiest
Chips	3	3	3	4	2	5	16	19	67%
Rice/Bean	12	3	1	1	1	5	2	3	31%
Meat	3	1	0	0	0	1	9	5	88%
Dagaa	3	4	4	4	5	4	9	5	40%
Breakfast	7	4	3	4	4	3	6	7	42%
Other	7	6	1	4	4	5	8	10	47%
Overall	***35***	***21***	***12***	***17***	***16***	***23***	***50***	***49***	***53%***

3.6 Group Differences

In this section, any interesting differences between groups other than by vendor are compiled. The ones selected were grid vs off-grid vendors, community comparisons and by gender.

3.6.1 Grid vs Off-grid Vendors

70 vendors surveyed had access to grid electricity, 23 did not and 29 were unrecorded. There was no significant difference between grid-connected and off-grid vendors when it came to electricity usage as a cooking energy specifically; vendors everywhere predominantly used charcoal for cooking regardless of electricity access. Vendors with direct grid connections and those located in areas with sufficient street lighting are able to use electricity for lighting during darkness hours, whereas off-grid vendors were either unable to do so or relied on the unhealthier kerosene lanterns or candlelight. This could be the reason why the business hours were longer among grid-connected vendors compared to their off-grid counterparts (Table 13).

If you look at the 12 hours of darkness (8pm to 8am) grid-connected vendors were open almost twice as long on average as off-grid vendors. However, this may not be due to accessing electricity, two-thirds of the off-grid vendors were located in Kamanga, a fishing community where the majority of the vendors were dagaa fryers whose businesses are only open between 7am and 9pm (Table 11 & 14). Furthermore, there is a similar difference between grid-connected and off-grid vendors during daylight hours. Grid-connected vendors were open on average of 10.8 hours out of the 12 hours between 8am and 8pm, compared to 7.6 hours for off-grid vendors.

Table 13: Grid-connected vs off-grid vendors, opening hours

	Sample size	Average Hours Open		
		24 hours	Daylight only: (8am-8pm)	Darkness only: (8pm-8am)
Grid-connected vendors	60	13.5	10.8	2.7
Off-grid vendors	21	9.1	7.6	1.3
All vendors	***81***	***12***	***10.1***	***2.3***

Grid-connected vendors would also greatly benefit from having access to electricity as they are able to power fans, televisions, radios, refrigeration and a range of other electrical appliances to offer a better service and/or food to their customers compared with off-grid vendors. However, this would come at an extra cost, which could be why grid-connected vendors spent 27% of their overall costs on energy, compared to 20% of off-grid vendors.

Table 14: Access to electricity by vendor

	Yes	No	Unrecorded
Chips Mayai	17	0	11
Rice/Beans	19	3	0
Chicken/Meat	8	2	4
Dagaa	1	10	0
Breakfast	7	1	8
Other	18	7	6
Overall	***70***	***23***	***29***

Table 15: Grid vs off-grid - % interested in solar and electric cooking

Access to Grid Electricity	Solar		Electricity	
	% Yes	% No	% Yes	% No
Yes	84	9	70	27
No	74	17	44	52
Unrecorded	83	14	79	10
Overall	***82***	***12***	***67***	***28***

Another interesting comparison between grid-connected and off-grid vendors is their interest in cooking with solar or electricity. Both groups showed a strong interest in cooking with solar, 84% of grid-connected and 74% of off-grid vendors responded that they were interested compared to 9% and 17% respectively who were not. However, when asked if they were interested in cooking with electricity, the off-grid vendors were not so enthusiastic; 52% of them stated they were not interested compared to 44% who were. This contrasts with grid-connected vendors, of which 70% were interested, and only 27% who were not (although this is still over a quarter of them). These differences may not be due to grid access and more due to the fact that most off-grid vendors in this survey were dagaa fryers, who, as Chapter 4 details, were more concerned with the compatibility of electric cooking with their cooking practices as opposed to being averse to electric cooking generally.

3.6.2 Community Comparisons

Table 16: Community comparisons (= also "other" vendor group)*

Community	Most common vendor	% Charcoal Use	% Wood Use	% Gas Use	Av. Covers	Av. Staff	No. Pots	% Weekend Busiest
Kamanga	Dagaa	38.5	84.6	7.7	42.3	16.6	n/a	38%
Sahara	Rice/Bean	100	0	0	49.6	2.9	9.4	8%
Igoma	Chips	75	25	0	58.2	2	15	46%
Nyamalango	Chips*	87.5	18.8	25	80.3	5.3	7.3	32%
Malikusema	Chicken/Meat	100	0	12.5	34.4	4.3	10.1	88%
Nyamhangolo	Breakfast*	100	10	40	31	1.4	8.4	91%
Kisesa	Rice/Bean*	100	8.3	8.3	58.5	2.3	6.6	56%
Kiseka	Chips*	90	10	10	70	4.7	10.1	78%
Buhongwa	Chips*	100	0	0	61.7	4	7.8	70%
Kiloleli	Chips	100	0	0	66.4	1.9	8	90%
Other	Chicken/Meat	69.2	15.4	7.7	37.9	3.3	5.8	50%
Overall	***Chips****	***86.1***	***17.2***	***10.7***	***59.2***	***3.4***	***8.8***	***53%***

Excluding Kamanga, which predominantly comprises dagaa fryers, there was a range of foods being sold in each of the other nine communities in Mwanza. However, some vendors were more prevalent in some communities than others. Chip vendors were most common in Igoma, Nyamalango, Kiseka, Buhongwa and Kiloleli, meat stew vendors were most common in Malikusema, the food market, rice/bean vendors were the most common in Sahara and Kisesa, two urban markets, and breakfast vendors were most common in Nyamhangolo, the residential community, perhaps because of commuters travelling into Mwanza each morning.

Nyamalango had the most diverse use of cooking fuel including 18.8% using firewood and 25% using gas; a third of all gas-using vendors surveyed were located there. They also sold the most covers (perhaps due to the faster, more efficient fuel) and employed the second largest workforce after Kamanga which in unique (3.1) and had the second lowest average number of pots per vendor. Vendors from Nyamhangolo also stood out. They had significantly the highest proportion using gas, at 40%, although 100% still used charcoal and 10% used firewood, so fuel stacking was very common. Unlike Nyamalango, which also had many gas users, Nyamhangolo sold the fewest covers per day and had the smallest workforces. Sahara, Buhongwa and Kiloleli were the only communities who exclusively used charcoal, and they generally correlated the overall average.

There was also a notable difference in the busy days of the week between communities. Just over half of vendors put either Saturday or Sunday as their busiest days of the week, but in Malikusema, Kiloleli and Nyamhangolo it was far higher, 88%, 90% and 91% respectively, compared to Sahara (8%) and Nyamalango (38%).

3.6.3 Gender

Overall, 58 vendors surveyed were female, 42 male and 22 were unspecified, so food vendors were generally more female but not by a significant margin. The primary gender difference was what foods were predominantly cooked by each gender. 23 of the 25 chip vendors (92%), were male; over half of all males in the survey (54.8%) were in fact chip vendors, compared to just 3.4% of all females. Females on the other hand accounted for 19 of the 21 rice/bean vendors (90.5%); 32.8% of all females surveyed were rice/bean vendors, compared to just 4.8% of males. Furthermore, females accounted for most of the breakfast (71%) and other (74%) vendor groups. Meat stew vendors were split quite evenly.

Table 17: Vendor groups by gender

Vendor	Male	Female	Unspecified
Chips	23	2	3
Rice/Bean	2	19	1
Meat	5	7	2
Dagaa	1	0	10
Breakfast	4	10	2
Other	7	20	4
Overall	***42***	***58***	***22***

Table 18: Cooking fuel choice by gender

Vendor	Male	Female	Unspecified
Charcoal	36	56	13
Wood	3	6	12
Gas	9	4	0
Electricity	2	0	0

The surveys also found that males used gas more than women, although this may be because males were mostly chip vendors who were the group that used gas the most (Table 6). Women use firewood slightly more than men, but this data is unreliable as 12 of the 21 wood users were unrecorded and 10 of these were in Kamanga where firewood was ubiquitous. Finally, charcoal was the primary cooking fuel for both males and females.

When cross-tabulated with each of the survey questions there were not many differences found that can reliably be attributed to solely gender. One difference is that males spent an average of 18,761 TSh and females 15,833 TSh on fuel, about 1,000 TSh either side of the overall average (17,000). It is likely that most gender differences found in the data is because of the male dominance of chips mayai and the female dominance of rice, bean, and breakfast cooking. Also, the surveys only recorded the gender of the respondent and their position in the business was not specified. Vendors on average had 5 staff, so the gender recorded is not representative or reliable enough to base conclusions on.

4 Market Potential of Solar Cooking

This section evaluates the survey responses from questions regarding vendors' perceptions of solar-powered cooking, what features would be most important to them and what they would want to cook with a solar-powered cooking device. It also includes similar questions on cooking with electricity generally, particularly grid-electricity, to identify any differences between grid and solar electricity.

As this section relates to cooking with solar power, only the four case study vendor groups are specifically analysed. This is because it is unnecessary to delve into too much detail on breakfast vendors as a DC solar stove cannot realistically meet their cooking times. Also, the 31 vendors' cooking practices in the "other" group are too diverse to design a specific product for.

4.1 Interest of and Barriers to Electric Cooking

Before the vendors were asked about their views in cooking with solar power, they were asked about their views on cooking with electricity generally. 71%, said that they were interested in cooking with electricity, but when asked what was stopping them, 84% of the responses stated cost as the biggest barrier – cooking with electricity was generally perceived to be too expensive.

Table 19: Interest in cooking with electricity

Vendor	Interested in Cooking with Electricity		
	Yes	No	% Yes
Chips	23	2	92%
Rice/Bean	14	7	67%
Meat	10	4	71%
Dagaa	3	8	27%
Overall	***82***	***34***	***71%***

Table 20: Barriers to cooking with electricity

Vendor	Barriers to Cooking with Electricity			
	Cost	Inappropriate	Nothing on Market	Uninterested
Chips	22	0	2	0
Rice/Bean	15	0	3	2
Meat	9	1	1	0
Dagaa	3	4	1	1
Overall	***79***	***5***	***13***	***5***
Overall (%)	***84%***	***5%***	***14%***	***5%***

This was particularly evident with chip vendors – 92% were interested in cooking with electricity, with 92% also stating cost as the primary barrier of access. The rice/bean and meat vendor groups' responses correlated strongly with the overall data. Dagaa fryers on the other hand, felt very differently; only 27% of the vendors surveyed were interested in electric cooking and the primary barrier was inappropriateness, closely followed by cost. This is unsurprising given the fact that most dagaa fryers are located in off-grid areas and the sizes of the pans and quantities of food they cook are very large – frying 150kg of dagaa each day with electricity understandably seems implausible and/or expensive given the current cost of grid electricity and limited incomes of dagaa fryers.

The second biggest barrier to electric cooking for vendors, the survey found, was that there was currently nothing on the market (14%). At least one from each vendor group felt this way; rice/bean vendors had the most responses for this, perhaps because the electrical goods currently on the market are too small and incompatible to match the cooking pots vendors currently use for cooking the large quantities of rice and beans necessary.

There are some electrical cooking devices available in Mwanza, but they are relatively expensive and limited in their compatibility with food vendors' needs, for they are primarily aimed at households. The only electrical cooking appliances on the market that are compatible with food vendors' cooking practices are products like electric pressure cookers, chip fryers, electric hobs/hotplates and perhaps microwaves – all of which are expensive with limited or no pay-as-you-go payment options, require grid-connection and are usually too small for the quantities the vendors need to cook.

Image 18: Electric fryers are one of the only electrical devices available for chips

4.2 Interest of and Barriers to Solar Cooking

The vendors were more interested in cooking with solar than they were with electricity (Table 21); 88% overall were interested, as were 100% chip vendors, 92% of meat stew vendors and 77% rice/bean vendors; all of which were much higher percentages than cooking with electricity. The most significant difference is with the dagaa fryers, 73% were interested in cooking with solar compared to just 27% with electricity.

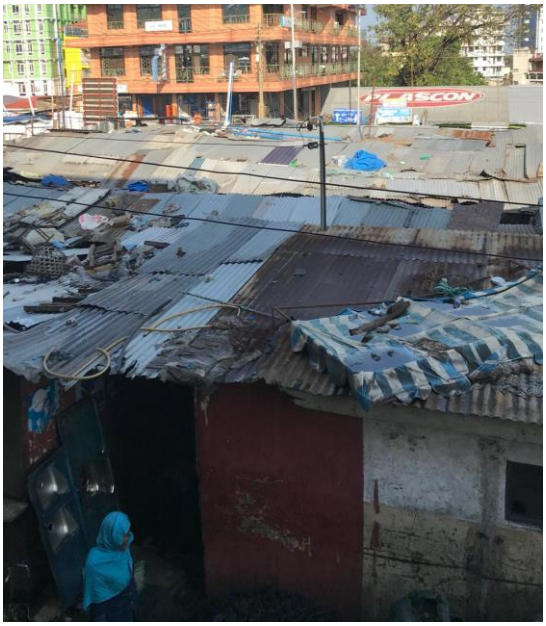
Table 21: Interest in cooking with solar vs electricity

Vendor	Interested in Cooking with Solar			Electric Cooking
	Yes	No	% Yes	% Yes
Chips	25	0	100%	92%
Rice/Bean	17	5	77%	67%
Meat	12	1	92%	71%
Dagaa	8	3	73%	27%
Overall	***100***	***14***	***88%***	***71%***

Table 22: Barriers to cooking with solar

Vendor	Barriers to Cooking with Solar				
	Cost	Inappropriate	Nothing on Market	Uninterested	Unreliable
Chips	6	-	14	-	1
Rice/Bean	6	-	10	1	2
Meat	3	-	5	-	-
Dagaa	1	-	5	2	1
Overall	***27***	***1***	***58***	***3***	***4***
Overall (%)	***29%***	***1%***	***62%***	***3%***	***4%***

Image 19: Spot the solar panel! Solar power is unusual for vendors in communities like Sahara Market



Unlike the barriers to cooking with electricity, which was mostly financial, the biggest barrier to solar cooking was lack of access - there was nothing on the market, or vendors were unaware of any in existence. 62% of responses stated this compared to just 14% for electric cooking. Cost was the second largest barrier, 31% perceived solar cooking to be too expensive. Only a small proportion felt that solar power was too unreliable (4%), were simply uninterested (3%) or believed solar cooking to be inappropriate for their cooking practices (1%) – but this latter figure is also because there's nothing on the market for them to know if it's compatible or reliable.

Evaluating vendors' interest in solar-powered cooking is problematic because there is simply nothing for them to base their judgement on. With electricity, people tend to have some experience with electrical cooking appliances and have at least a basic idea of its costs, performance, pros and cons etc. even if they have never owned or used one before. Solar-powered cooking products on the other hand are just concepts, vague images in people's minds and with no context, it is easy to imagine a solar-powered stove that has all the answers. Therefore, although this data indicates a strong interest in solar cooking, it may differ when the vendors' see and use products for themselves - which is why the testing of the prototypes was so paramount to this project.

4.3 Preferred Solar Stove

When asked what pot or pan they would most like to be solar-powered, the two most popular choices were a wok (46%) and a pressure cooker (40%). Frying pan was the third most popular choice accounting for 10% of responses and only 4% desired a water heater. However, due to a translation error, there was a mistake in the available choices in the survey question, so the respondent did not necessarily know that the water heater was capable of cooking rice, beans or any foods at all. If it was made clear that the "water heater" option referred to the prototype that is also a rice/bean cooker, the survey responses would undoubtedly be very different.

Table 23: Preferred pot/pan to be solar powered

Vendor	Wok	Pressure Cooker	Water Heater	Frying Pan
Chips	11	6	1	5
Rice/Bean	8	7	1	2
Meat	7	8	0	1
Dagaa	3	0	0	1
Overall	*46*	*40*	*4*	*10*
Overall (%)	*46%*	*40%*	*4%*	*10%*

Chip vendors preferred a solar-powered wok over all others, with almost double the number of vendors choosing a wok over the second-most preferred, which was a pressure cooker. Out of the 28 chip vendors grouped together in this survey, only four cooked anything other than chips, chips mayai or mishkaki i.e. things that a pressure cooker cannot cook. Regardless, over a quarter of them (26%) selected the pressure cooker other the others, including a frying pan and water heater, which indicates that they may be interested in cooking new foods with solar. This was supported when chip vendors were asked what foods they would like to cook with solar, 61.3% of chip vendors chose foods that they did not currently cook, compared to an almost 50-50 split with the overall sample, and the most common new foods they wanted to cook were rice, banana, ugali and fish.

Rice/bean vendors also chose a wok and a pressure cooker as their preferred choices, but if they were aware that the water heater could also cook rice and beans, then they certainly would have chosen that more, especially as over half of them want to cook the same foods they currently cook (mostly rice and beans). The ones who did want to cook new food with solar wanted to cook ugali, beef and fish. Meat stew vendors also chose the pressure cooker and wok, but when asked what they would cook with solar, twice as many would cook new foods, mostly banana, rice and beans. Dagaa fryers were only interested in a solar-powered wok and/or frying pan and none of those surveyed were interested in cooking anything else with a new solar-powered cooking device.

Table 24: What would you cook with a solar stove?

Vendor	Same Food	New Food	Most common new foods
Chips	12	19	Rice (4), Banana, Ugali & Fish (3)
Rice/Bean	10	9	Ugali, Beef & Fish (2)
Meat	3	6	Banana (3), Rice & Beans (2)
Dagaa	5	0	-
Overall	***41***	***40***	***Beans (11), Rice & Banana (10), Beef (8), Makande (7), Ugali (6), Chicken & Fish (5)***

4.4 Desired Features of Solar Stove

Vendors were asked to rate the importance of 8 different factors of a hypothetical solar-powered stove: price, power, adjustable temperature, size, durability, portability and looks (Table 25 & 26). The aim was to identify which factors vendors believed to be the most important, so that they can be prioritised when developing the next generation of prototypes and inform their specific designs. They were asked to rate each factor out of *very important*, *important,* or *not important*.

Overall, the most important factors the vendors chose were durability and power. 18.1% of the 91 vendors who answered the question ranked durability as *very important* and only 4.3% chose *not important* - one of the lowest out of all factors. Power was a close second, with 15.8% rating power as *very important* compared to just 4.2% as *not important*. Furthermore, durability and power received the highest number of responses with 94 and 95 respectively out of 122. The surveys clearly indicated that durability and power were the most important factors chosen by the vendors overall

Determining the least important factors was more difficult. Looks and size received the most *not important* ratings, 15.1% and 11% respectively, yet recorded the third and fourth highest “very important” ratings, 12.1% and 11% respectively. Vendors were almost split 50-50 in either thinking they were very important or not important at all. This is likely due to the polarisation of vendors’ cooking needs; dagaa fryers for example rated size as the most important, 67% “very important” compared to 5% from rice/beans vendor (Table 26).

Table 25: Importance of various features of hypothetical solar-powered cooking device

		Number	Percentage
Price	Very Important	3	3.3
	Important	83	90.2
	Not Important	6	6.5
	Overall	*92*	
Power	Very Important	15	15.8
	Important	76	80
	Not Important	4	4.2
	Overall	*95*	
Adjustable Temperature	Very Important	9	11
	Important	66	80.5
	Not Important	7	8.5
	Overall	*82*	
Reliability	Very Important	9	7.1
	Important	77	84.6
	Not Important	5	4.1
	Overall	*91*	
Size	Very Important	10	11
	Important	71	78
	Not Important	10	11
	Overall	91	
Durability	Very Important	17	18.1
	Important	73	77.7
	Not Important	4	4.3
	Overall	94	
Portability	Very Important	4	4.7
	Important	69	56.6
	Not Important	13	10.7
	Overall	*86*	
Looks	Very Important	11	12.1
	Important	66	72.5
	Not Important	14	15.1
	Overall	*91*	

Looks and size may have received the most *not important* ratings, but price and portability received the lowest number of *very important* ratings - 3.3% and 4.7% respectively. Again, this is because of differences between vendor groups, particularly the dagaa fryers; 38% ranked price as not important, compared to a maximum of 9% with the other vendors. These differences are explored further in Table 26. Reliability and adjustable temperature were the two remaining features that recorded relatively neutral responses - both had two of the highest *important* ratings. Reliability received the least *not important* ratings, but also the second least *very important* whereas adjustable temperature had average response rates to *very important* and *not important*.

Table 26: Importance of various features of hypothetical solar-powered cooking device by vendor (%)

		Chips Mayai	Rice/Beans	Meat	Dagaa
Price	Very Important	10	0	0	0
	Important	91	100	91	63
	Not Important	0	0	9	38
Power	Very Important	20	16	8	33
	Important	75	84	92	33
	Not Important	5	0	0	33
Adjustable Temperature	Very Important	24	5	0	33
	Important	77	90	100	50
	Not Important	0	5	0	17
Reliability	Very Important	16	5	0	25
	Important	74	95	100	75
	Not Important	11	0	0	0
Size	Very Important	14	5	0	67
	Important	82	74	100	33
	Not Important	5	21	0	0
Durability	Very Important	17	37	0	29
	Important	83	63	100	43
	Not Important	0	0	0	29
Portability	Very Important	5	5	0	20
	Important	90	84	100	40
	Not Important	5	11	0	40
Looks	Very Important	24	18	0	33
	Important	71	77	92	67
	Not Important	5	6	8	0

When categorised by vendor type, you can see how the responses vary depending on their cooking practices. This is key because the proposed next generation of prototypes (G2) are each specifically designed for a target group, so understanding the specific demands of specific vendors informs the product development effectively. The factors rated most important to chip vendors were adjustable temperature and looks, with 24% of responses ranking each of them as *very important* and 0 *not important* responses for the former and 5% for the latter. However, price and durability were also two factors with 100% *important* or *very important* responses. The factor ranked least important was reliability – perhaps a reflection of their current pots/pans (Table 16).

The most important factor for dagaa fryers was size; unsurprising given the size and strength of their current pans (Image 10). 67% ranked size as *very important*; 100% including *important* responses. Portability and price were both rated the least important, 40% and 38% respectively rating them as *not important* – the two highest figures for all *not important* responses. The other factors were mostly spread evenly, but no dagaa fryer said that reliability and looks were *not important*, 75% and 67% respectively said they were *important* factors, with the remaining saying *very important*.

For rice/beans vendors, durability and looks had the rated most *very important* ratings, 37% and 18% respectively. Alongside price, power, reliability and durability each had 100% ratings of at least *important*. Their least important factors were size and portability, 21% and 11% respectively. The data collected from the meat stew vendors was unreliable as almost all the responses were *important*, so identifying preferred features was difficult. Power was the only factor ranked *very important* (just one vendor) and the only factors ranked *not important* were one person each for price and looks.

5. Prototype Testing

5.1 Preliminary testing

Before we tested the prototypes with the vendors, we experimented with some preliminary tests to evaluate the prototypes' capabilities and see what foods were best to cook in them and how/if we could optimize their performance. We initially used four 250W 60-cell solar panels: one for the water heater, one for the pressure cooker and two for the wok. However, we quickly learned we needed more power, so we replaced them with 325W 72-cell panels, but only purchased two in case they were not suitable either. The plan was to test the former two prototypes first and the wok afterwards. However, at the time this report was completed the wok had not been yet tested with the vendors, but Kua Solar staff are currently working on it (2.3).

Image 20: Pressure cooker prototype in extra insulation

Asides from increasing the power of the solar panels, we tested various insulating materials on the water heater and pressure cooker to improve their performances as much as possible. Initially, we found that wrapping them both in thick blankets was very effective, but we were strongly advised against this Kua Solar staff, who were locals in Mwanza, as there was a cultural taboo about covering things up in blankets, particularly in relation to food, so we had to find innovative ways to insulate them without having blankets visible from the outside.

For the pressure cooker, we wrapped the underside with cut outs of a blanket and then placed it into a larger cooking pot (Image 21) with the edges wrapped together with strong foil. This improved its performance almost as much as wrapping a blanket completely around it; it could cook the necessary food – up to 2 chickens using solar only and in comparable times to a typical charcoal jiko stove (5.3). Once the prototype was ready, it was tested with the case study chicken vendor in Malikusema for five days and another chicken stew vendor for one day, but they used charcoal-fuelled pressure cookers rather than the standard cooking pots used by the case study vendor.

Image 21: Water heater with thick blanket taped to the underside of the lid

For the water heater, we stuffed foam insulation underneath the cooking pot but within the external frame. We also taped one blanket to the underside of the external lid and taped over it. We left the other blanket with the vendor and told them that using it in between the cooking pot and top lid will improve the performance, but made it optional in case they did not want to use it (they did). After this insulation, we were able to cook rice in the water heater in comparable times to charcoal. It was then tested with the case study rice/bean vendor in Sahara market for four days and a pilau and beef stew vendor for a day.

For testing the wok further, I would advise starting by using it as a hybrid to cook chips. Using charcoal and a jiko stove, as well as the solar, heat about 3 litres of cooking oil to cooking temperature (typical for chip vendors) and then cook about 1kg of potato chips. Once cooked, remove the jiko and see how long solar power only can maintain the wok at cooking temperature by cooking 1kg of chips at a time. Once the jiko is removed, I would wrap a blanket underneath the wok and clip it to the edges using appropriate clippers, then put the whole thing in a larger wok, similar to the pressure cooker. Furthermore, adding an insulated lid on top will also improve the heat retention. If this works, then I advise doing a similar thing with dagaa.

5.2 Solar Water Heater

Over the course of four days, the case study rice/bean vendor was able to cook up to 500g of rice and 1kg of beans (separately) in the solar water heater prototype, as well as heating up water for preparing ugali and for washing multiple times a day (Table 27). As the water heater was not large enough to cook the necessary quantities of rice needed, or the beans fast enough to be sold to customers, we supplied the food that was tested by the vendor. The other vendor who tested the prototype cooked their own 500g beef stew and then 1kg of pilau, but it was not possible to interview them, so data is only sourced from their cooking diary. The following feedback and suggestions for improvement are from post-testing interviews, cooking diaries and my own conclusions. Quotes from the interview are enclosed in speech marks.

Positive feedback

- "I like the way once you have started using it there are no changes, if it was charcoal then you have to change to increase the amount of charcoal, so once they've started using the stoves you just use it up to the end."
- Cooked all food to the "same quality" as their usual charcoal stoves
- "People were coming to see, and they think it's a better thing than using charcoal. Others were asking if they could have them for their recipes"
- Size good for amount of beans they require to cook each day (1kg)
- Versatile, proved to be able to cook 4 different foods as well as heat water for multiple purposes
- "There is no fear of electric shock"
- Clean and liked the way it looked

Image 22: Vendor cooking 500g of rice

Negative feedback

- "The main thing I didn't like from this stove [is] when the blanket gets wet"
- "The size should be bigger because I am cooking up to 5kg- 6kg of rice each day"
- "for the beans cooking, it is quite slow…" – it usually takes them two hours to cook 1kg of beans, but prototype took almost four hours to cook the same amount (with relatively strong sunlight

Suggestions for improvement

- Large enough to cook 5kg of rice in one cook – around 45 - 50cm x 20-23cm, around 30 litres
- Powerful enough to cook 1kg of beans within 2 hours
- Maintain good looks, quality of food cooked, and versatility to cook multiple different foods

If an enlarged version of this water heater can cook 5kg of rice, 5kg of beans, or 2kg of beef stew in one day, each in comparable times to charcoal, then it will have tremendous great potential with food vendors in Mwanza. Ambitious, but if so, it will likely be commercially viable if they can last at least two years - so vendors can definitely make a significant financial saving. If bought, this vendor believes she can spend 40,000 (£13.28) TSh a week on payment, but this is based on replacing ***all*** her charcoal, which it would not. If it can replace half of this charcoal though, 20,000 TSh (£6.64), then that is over 1 million TSh (£332)a year, as Chapter 7 details further.

Tables 27 & 28: Cooking diaries for prototype testing: water heater (left) and pressure cooker (right)

Water Heater		
Time start	**What cooked**	**Time cooked**
Day 1		
09:11	Water for washing	61m
10:34	Water for ugali	56m
11:36	Water for rice (little)	9m
11:45	Rice (0.5kg)	45m
14:40	Water	52m
Day 2		
08:35	Water for rice	69m
10:09	Water for beans	23m
10:32	Beans	226m
15:00	Water	49m
Day 3 (Vendor 2)		
11:05	Water for pilau (not boiling)	20m
11:51	Beef (0.5kg)	41m
13:00	Pilau (1kg)	87m
Day 4		
10:20	Water for cleaning	182m
12:39	Water for washing dishes	56m
13:40	Water for washing dishes	54m
12:38	Water for washing dishes	46m
Day 5		
08:39	Water for beans	33m
19:52	Beans (1kg)	207m
14:05	Water for washing dishes	55m

Pressure Cooker		
Time start	What cooked	Time cooked
Day 1		
09:42	Water	n/a
11:36	Chicken	54m
14:00	Water	30m
15:00	Water	35m
15:50	Water	30m
16:34	Water	32m
Day 2		
09:43	Water	77m
12:17	Chicken (2)	70m
Day 3 (Vendor 2)		
09:05	Water	85m
11:45	Chicken (1.5)	80m
13:15	Water	60m
16:45	Water	26m
Day 4		
08:42	Water	81m
10:20	Chicken (1.5)	85m
13:10	Water	117m
Day 5		
10:15	Water	225m
14:00	Water	80m
15:30	Water	60m
Day 6		
09:01	Water	70m
11:24	Water	68m
12:33	Water	47m
13:20	Water	40m
14:15	Rice	45m

5.3 Solar Pressure Cooker

The case study chicken vendor had the solar pressure cooker prototype for five days and on three of them was able to cook chicken stew using solar power only. On Day 1 we had to pay for the chicken as the vendor was uncertain if customers were willing to pay for something cooked in the prototype, so we gave the enumerator and translator a free lunch, but beyond that the vendor cooked their own food and sold them to customers – all using solely solar power. Of these four days, the weather was only good enough for the vendor to cook chicken on two of the days, but on those two days the vendor cooked one and a half chickens in one go and then sold them to paying customers. The other vendor who tested the pressure cooker, on Day 3, also used it to cook one and a half chickens, as well as heat up water multiple times. Cooking diaries were kept with both vendors and they were both able to participate in two very productive post-testing period interviews. Again, the following feedback and suggestions for improvement are based on these interviews, as well as the cooking diaries and my own conclusions. The case study vendor's quotes are signified with CSV and the other vendor as OV.

Positive feedback

Image 23: Two chickens cooked using solar only

- "The quality of food is good when you're cooking with the solar stove" (CSV)
- "It gets heated very easy, it takes a shorter time to cook the chicken than the charcoal [and] wood…one day we cooked the chicken for 70 minutes, and then after we cooked another chicken [and] 70 minutes it becomes very soft" – CSV who uses cooking pot
- Can cook 2 chickens with vegetables and soup "in 50 minutes, if the sun is good" CSV

Negative feedback

- "The size is too small. It would be better if we could have a one that could cook 5 in one go" CSV
- Too long to cook – 80 minutes compared to their charcoal pressure cooker doing it in 30 - OV
- "The PC is good for using the solar but it's a dependent on the weather, the challenge is when it is rainy, it reduces the capability of the stove's power…include a battery" CSV
- Hard to check the progress of the chicken – "because they cook different chickens, some are so soft and take a shorter time to be ready, some are hard so they take a long time… so they need to open up the pot every time to see [which loses heat]" OV
- "[The pressure cooker]" can cook very quickly when you close the top of the lid, but when you remove that... the pressure decreases so it cannot be used to cook ugali" CSV

Suggestions for improvement

- Large enough to cook at least 5 chickens e.g. 30cm x 15cm or 18 litres
- Able to cope with cooking up 15-20 chickens a day
- Automatic release valve
- Battery to be able to cook during rainfall, after explaining how expensive this is vendor replied "there is no problem if the price can be more than 1 million, but if you can give us for the instalments can be 1-2 months, so it will be easier for us to afford… over 1-2 years" CSV
- Design a way to check progress of chicken "the top can be able to open up every time" OV
- "We need [the power] adjustable. It would be much better" OV
- Make it more visible by supplying a table – "it can be on top of the table, so it will be much easier for the customer to see… it's good if you advertise the solar stove" OV

Both vendors are willing to test a future prototype and even buy one if it met their needs, although one insisted that we speak with the entire staff and not only him when/if the time comes. They both need it larger to cook the quantity of chicken they need as the current prototype was too small. However, they suggest the current prototype was "a good size for cooking the beans (2kg) and rice" (CSV) and also requested one that can cook ugali. Furthermore, they highlighted how solar cooking can save them money:

"I want to use a solar stove because the operational costs for a day will be reduced to a low cost, so it will be better to use the solar stove, because it saves us money" (OV)

"it's saving the money and be able to pay in instalments over a certain period... If the price can be 20k per day, over 6 months it would be much better" (OV)

They suggested seasonal PAYG "because March-September it is the peak season, so it will be easy to make payment for instalment, even if you can add the battery, it's ok, but over one-year payment" (CSV)

6. Target Customer Profiles

Chapter 7 outlines the proposed designs for the next generation of prototypes (G2), and they are mostly all targeted at one of the four case study vendors evaluated in this report. This Chapter is a summary of each of these vendors before the designs are proposed.

6.1 Chips Mayai Vendors

- Predominantly male
- Typically sell 2-3 foods – chips, chips mayai and mishkaki
- Mostly charcoal, spend a third of overall costs, about 12,000 TSh a day
- Most have access to electricity
- Typically 2-3 workers per vendor
- Uses almost entirely woks and frying pans, spending 20,000 TSh on each, which last roughly 2 years
- Averages about 60 covers a day
- Weekends are busiest days, many open 24/7, average open 12 hours each day
- 11am – 7pm busiest hours
- Were majority of vendors in Igoma, Nyamalango, Kiseka, Buhongwa, Kiloleli and overall
- Very interested in cooking with electricity, but too expensive
- Very interested in cooking with solar, but nothing on market, also expensive
- Want solar wok the most, then solar pressure cooker, followed by frying pan
- Features of solar stove most desired is adjustable temperature, then looks, power and cheap
- Least desired are portability or reliability
- Desire to cook new foods with solar power such as Rice, Banana, Ugali & Fish

Chip mayai vendors are extremely common in Mwanza Region, so any solar product that can meet their needs has huge commercial potential. However, they are very cheap and easy to set up, so there is a lot of competition, keeping prices of chips mayai down. Unless you are a sheltered, seated restaurant with electricity and a good location, vendors cannot charge more than 2-2,500 TSh (66-83p) per portion, which limits their profits and consequently the feasibility of affording to invest in a DC solar-powered cooking product. However, their cooking practices are very homogenous, so a standardized product that works in Mwanza, will likely be successful across Tanzania.

Image 24: Typical chips mayai vendor - Igoma

Image 25: Typical chips mayai being cooked on charcoal grill which is also used for mishkaki - Malikusema

Image 26: Typical wok for deep frying potato chips - Nyamalango

6.2 Rice/Bean Vendors

Image 27: Rice, beans and soup cooked by vendor - opposite Rock City Mall

Image 28: 10kg of beans cooked in 50 x 22cm cooking pot - Nyamalango

Image 29: Rice for sale - Nyamalango

- Mostly female
- Most common vendor in Sahara and Kisesa
- Sell as many as 6 foods per vendor, an average of 4 and wide range of foods
- Mostly charcoal spending average of 21% fuel, 16,000 TSh
- Have access to grid electricity
- Typically 3 workers per vendor
- Use very large pots to cook large quantities – 5-8kg rice or pilau, or 1-5kg of beans
- 40,000 TSh per pan, mostly cooking pots
- Open 13 hours a day, usually 8am – 4pm
- Weekend and Mondays are busiest
- 47 covers a day on average
- Interested in cooking with electricity but too expensive
- Interested in cooking with solar but nothing on market and to a lesser extent too expensive
- Would want an improved version of the water heater prototype
- Split 50-50 between cooking new and same foods with solar stove
- Most desired factors were durability, power followed by looks
- Least desired were size and portability
- Interested in cooking new food - ugali, beef & fish

Rice/bean vendors would benefit greatly from a larger version of the water heater to cook at least 5kg of rice. Most of those selling rice cooked at least this amount, so any solar stove that can replace biomass for rice has huge potential in Mwanza Region. For beans however, the size of the water heater was suitable, but they need one with a faster cooking time, so the pressure cooker may be more ideal.

Each of these vendors tends to cook multiple foods, so versatility in a solar stove would be very valuable to them. Both the water heater and pressure cooker have this strength but are limited by size and power. Rice/bean vendors also tend to cook their foods in large batches once or twice a day, 5 days a week, rather than several times a day, all week, so would have more time to cool down in between uses and may have lower risk of overheating. Solar alone could not realistically replace all charcoal consumption but if a solar stove can cook at least 2 or 3 of their foods each day, the savings from these alone would be enough to pay for a solar stove and increase their profit substantially once payment is complete (7.1).

6.3 Chicken/Meat Stew Vendors

- Split between male and female
- Number of foods sold varied, but most commonly with ugali or rice
- Mostly charcoal, spending 38% of costs on fuel, about 20,000 TSh a day
- Most have access to grid electricity
- Typically 5 workers per vendor
- Typically sell 50 covers a day
- Open 12 hours a day, busiest 9am to 6am, Saturday busiest day
- Own an average of 13 pots/pans costing 31,000 TSh each
- Mostly cooking pots lasting 1.5 years
- Most common vendor in Malikusema & "Other"
- Interested in cooking with electricity but too expensive
- Interested in cooking with solar but nothing on market and too expensive
- Interested in solar wok and pressure cooker and cooking new foods
- Slight preference for power and least important is looks
- Interested in cooking new food – banana, rice and beans

Image 30: Chicken being cooked by charcoal-fuelled pressure cookers - Malikusema

Image 31: Typical cooking pot used for meat soup

A solar-powered pressure cooker would be very useful for vendors cooking meat stews/soup. Relatively few of them use pressure cookers (Image 31), the majority use typical cooking pots (Image 32) with charcoal and a jiko stove.

This is important to note because a solar pressure cooker will not primarily be competing with other pressure cookers but cooking pots when it comes to these vendors. This gives them an advantage because cooking times will be shorter. However, a disadvantage is cost disparity - cooking pots are significantly cheaper than pressure cookers anyway, but including solar power, the price between a new cooking pot and a new solar-powered pressure cooker may be too great for some. Also, unfamiliarity is a factor: changing vendors' cooking behaviours is problematic, but if financial savings and improved health and environmental factors are so great, vendors may embrace the change.

Image 32: Beef soup for sale alongside ugali, chapati and tea

Furthermore, meat stew vendors tend to cook two or more different foods, typically ugali or rice, so like the rice/bean vendors, versatility would be extremely beneficial to them. Meat stew can also be cooked in a water heater, it was cooked by a vendor during the prototype testing, but an enlarged pressure cooker would be most ideal for these vendors.

6.4 Dagaa Fryers

Image 33: Vendor cooking three batches of dagaa simultaneously

Image 34: Kamanga has about a dozen dagaa fryers all sharing a workplace

Image 35: Dagaa fryer finished cooking for the day and waiting for customers

- Split between male and female
- Only really sell dagaa, but sometimes sells with ugali or chips
- Almost all wood, spending 12% of total costs on fuel, around 28,000 TSh
- Don't usually have access to grid electricity
- Very high workforce, 19, as fishermen and others in supply chain were likely included in survey responses
- Average of 37 covers
- Typically open 8 hours a day, 8am to 4pm
- Most common vendor in Kamanga and Dampo
- Used mostly frying pans and woks, costing 32,000 TSh and lasting 3 years on average
- Not interested in cooking with electricity responding that it was inappropriate for their cooking and also too expensive
- Interested in cooking with solar but main barrier was nothing on market
- Interested in solar-powered wok
- Tend not to want to cook new foods with a solar-powered stove
- Most important factor to them is size
- Least important are portability and price

Dagaa fryers were consistently unique in their cooking practices throughout this research project. If may be impossible to produce a solar-only version of their enormous pans that can cook 150kg in 20-30 litres of oil daily, and also be affordable and durable, so it would most likely have to be hybrid and used as suggested in 5.1.

Aside from the potential financial savings a solar-powered device can offer dagaa fryers, the health benefits are even greater as it would be replacing firewood as opposed to charcoal. However, even if a vendor can significantly reduce their firewood consumption with a solar-powered device, they will still be surrounded by dozens of wood stoves in communities like Kamanga so health benefits will be limited.

Communities like Kamanga and Dampo would be ideal locations for further testing of the new generation of prototypes and/or demonstrations for any eventual final products.

7. Proposed Second Generation Prototypes (G2)

The first five proposals are iterations to the three G1 prototypes: water heater, pressure cooker and wok. The other two are original concepts that are proposed for the next round of testing. For each, key requirements are listed, target vendors defined, and potential fuel savings estimated. This latter figure is an estimation based on the baseline cooking diaries and survey data, as well as estimated charcoal costs. Calculating shillings per kilogram of charcoal was difficult because charcoal is usually sold in buckets and its cost varies depending on location, economies of scale and time of year, but estimates were based on 1kg for 1,500 TSh. Annual fuel savings were based on the estimate that vendors will not be able to use the stoves for about 100 days each year due to rain (rounded to 14 weeks), so estimated annual fuel savings are multiplied by 38, rather than 52.

7.1 Rice/Bean Cooker

This is a larger, more powerful version of the G1 water heater designed for cooking at least 6kg of dry rice at a time (19L volume cooked). Vendors typically use pots 45-50cm x 20-25cm for 5-6 kg of rice, so a ***45 x 20cm*** (***31L***) solar version should fit 6kg, as its maximum should be 8-9kg of rice (23-28L cooked). As rice vendors tend to cook multiple foods (Table 9), this could also be used for large quantities of soup, stew, beans, tea or water for ugali and cleaning – its versatility is a key strength.

Key Requirements

1) Large enough to cook at least 6kg of rice
2) Versatile to also cook beans, stew, pilau etc. (increased power to cook beans faster)
3) Insulation in between the two lids that does not include loose blankets
4) Underneath cooking pot is insulated with high quality insulation
5) Durability was rated as very important with rice/bean vendors but should maintain good looks

Target customers

Rice vendors are the primary target, they are very common, almost half those surveyed sold rice, but if this can be powerful enough to cook beans fast enough (5.2) then all 22 vendors in the rice/bean group can be targeted. Most of these also cooked multiple other foods, such as soup and stew, both could also be cooked with this. Multiple food vendors are ideal as they would benefit from its versatility, increasing fuel savings.

Potential fuel savings for vendor

The case study vendor used an average of 1.1kg of charcoal each day to cook 5kg rice, as well as 0.7kg for beans and 0.8kg for beef stew. If a solar product could cook the rice and either the beans or stew (may not have time for three each day), then 1.8-1.9kg of charcoal can be saved daily, including multiple water warmings (Table 27), perhaps 2.2kg overall (100-150g per water warming). This is 11kg in a 5-day working week and vendors can also use it for weekend domestic use, so weekly savings can easily be 15kg, 22,500 TSh, which, accounting for rainy days, is **855,000 TSh** annually if it can be redesigned to cook 5kg rice and either 1kg beans or 2kg beef stew 5 days a week. If it can cook all three and is used 7 days a week, annual fuel savings may rise to over **1 million TSh.**

The rice/bean vendors surveyed typically spent 16,000 TSh a day on fuel and cooked six foods, so on average 2,667 TSh per food cooked. Replacing two of these with solar, 5 days a week, saves 26,670 TSh, or **1.01m TSh** a year. Replacing three foods, 7 days a week, is **2.13m TSh**. Conversely, if used for rice only, the estimated annual figure would be **427,500 TSh** for 5-day week and **598,500 TSh** for a full week, so multiple food vendors would benefit far more. Generally, ***estimated fuel savings range from 855,000-2.1m TSh a year (£284 - £700)*** when at least two foods are cooked - the more foods it can cook in a day and the more days the vendor is open, the more money can be saved by the vendor.

7.2 Enlarged Pressure Cooker

This is a larger, more powerful version of the existing solar pressure cooker, designed specifically for larger quantities of meat stew. ***30cm x 15cm*** should be large enough for 5 chickens, about ***18 litres***. It could also be used to cook smaller batches of rice and beans amongst other foods. Adjustable power is also introduced.

Key Requirements

1) Large enough to cook at least 5 chickens in one go and up to 20 in a day
2) Reposition heating elements to maximise heat transfer at the expense of hybrid option
3) Insulate heating elements without loose blankets and put inside of larger metal pot with edges welded together so it looks like a single pot from outside (Image 21)
4) Adjustable power

Target Vendor

Meat stew vendors are a key target customer for this enlarged pressure cooker, as its design is largely based upon the case study vendors. However, but rice/bean vendors could also greatly benefit from this, as cooking times would be much faster than the water heater or conventional cooking pot with charcoal and a standard jiko stove, although they may not be able to cook in such large quantities.

Potential fuel savings for vendor

If this can cook 5+ pieced-out chickens in one go, the case study vendor could save about 3kg of charcoal each day. They used just over 4kg a day on average but the ugali, vegetables and banana have been estimated to collectively account for a quarter. They are open all week so could save 21kg of charcoal and 32,000 TSh each week, which ***can save them 1.2 million TSh each year (£400).***

The surveys indicated that vendors like this spend 20,000 TSh a day on fuel. The second vendor who tested the prototype also spent this and claims that if it can cook 8 chickens in under an hour, it will reduce his charcoal consumption by 90% - this vendor uses charcoal-fuelled pressure cookers (Image 31), although no baseline data was collected from this vendor to verify this claim. Regardless, if we took his lowest estimate of saving 18,000 TSh a day, that could be 4.7m TSh a year saved.

7.3 Insulated Pressure Cooker

This is simply a more insulated version of the existing solar pressure cooker – roughly same size (*7L*) and power - just better insulated with an automatic release valve. The existing pressure cooker prototype was very good once it was insulated further, so a more efficient, nicer looking version would be ideal for vendors cooking smaller batches of food. Fuel savings are too difficult to be estimated without any baseline data, but its versatility gives it high potential for commercialization, at least for further testing.

Key Requirements

1) Reposition heating elements to maximise heat transfer as the expense of hybrid option
2) Insulate heating elements without loose blankets and put inside of larger metal pot with edges welded together so it looks like a single pot from outside (Image 21)
3) Adjustable power

Target Vendor

This is ideal for cooking smaller portions of meat stew (up to 2 chickens) but bean vendors could also be targeted as, although limited so around 2kg per cook, cooking times would be fast. Domestic market can also be considered.

7.4 Hybrid Dagaa Wok

Dagaa fryers typically use large pans 75-85cm x 15-20cm with a flat bottom, about 50-60cm base diameter with slanted edges (Image 37), at least ***60 litres***. Hybrid may be the only possibility. If so, I propose the cooking method described in 5.1.

Image 36: Typical wok used for frying dagaa

Key Requirements

1) Similar shape and size to fit 11L of oil and 3-4kg of dagaa
2) Powerful enough to maintain cooking temperature of frying dagaa throughout the day
3) Hybrid
4) After size, reliability was ranked as most important

Target Vendor

Dagaa, as well as tilapia or furu fryers are the most feasible target customers for such a product.

Potential fuel savings for vendor

Calculating potential fuel savings without testing a prototype is purely academic but the case study dagaa fryer spent 30-40,000 TSh a day on firewood in batches costing 10,000 TSh each (Image 38). The average cost per day on fuel in the surveys was 28,000 TSh, so using 25,000 TSh per day as an example and assuming they work 6 days a week, dagaa fryers can spend 150,000 TSh a week on firewood.

Image 37: 10,000 TSh (£3.30) worth of firewood - Kamanga

I propose a stove that can at least cut this by a third. If a solar hybrid wok is appropriate size and shape – the vendor can start the morning as usual, buy 10,000 TSh worth of wood (or charcoal equivalent) and start cooking in the hybrid wok. Usually, the vendor would buy more wood around noon and again in the afternoon, but if solar can maintain the cooking temperature then they will not need to buy the extra batches of wood while the sun is strong enough.

If this wok can replace just one batch of firewood a day, then they can save 60,000 TSh a week with a day off. Accounting for rainy days, this is ***2.2m TSh a year (£730)***. If it can replace two batches, this would be ***4.4m TSh a year (£1,460)***. Vendors would also benefit from major health improvements as firewood usage is significantly more dangerous than charcoal, especially in communities like Kamanga, with dozens of large wood fires all burning simultaneously throughout the entire day. It may not be possible to design such as device considering we were unable to get a smaller wok to maintain the heat of 3L of oil, although with repositioned heating elements, reshaping, extensive insulation and increased power this may be achievable, or at least worth testing (5.1).

Designing a wood hybrid stove is problematic as it can be difficult to control the flames and the heating elements or connectors may get damaged. It would also need a large exposed area at its base for the wood which makes it difficult for solar to maintain the temperature as the heating elements will not be in ideal positions. Therefore, a charcoal hybrid may be more appropriate. If a standard jiko stove with charcoal can start the days' cooking instead of firewood, then a much smaller surface area will need to be exposed at the base, so maintaining cooking temperature with solar only will be easier as the heating elements will be more central. If this can be designed, the financial, health and economic benefits to the vendors would be massive and such a product would be very commercially viable. However, estimating fuel savings will require further testing.

7.5 Chips Mayai Set

Chips mayai vendors have two primary cooking methods; they deep fry the raw potato in a deep wok (Image 27) and fry the chips mayai in a small frying pan (Image 26). Solar versions of these would have huge potential as chips mayai vendors are so common in Mwanza. However, in the cooking diaries, it was not recorded how charcoal consumption was split between the two, only the total charcoal consumption was recorded. Therefore, even though this proposal comprises two different solar stoves, their estimated potential fuel savings is combined, excluding any mishkaki or grilled foods vendors may also sell.

Chips mayai vendors frequently cook two or three portions at a time when busy so each set should include two frying pans, roughly ***20 x 3cm***, perhaps powered by the same solar panel(s) as they will not require much power. One wok, about ***50 x 20cm***, should be enough but, as Image 39 shows, chips mayai vendors sometimes cook two or more batches of chips at one time if they are busy, so a second wok could also be offered as an extra, but I would suggest having one wok and two frying pans included in the "chops mayai set".

Image 38: Vendor deep frying two batches of potato chips whilst frying a portion of chips mayai

Key Requirements: Wok (solar only)

1) Large enough to fit up to 3L of oil and 2kg of potatoes
2) Powerful enough to cook 3L of oil using solar only
3) Capable of cooking at least 15 batches of chips a day
4) Reposition heating elements on bottom at expense of hybrid
5) Significant insulation on bottom and lid

Key Requirements: Wok (hybrid)

1) Large enough to fit up to 3L of oil and 2kg of potatoes
2) Powerful enough to maintain cooking temperature of 3L of oil throughout each day, at least 15 batches a day
3) Reposition heating elements to minimize heat loss (exactly above edges of typical jiko stove)
4) Significant insulation over heating elements and lid

Key Requirements: Frying Pan

1) Will need to cook chips mayai in 2-3 minutes (4 max)
2) Chips mayai must be cooked to order quickly, to order, so frying pan may have to stay on all day
2) Typical portion of chips mayai weighs about 300g
3) Needs to be able to flip the chips mayai like a pancake

Target Vendor

The set is specifically designed for and targeted at chips mayai vendors. The frying pans can only be feasibly be targeted at chips mayai vendors, but the wok could be targeted at vendors who deep fry anything such as yam, vegetables, fish (for meals) and donuts.

Potential fuel savings for vendor

On average, the case study chips mayai vendor used 7.8kg of charcoal each day, about 12,000 TSh, which was the same average fuel cost of the chips mayai vendors surveyed. Most only sell chips mayai, but many also cook mishkaki using the same charcoal for frying the chips mayai, which solar power cannot replace. Using 8-10,000 TSh out of 12,000 TSh a day (66-83% of total charcoal) as an estimate for what this set can replace, open 6 days a week this set would replace 48,000-60,000 TSh a week, which could save the vendors ***1.8m-2.3m TSh a year (£600-760)***.

7.6 Ugali Pot

Ugali is extremely common in Mwanza and was sold by almost half of all vendors surveyed. The problem with a solar-powered ugali pot is that because it must be continuously stirred, you cannot use a lid which makes it difficult to limit heat loss. Ugali pots varied greatly in size, a 25 x 15cm was typical for cooking 1-2 portions (Image 40). But the case study vendor used a ***36 x 15cm*** pot to cook 2-2.5kg.

Image 39: Typical cooking pot for ugali (23x14cm)

Key Requirements

1) Large enough to cook 2.5kg-5kg
2) Powerful enough to cook without a lid always on or be designed so it is possible to stir with a lid on
3) Can withstand constant stirring and scraping of inside the pot

Target Vendor

Ugali is so common it is difficult to identify a single target vendor; it can be targeted at any vendor or households who cooks, or wants to cook, ugali. This can also be used for cooking small quantities of foods like vegetables or rice.

Potential fuel savings

The only reliable data collected in this study is from one of the case study vendors who used an average of 600g of charcoal to cook 2-2.5kg ugali, costing 900 TSh - 5 days a week, so 4,500 TSh weekly or **171,000 TSh annually**, so a solar version may not be worth buying. However, the surveys indicate that some vendors cook 5kg, so if this uses twice the amount of charcoal, 1,800 TSh a day, seven days a week, savings could be ***478,000 TSh a year (£160)*** as well potentially cooking other foods such as vegetables or heating water.

7.7 Summary of second-generation prototypes (G2)

These prototypes are proposed to be designed like the G1 models with the heating elements directly on the pot/pan. However, it is worth noting that due to the importance of versatility to maximise fuel savings, an alternative design could be to have the heating elements on a separate hotplate and different pots and pans can be used interchangeably.

Table 29: Dimensions and estimated fuel savings of the G2 prototypes

G2 Prototypes	Dimensions & Volume	Quantities of Food per Cook	Estimated Annual Fuel Savings (replacing bold food)
Improved rice/bean cooker	*45 x 20cm* 31 litres	**6kg Rice 1kg Beans or 2kg beef**	855,000 - 2.1m TSh
Enlarged pressure cooker	*30 x 15cm 10 litres*	**5+ chickens** 3kg rice	1.2m TSh
Insulated pressure cooker	7+ litres	2 chickens or 2kg beans or 2kg rice	-
Dagaa hybrid wok	80 x 15cm 60 litres	**150kg dagaa 11L cooking oil**	2.2m TSh
Chips mayai wok	50 x 20cm	**2kg potatoes 3L cooking oil**	1.8-2.3 TSh
Chips mayai frying pan	20 x 3	**300g chips mayai**	
Ugali pot	36 x 15	**2.5-5kg ugali**	478,000

8. Recommended Next Steps

I recommend applying for funds to conduct a further 12- to 24-month research project before considering commercialization. I would focus on product development and diversifying the product range through further testing in the field and expanding baseline market research to new sectors and geographical markets. It is possible that with only minor alterations the current water heater and pressure cooker could both be commercialised soon. However, I recommend against this and to instead focus first on conducting further research for the following reasons:

Unknown durability – We do not yet know how long these products can last. All solar-powered products are long-term investments, especially for low-income customers like Tanzanian food vendors. It will take most of them about a year to pay for one of these products, whether through PAYG, savings or loans, so any product would have to last them two or three years to have a significant financial impact. Not only must the products last for this long, but unlike households, vendors will be using them daily to cook large quantities of food and transporting them regularly to and from their workspaces each day. This needs to be tested before commercialization.

Products can be improved – Using the findings from this research study, the manufacturer now has specific details of how to redesign the current prototypes to specifically meet the needs of Tanzanian vendors that maximizes compatibility and the impact they can have of the customers' livelihoods. With further research emphasizing product development, these can be improved further: making the products more compatible, beneficial and desirable.

New products can be introduced – The three G1 prototypes are good quality but are not very appropriate for some very common vendors. For example, the current wok could be sold to dagaa fryers and chips mayai vendors, but it is too small and round-bottomed for the former and too big for the latter - the two proposed G2 woks, specifically designed for each vendor, would be far more commercially viable and possibly other products can be designed through more research. These will need to be tested and improved again at least twice before commercialization and the most effective means of achieving this is through an upscaled research project.

More data collected on potential fuel savings & health improvements – A key part of the proposed project is to collect more data evidencing how much biomass fuel and money can be saved, and how health and living conditions can improve, when vendors can access a DC solar-powered cook stove. We may know that these stoves save money and improve health conditions but having the data to prove this will be invaluable for future grant applications and advertising – funders and customers will want to know how much fuel and money has been saved with similar vendors in the same country, and we don't yet have this data, we only have estimations based on proposed iterations. We need concrete, reliable data.

Cheaper/new solar panels - Solar panels are getting cheaper annually so in 12-24 months' time this would reduce the cost of the products, which means cheaper products for the customer and/or higher profits for the manufacturer. Also, new technologies and innovations in solar power may emerge that affect the products or solar panels (although this can be argued for every subsequent year!)

More market research – The proposed project includes expanding baseline market research across vendors around Tanzania and exploring potential new customers in Mwanza. Furthermore, more baseline cooking diaries are proposed with more vendors for longer periods of time. A year or two of more research would vastly improve a commercialisation strategy as we would understand the national cooking market in far more depth, rather than only Mwanza, as well as potential other sectors such as the catering business, hospitals, schools, event planners, canteens etc.

Therefore, the next steps recommended by this paper is to raise funding to upscale this study into a much larger product development research project with the following research objectives:

1) Ensure prototypes are compatible with the vendors' cooking practices

The seven prototypes proposed in this paper need to be tested with vendors in the field to determine how compatible they are with the Tanzanian cooking practices. Vendors should not need to significantly change their cooking methods. To investigate this, cooking diaries can be kept with vendors testing prototypes to evaluate their compatibility and performance. Subsequently, the same can be done with the redesigned G3 prototypes until a commercially viable product is developed.

2) Evaluate potential fuel savings and health benefits of each prototype

Collecting reliable data on fuel savings and health benefits would be useful for future grant applications and advertising. An upscaled project can calculate how much less charcoal is used, in weight and cost, over a longer time period which is invaluable information. The project can also discuss with the vendors and their workforces the health, convenience and safety benefits of utilizing the prototypes in post-testing interviews.

3) What changes need to be made to the prototypes to make them more commercially viable?

Enumerators can keep cooking diaries with the vendors who are testing the prototypes to identify any issues or comments by people about the prototypes, but the primary method for determining this will be through the post-test interviews. Like in this study, we would discuss with them at length, and in specific details, what needs to be done to the prototypes to make them more compatible with their cooking practices, maximize their fuel savings and be of greatest benefit to themselves and their businesses.

4) Test the long-term durability of the prototypes

Even if the products are very compatible with existing cooking practices and vendors can greatly benefit, if the products are not able to last more than a year then they are not commercially viable. Testing the long-term durability is paramount and this requires long-term testing that can done effectively in an upscaled project. It is also why this paper suggests testing a G1 prototype from now to see how long the current prototypes last.

5) Explore potential of new markets

Food vendors in Mwanza is a good starting point, but if the ultimate goal is to commercialise them nationally and beyond, new sectors and geographical markets need to be researched in detail to inform an optimal commercialization strategy.

6) Establish pricing and financing mechanisms

Most of the customers will not be able to afford to pay for the products upfront, so some form of financial assistance will be required. PAYG is an obvious option as Kua Solar Ltd. currently use it for their solar home systems business. However, it is worth exploring all options throughout this research period and seeking partnerships with community savings groups, NGOs, financial institutions, local government, community leaders, businesses etc. as detailed further in 8.2.

9. Conclusion

Overall, this working paper has highlighted that despite being in the very early stages of development, DC solar-powered cooking has great potential with food vendors in Mwanza Region, Tanzania and beyond. It may be too soon to be ideal for commercialization at the time this paper was published (July 2020), but with an upscaling of this research project for further product development, market research and streamlining the supply chain, commercialisation is certainly viable if funding can be secured and the products are produced based on the designs that specifically meet the needs of Tanzanian food vendors and are compatible with local cooking practices. It is also paramount that the longevity of the products is tested thoroughly and that a PAYG option is available to increase accessibility and affordability.

This emerging technology has the capacity to bring clean, renewable, affordable cooking energy to a region that heavily relies on biomass for cooking. The impact this technology can have on Tanzanian vendors should not be understated - financial savings, increased income generation, poverty reduction, improved health and well-being, time savings, better working conditions, gender equality and raising living standards are all lasting impacts DC solar-powered cooking can make to ordinary Tanzanians.

10. Appendices

Appendix 1: Baseline Survey (English version)

1) What do you cook?

2) What days is your business open and what are your opening/closing times?

3) How long does it take you from arriving before you serve your first meal?
   a) How long to set-up?
   b) Prepare food?
   c) Light stove and get it to temperature?
   d) To cook?

4) What is your busiest day/time for cooking (not serving…)?

5) How frequently do you cook?
   a) <Hourly b) 1-2 hours c) 2-4 hours d) 4+ hours

6) How many portions/people do you serve per day
   a) on average
   b) Worst/Best day

7) How do you size the portion? (weight or volume of ingredients (potatoes; rice etc)

8) How many people work here?

9) What fuel(s) do you use? (if more than 1, which is most?)
   a) Charcoal b) Wood c) LPG d) electricity e) Other _____

10) How much money do you spend on fuel per day/week?

11) What is this in weight/volume?

12) Where do you buy your fuel from?

13) Why do you use this fuel? (e.g. cheap, accessible, tradition, no alternative…)

14) What percentage/fraction of your overall costs are on fuel?

15) What pots/pans do you use to cook this? including sizes - measure if possible
    a. How much does each item cost?
    b. How long does each tend to last?
    c. Where do you buy these from?
    d. How many pots and pans do you have in total?

16) Do you have access to electricity?

17) Are you interested in cooking with electricity? yes/no

18) What is stopping you from cooking with electricity?
   a) Cost b) inappropriate c) nothing on market d) don't like e) no access to electricity

19) Would you like to cook with solar? yes/no

20) What is stopping you from cooking with solar power?
   a) Cost b) inappropriate c) nothing on market d) don't like

21) If you could design the perfect solar-powered stove for your business what would it be?

   a) wok b) pressure cooker c) water heater d) frying pan e) Other _____

   - What would you cook with it? (Anything you can't cook with your current fuel/stove?)

   - how big would it have to be? (measure)

   - which of these factors are most important to you? (very important, important or not important)

Attribute	Importance
a) Affordability	
b) Payable in instalments	
c) Power	
d) Adjustable Temperature	
e) Reliability	
f) Size	
g) Durability	
h) Portability	
i) Looks	

22) How much would you pay for a solar stove? If it met your criteria
   a) To purchase out-right
   b) Per day, week, or month

23) Would you be interested in testing out a solar stove for a 1-week cooking diary?

Thank you very much for helping us by participating in this survey!

(Each survey also recorded gender and community)

Appendix 2: Blank Baseline Cooking Diary (English version)

Time Start Cooking	Food/Meal Cooked	Pots & Pans Used	Time Finished Cooking	Notes

Appendix 3: Blank Prototype Testing (English version)

Time Started Cooking	Food/Meal Cooked or Lid Opened	Time Finished Cooking	Weather	Feedback

Appendix 4: Post-testing interview guide

Thank you for testing the prototype. Do you mind if we record this interview for research purpose?

1. What did you cook with the prototype?

2. How did the **quality** of the food cooked in the prototype compare to your usual pan?

3. How did the **speed** of cooking compare?

4. What did you think about the **size and shape** of the prototype?

5. What size and shape would be ideal for you? [measure using tape or take photo]

6. Did you find the prototype simple to use? How can we make them simpler?

7. Were your utensils/equipment compatible with the prototype?

8. Did you experience any problems with working the stoves?

9. Did the panels or cords inconvenience you in any way?

10. What feedback did you get from the customers or neighbours?

11. What **changes** would you make to the prototype?

12. What did you **like most** about the prototype?

13. Is there anything you **did not like** about the prototype?

14. How is cooking with solar better than charcoal?

15. How is cooking with charcoal better than solar?

16. How much money do you spend on charcoal each day or week?

17. What **percentage** of your overall costs are spent on charcoal?

18. How important of an issue is the cost of charcoal for your business?

(e.g. if the price of charcoal rises or lowers significantly, how would this impact your business?)

19. If they made the changes to the prototype - how much charcoal could you save each day/week?

*20. If they made the changes to the prototype – **how much money could you save** each day/week?

21. Apart from this prototype, what other solar-powered pots or pans could help your business? (**what food would they cook, measurements and power requirements**)

22. Are you interested in testing a new prototype at least one month? (no pay)

23. After the next round of tests (or two!) they will make a sellable product – if we make these changes, **how much would you pay** for such a product?

24. Or… how much could you **afford** each day or week or month to pay (remind them of fuel savings)

24. The more improvements they make, the higher the cost – would you prefer to have an expensive solar stove that meets all your needs, or a cheap one that is limited in power, size, and durability?

Thank you very much for taking the time to speak with us