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Cleaning the air through cooking: providing alternative energy solutions for cooking practices in the Bidibidi Refugee Settlement in Yumbe district in Uganda

Pesitho ApS

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Executive Summary

The increasing focus on addressing the impacts from traditional fuel burning cooking practices, have spurred a number of innovative streams around the development of improved (clean) cookstoves (ICS). In particular, technologies and systems that have the ability to provide multi-dimensional benefits for air quality and the environment, socio-economic well-being and health, and gender equality and safeguarding, while being accessible and fully adaptable to different individual and household contexts.

For this purpose, this study investigates the impacts of the fully solar powered electric cookstove, the ECOCA. A compact, self-contained, multi-purpose home cooking unit consisting of a battery pack, solar panel and a highly insulated pot. It has ability to charge small appliances, allowing for the typical household to cover basic electricity needs and even engage in electricity-based income generating activities. Proposing a clean, efficient, sustainable and environmentally friendly cooking system.

The study takes place within the Bidibidi Refugee Settlement in Northern Uganda, with 20 households, ten with access to their own ECOCA and ten with only access to traditional fuel cooking methods and solid biomass fuel. The ECOCAs had been installed earlier in 2019 as part of the pilot project between Pesitho ApS and Caritas Denmark, that installed 50 ECOCAs in the Bidibidi Refugee Settlement. As a result, the project focuses primarily on investigating the emissions, respiratory, and well-being impacts between traditional fuel burning cooking methods (solid biomass/ charcoal/ firewood) and solar voltaic clean cooking methods, in this case, the ECOCA.

To do so, three main research activities were conducted in the Bidibidi Settlement, consisting of monitoring air quality, respiratory testing and an investigation of user behaviour, attitudes and perceptions around clean cooking. More specifically, the project collected twenty 24-hour air quality samples, measuring personal exposure to harmful air pollutants (particulate matter, PM and carbon oxide, CO) from the main household cook. In addition, carrying out 23 interviews with non- and ECOCA-users, as well as 21 spirometer tests, using a handheld spirometer that measures the volume of capacity of the first second, as well as the total respiratory capacity.

While the sample size of the study does not allow for statistical claims, the project generates valuable insights in the use, impact and potential of the 100% solar powered ECOCA; highlighting key challenges that may require a combination of technical and non-technical (behavioural) solutions for sustained adoption. Particularly when looking to capture a fuller array of proposed benefits from this clean cookstove.

Theoretically speaking, using the solar powered ECOCA cookstove should mean there are no emissions produced from cooking, therefore if used exclusively, reduces one's exposure to harmful PM and CO. However, the research shows that there are technical limitations in the level of peak power and the charging performance with the piloted ECOCA; to which interview

respondents stated difficulties in consistently cooking heavier meals such as beans. For this reason, the ECOCA is used sparingly across daily cooking needs, mostly covering morning meals like porridge. Additionally, also limiting the scope of its use, is the single pot provided with the ECOCA which was stated to not being ideal for cooking large portions or cooking consecutively all meals, as there are often traces of taste from previous cooked foods, like onions or silver fish.

The results of air quality measurements are aligned with the interview results. While there is a difference in the total measured particulate matter emissions (~10% less) and carbon oxide (~27% less) parts per million between the studied ECOCA and non-ECOCA households, such difference is not as stark as conceptually considered. Reflecting that the sampled ECOCA households continue to experience exposure to harmful emissions since fuel burning is still a predominant activity for cooking and lighting.

Admittedly, there were no differences in the lung function tests between ECOCA and non-ECOCA household participants, but the project does not claim significance of this result for two reasons: First, due to the small sample size of spirometry data, this project does not claim any statistical validity on such comparisons. Second, the results of lung capacity testing are dependent across several components such as age, ethnicity, height, and the contextual background of the participant across her/his life. Therefore, having had access to the ECOCA for only a few months would conceptually have minimal impact in the lung capacity of its users.

It is key to note, however, that the studied ECOCA was a version implemented on its first pilot project and therefore being in the earlier stages of the technology development process. It is in that context where the ECOCA shows, through this study, the potential benefits to be captured, and the already stated positive impact in the lives of residents of the Bidibidi Settlement. Despite air quality readings were relatively comparable, between non- and ECOCA households, when an ECOCA household exclusively or largely uses the ECOCA for cooking and lighting activities, emissions were greatly reduced, on the studied sample. Even with this early version of the ECOCA, users reported that they could cook all their meals in a day (depending on the weather and amount of sunlight) including their most preferred or frequent meals.

More notably, the respondents of ECOCA households remarked benefits around well-being and health from two perspectives, which are remarked when compared with the non-ECOCA household responses. First, in the reduced need for firewood (and its collection) and, second in the reduced exposure to smoke. Almost all ECOCA respondents said their trips were significantly reduced after receiving the ECOCA and stated sleeping better, reduced headaches, burning eyes and physical exhaustion. Hence, ECOCA users mainly explained the ways they felt better since receiving the ECOCA, whereas non users focused on the issues they had every day. This is of significance considering that firewood collection was stated to be carried out up to 6 times per week and taking 2-6 hours each trip, without including fire preparation, cooking, and dealing with the impact of smoke and heat. Hence sampled households could spend up to 36 hours a week in firewood collection activities. In most ECOCA households, collection activities were said to be reduced by at least 50%, even needing to conduct only 1 firewood collection trip per week. The study, through its interviews, also found psychological benefits from ECOCA households including: worrying less about having to collect firewood the following day, and what it would mean if they could not collect adequate firewood in order to cook for the family. For non-ECOCA households, the worst-case scenario responses were 'we do not eat'. Comparatively, ECOCA households all answered, that they could use the ECOCA. Although small scale data, there are apparent benefits to the ECOCA cookstove clearly documented throughout this research, having significant stated impacts on the daily life of residents on the Bidibidi Settlement, even with this early version of the ECOCA.

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Introduction

Clean and improved cookstoves are increasingly becoming an aspect of discussion within international development. The most frequent topic typically refers to the fact that almost a billion people are without access to electricity, with three billion people depending on wood fuel as their main energy source for cooking (World Health Organisation, 2018). Further, that biomass combustion causes various respiratory diseases leading to over 4 million premature deaths every year, more than malaria and tuberculosis combined (World Health Organisation, 2018).

There are various statements associated with improved cook stoves (ICS), addressing issues like solid biomass fuel-burning practices for cooking, which create negative impacts like resource dependency on fuels that contribute greatly to deforestation also exacerbating climate change, particularly through black carbon particles falling on the ground, increasing sunlight absorption (WHO, 2018). ICS aim to reduce the amount of fuel like charcoal and firewood needed for everyday cooking which impacts one’s health, as well as personal safety associated with the time-consuming activity of fuel collection (~20 hours/week). This activity is traditionally left to women, who are at risk of personal attacks whilst collecting firewood, facing threats from locals, militias and animals (FAO & UNHCR, 2017).

Our project investigates the claim of reducing exposure to air pollutants like PM 2.5 and 10, fine particle matter and CO, Carbon monoxide as well as further health implications associated with cooking using solid biomass across households the solar powered ECOCA cookstove and households using traditional cookstoves. This project also looks through the multidimensional economic, social, cultural and environmental benefits that can be captured alongside of health, such as improved food security (through reduced dependency on fuel-materials and burning), as well as increased livelihood opportunities and reduction in use of natural resources. The study takes place at the Bidibidi Refugee Settlement in Northern Uganda, where 50 ECOCA cookstoves have been installed as part of a pilot project between Pesitho Aps and Caritas Denmark.

Aims of the project

The project focuses on investigating the emissions, respiratory, and well-being impacts between traditional fuel burning cooking methods (solid biomass/ charcoal/ firewood) and solar voltaic clean cooking methods, such as the ECOCA. The aim is to evaluate the type and level of impact of each cooking method, resulted from air quality, as well as the impact on daily lives of the end users of the cookstoves, such as wellbeing (health and economic creation) and safeguarding. The research and data collection conducted at the Bidibidi Settlement, consists of scientific monitoring of air quality (emissions testing and respiratory effects) and investigation of user behaviour, attitudes and perceptions around clean cooking, renewable energy within a post-conflict or vulnerable populations setting. The solar powered cookers, ECOCA, are currently in operation in the Bidibidi Refugee Settlement, provided by Pesitho ApS with local support from Caritas Denmark/Uganda.

1.1 Research questions/hypothesis.

To this end, the main question of this research is:

- What impacts do solar powered electric cookers have within the Bidibidi Settlement in Yumbe Uganda?

The research then prescribes the following sub-questions:

- What benefits do solar powered electric cookers bring to the residents of the settlement?
- How do these solar cookers compare against traditional fuel-burning cooking methods?
- How solar powered cook stoves impact traditional gender roles?
- In what ways are solar cookers adopted by residents within the settlement?

Objectives of the project

The project's objectives are:

- Investigate the emissions, respiratory, and well-being impacts between traditional fuel burning cooking methods and the ECOCA.
- Evaluate the type and level of impact of each technology, in particular the effects on the environment in the form of air pollution and impacts such as deforestation, wellbeing (health and economic creation) and safeguarding.
- Understand the user dynamics of the ECOCA and how these compare with traditional methods.
- Provide a baseline of understanding of the impact of the ECOCA in the Bidibidi Settlement
- Identify insights for the continue development of the ECOCA, to further capture benefits to its users, and wider society

Methodology

The researchers selected 3 methods of research: monitoring personal exposure to pollutants over 24 hours, semi structured interviews with households and spirometry (lung capacity) testing with household members. These methods were conducted with a study sample of 20 total households within the Bidibidi Refugee Settlement in Yumbe, Uganda. The sample was split between 10 households that currently own an ECOCA and a sample of 10 households that cook using traditional/ solid biomass fuels. According to Caritas Denmark/Uganda and Pesitho ApS, there are currently 50 households within the Bidibidi settlement that own an

ECOCA, and therefore this study covers a sample of 20% within that selection of owners. The distance between households of the same village can be between 1-15-minute walk and the distance between villages can be between 10-20 minutes, driving. Households can be described as mud-brick homes with low ventilation, particularly in the place of cooking. The roofing is typically a thatch, made from collected tree branches and grass. Most of the families have a separate cooking room that is not attached to the house. This is also a mud brick style build. Graphic 1 below shows two images of selected typical household in the Bidibidi Settlement.

Graphic 1: *Comparing separate inside cooking room (left) and outside cooking (right) in the Bidibidi Settlement.*

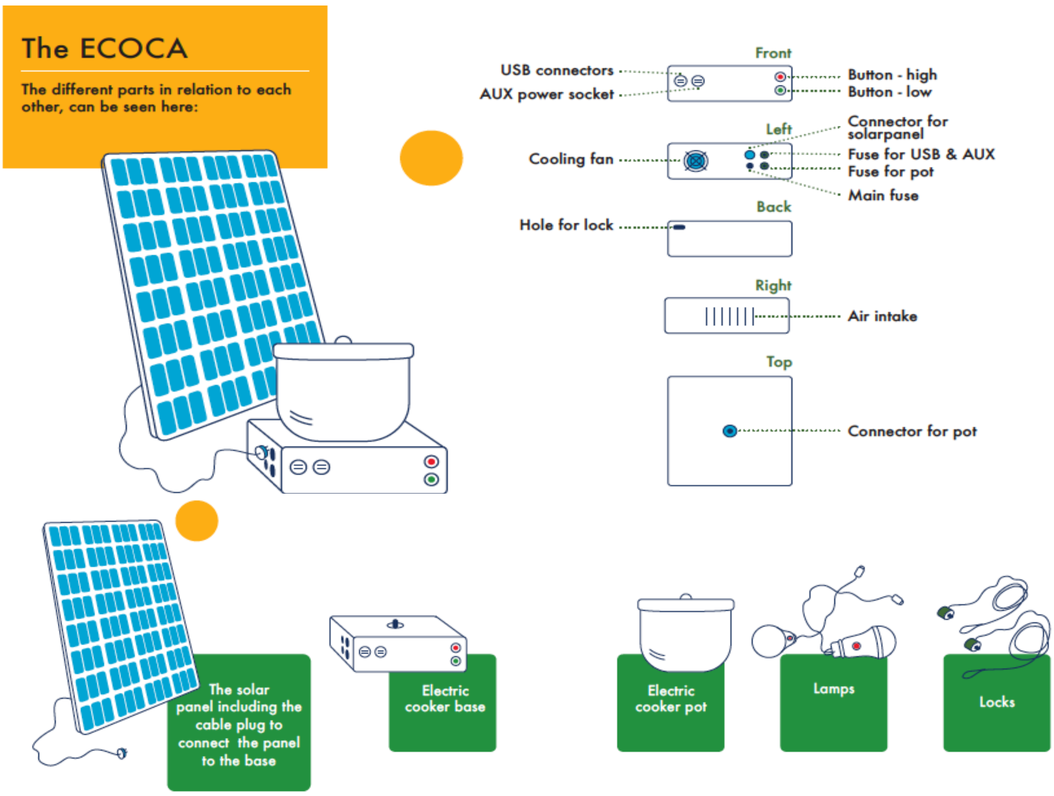
Initially, for representativeness, the research sought engagement with households with at least 5 members, engaging only with 2 adults (over the age of 18). This would mean in total, engagement with a total of up to 40 adults. However, once arriving to the field, the researchers followed the expert guidance of the local Caritas field staff who work with ECOCA households daily, monitoring their development and liaising relationships within the camp and with the host community. Due to technical issues with the ECOCA, the original selection of households was not fully available and instead researchers relied on households with functioning ECOCAs to conduct data collection. For example, see results a breakdown of the characteristics of each research household. Below this document elaborates how these methods were implemented across the sample.

The selection of households as well as all local engagements, was conducted in collaboration with Caritas Denmark and Caritas Uganda who have established relationships with residents within the settlement, having knowledge of the local practices, culture and language. Caritas Uganda provided trained field staff to work alongside of the with the research team, supervising engagement and translating all questions to local languages: Kakwa and Arabic. Full consent for participation was collected, either through signature or thumb print. Further, ethical approval for this study was granted by the Gulu University Research Ethics Committee and the Uganda National Committee of Science and Technology.

The field work also followed the guidelines and concepts multi-tier framework, in accordance with the 'Simplistic Model'. For example, in designing the research questionnaire and cookstove analytical framework. This multi-tier framework model allows for a greater understanding of the overall impact to the end user, as opposed to standard numerical measurement of pollutants. The multi-tier framework assists in structuring the questionnaires and surveys, including user behaviour, usability of the equipment and how the ECOCA impacts the lives of the end users, also offering a gendered lens. For example, the various aspects of cooking, including time spent in preparing both fuel and cookstove, and level of satisfaction with the cooking solution for both genders, and how this is impacted.

Outline of the concept

The solution to cooking with biomass or systems that require expensive fuel, is to shift to a clean, efficient, sustainable and environmentally friendly cooking system that uses solar photovoltaic as energy source. At the time of this study the pilot version of the ECOCA was available for assessment and therefore this study will refer to the ECOCA'S installed in 2019. The ECOCA is a compact, self-contained, multi-purpose home cooking unit consisting of a battery pack, solar panel and a highly insulated pot (Graphic 2). This insulation enables food to continue cooking without further energy input after reaching the boiling point. Aside from cooking, the ECOCA can be used to charge light bulbs, phones and small appliances, allowing for the typical household to cover their electricity needs as well as to engage in electricity-based income generating activities. The pilot ECOCA is a fully off-grid solution that comes with a 265-watt solar panel which provides power to a 20aH battery inside the cooking module.



Graphic 2. *Layout of the piloted ECOCA*

1.2 *How the idea was generated (e.g. is it an Application from another industry?)*

The concept of this research project was generated from the original purposes of the ECOCA cookstove, providing affordable and sustainable clean energy access to the world's most vulnerable. Preliminary research conducted at the Bidibidi Camp looked into to woodfuel usage and the illnesses associated with air pollution from cooking with solid biomass fuels, which the project team wanted to scientifically assess the levels of PM and CO impacting the end users when cooking with the ECOCA. According to WHO, using a solar cookstove should not emit any emissions (WHO, 2014). The ECOCA should be able to offer greater health and environmental benefits in comparison to other ICS on the market that while reduce the amount of biomass needed for cooking but do not eliminate wood fuel usage all together (Kaburu, et al., 2019; Gemert, et al., 2019). Therefore, this research also aimed to evaluate the behavioral usage of solar cookstove, since this would have a significant impact on the attained benefits from 100% renewable energy powered cooking. For this reason, it was necessary to measure if there were any reductions in personal exposure to emissions between households with access to the ECOCA and houses that rely only on wood fuel or charcoal. Furthermore, the ECOCA pertains more uses than just cooking, with solar lamps and USB ports for charging, meaning that end users may have more benefits than traditionally considered with ICS. Taking a multidisciplinary approach to this research means that the research included standard lung capacity testing as well as applying technical aspects from adoption of clean cooking equipment and socio-economic for understanding user behaviour.

Intellectual Property Rights

The data presented on this study is property of the consortium of Pesitho ApS and Aarhus University, and will be used for scientific publication purposes, as per the publication agenda noted on this document.

Assumptions made

Solar powered cooking technologies offer the opportunity to mitigate or even eliminate the negative impacts created from fuel-burning practices, not only by supplying access to energy but also addressing respiratory and major health issues, as well as negative impacts on the environment. Throughout the literature, the majority of available clean or improved cookstoves (ICS) often still require the use of charcoal or briquettes/pellets to function, thus only partially reduces issues around fuel sourcing and air pollution. One of the most noteworthy examples is the advanced biomass stove African Clean Energy (ACE)-1 that while it offers the capability for solar power and battery storage, it still creates ~60% of emissions and fuel requirements as conventional stoves (Hill, et al., 2015). Although fuel takes an important stance within this study, as the ICS provided for study assumed a solar powered energy source, additional elements are required for consideration, when it comes to the impact of air pollution, including kitchen types, social norms and socio-cultural attributes.

One of the primary impacts from fuel burning practices from cooking is the creation of particle matter (PM) and black carbon (BC) pollutants. The literature notes that when measuring PM and BC pollutants for cooking purposes either in comparison with ICS and traditional stove, or just ICS alone, the levels of emissions still exceed the World Health Organisation (WHO) guidelines. This is seen in the case of Nepal, by a factor of ~8 to ~28 (Rupakhetia, et al., 2019) and therefore, while symptom relief was often reported it does not make a significant impact for improvement (Gemert, et al., 2019). Notable, as seen in through previous literature cases, the use of the more polluting fuel burning technology may still be used even when a cleaner option is available. Hence, on this research protocol, it is considered that while assessing the capability of a zero emissions cook stove, the research will consider that families may not solely adopt this form of cooking, using alternative fuels to supplement their daily cooking needs. Given multiple factors, user families may choose to supplement the ECOCA with traditional cooking, and therefore only marginally reducing PM and BC, which will possibly result in the total emissions to still be higher than WHO guidelines.

In addition, this research protocol considered the relevance of monitoring cook stoves performance, also the type of kitchens or areas of cooking, as well as the types of fuels used alongside the ECOCA (The World Bank, 2018). Rupakheti et al who measures fine particle matter and black carbon in biomass fueled traditional cook stoves and improved cookstoves Nepal, give a baseline on this regard noting that if the kitchen is attached or separate from the main living space, it will impact time spent, and therefore exposure, with indoor pollution from cooking (Rupakhetia, et al., 2019). In the case of the Bidibidi Settlement, many households have a separate kitchen not attached to the main living area, which effects the impacts on lung capacity and overall health. Therefore, this aspect was considered in our research protocol.

One of the most common factors that impacts indoor air pollution levels, and results in exceeding the WHO guidelines, is user behavior. It has been noted that end users do not use their ICS continuously or even at all, therefore limiting the potential benefits of using an ICS cookstove against traditional practices, which may have on their health and monetary savings (Kaburu, et al., 2019; Gemert, et al., 2019). This may be due to lack of knowledge of the impact to health created from fuel burning in traditional cookstoves, highlighting the intrinsic need of further knowledge dissemination when providing ICS (Kaburu, et al., 2019). Moreover, the adoption of ICS cookstoves, in particular, solar cookers, is also influenced by social norms, family size and education, as noted by Gemert et al, where families with a higher education were more likely to adopt cookstoves, and families with larger families were less likely (Gemert, et al., 2019). This relates to the large portfolio of literature that comes from technology adoption and technology diffusion theories such as diffusion of innovations (Rogers, 2003) or the extended version of theory of acceptance and use of technology (UTAUT) (Venkatesh, 2016); or technological niche innovations through the multi-level perspective (Geels, 2002.). In particular through the analysis of Rogers (2003) across new technologies such as solar panels or electric vehicles where adoption of new technology is often linked to the socio-economic profile of individuals (Zarazua de Rubens, 2019).

Other socio-cultural attributes of social norms such as gender is of key pertinence to this research protocol. In particular, the households common cuisine, the preferred place and time of cooking affect preferences on the type of cooking fuel adopted for domestic use, as it has been previously identified in the refugee settlement in Kenya (Gemert, et al., 2019). The study noted that for women, cooking indoors after dusk provides a greater sense of security, and thus impacting their technology preference and choice often opting for biomass fuels instead of adopting of solar cookers which typically cannot be used after sundown (Gemert, et al., 2019). These factors will be considered in the research for this protocol, as the ECOCA has energy storage capability and thus it provides the ability of cooking after dark, not requiring sunlight at the time of cooking. In this context, it is also be important to assess family size in the adoption of the ECOCA, given that Gemert et al explain larger family sizes had a lower adoption rate of the solar cooker given the limitation on quantities of food that could be cooked at one time, depending on the capabilities of the unit. (Gemert, et al., 2019).

Implementation

The work conducted

The project conducted 3 methods of research. First, it used Particle and Temperature Sensor for air pollution measurements (Table 1) to test personal exposure to CO and particulate matter (PM) emissions while using different methods for cooking. The aim was to have 24hr measurement samples of 10 ECOCA user household and 10 non-ECOCA user households. The samples will include measuring personal exposure, meaning tracking emissions during the typical daily activities of individuals. For this purpose devices were worn by participants, upon consent, for a continuous 24hrs while conducting their normal day-to-day activities. For example, cooking, family activities or water collection only removing the device while sleeping or bathing. The device is non-invasive with small dimensions no bigger than a typical smartphone.

Graphic 3: *Interview within the Bidibidi settlement.*

The second method involved conducting a semi-structured interview. This was primarily aimed for the household member with the main cooking responsibilities in households to investigate the challenges and benefits of each cooking method to ultimately assess the value and limitations of the solar powered cooking solution. This method also aimed to capture characteristics of the household, and context specific details around cooking such as: fuel collection, income generating or goods exchanging activities. Interviews lasted between 15-30 minutes. The initial intention was to conduct interviews with at least 2 members of each household, typically a woman with the primary cooking responsibilities and her partner. However field research proved this to be a limitation since the second adult was rarely available for interviews, typically not present in the household. Interviews were conducted with the support of two trained field staff and 2 interpreters, provided by Caritas Uganda.

The third method implemented involved the analysis of the potential impacts on lung capacity between non- and ECOCA-users. The device used for this purpose is a handheld spirometer that measures the volume of capacity of the first second also the total capacity. This is following the guidelines from the European Respiratory Society (Society, 2010). the American Thoracic Society (Miller, et al., 2005) and the World Health Organization (WHO) (World Health Orgsanization, 2017). From these non-invasive measurements is possible to calculate a ratio to evaluate the respiratory capacity. This is considered the state-of-the-art measurement device for development of lung capacity in asthma patients. The tests were expected to be conducted with 2 adults on each of the 20 sampled households, but as with the interviews, the second adult was rarely available at the household. Each test lasted ~15 minutes, and were conducted with the “safe-t-check infection protection”, which are single-use one-way mouthpieces to avoid sampled individuals contact with each other, meaning a new mouthpiece will be use on each test (Table 1).

1.3 Data Collection, management and analysis

The main research activities were conducted by the two authors of this study who were always accompanied by trained Caritas Uganda field staff and interpreters from Caritas Uganda.

All data is stored in password protected devices (i.e. laptop) and follows the guidelines and principles of data collection the Act of Parliament of Uganda of 2019 on Data Protection and

Privacy, along with Aarhus University. In doing so, all data is fully anonymised and full consent was sought from respondents. Data is anonymised by eliminating the possibility of re-identification of respondents and households (European Commission, 2018). This means no reference to personal data or locational aspects, with pseudonymisation. Instead of personal or other details that could link respondents to data, the study will use unique identifiers that are not connected to the respondent's real-world identity. For example, Respondent 1 (R001). See a breakdown of these on the results section.

Quantitative data is analysed mostly with Rstudio (MAC) Version 1.1.442, or Microsoft Excel, where relevant. This will include processing for example the 20 household 24hr samples of air quality emissions, or the answers to the interviews conducted with each household.

Table 1. *Research instruments*

Emissions testing device. Particle and Temperature Sensor (PATS+) for air pollution measurements. This device uses designed by the Berkley Air Monitoring Group. • Lower particulate matter detection limit is 10 to 20 µg/m3 • Upper particulate matter detection limit is 30,000 to 50,0000 • µg/m3 • Data logging of up to several gigabytes (SD card) • Internal, rechargeable battery with a run-time of ~72 hours and • the option to add an external battery that can extend run-time • to several days or weeks • Logs particulate concentration, temperature, humidity, • movement, and battery voltage • Optional carbon monoxide sensor (0-500 ppm) • Logging intervals can be specified by the user	
Test lung capacity: Vitalograph Micro Spirometer. Hand held with touch screen. In contrast to turbine spirometers the micro does not feature any sensitive moving parts, guaranteeing robustness and the highest possible measuring accuracy - even at very low or high flow rates. Dimensions: 15x7.6x3cm Weight: 0.141kg https://www.onemed.dk//Archive/ContentArchive/Dk/959889.pdf **Safe-t-check infection protection**	 

These mouthpieces adapt to all spirometers including the selected Vitalograph Micro. Its 8-point peripheral support creates a complete seal, eliminating the threat of cross-infection. https://www.sdidiagnostics.com/products/82-supplies/mouthpieces/safe-t-chek	

The project findings

The project engaged with a total sample of 20 households, 10 with an ECOCA and 10 only using fuel burning cooking methods. Overall the profile of the houses between ECOCA and non-ECOCA is relatively consistent, in terms of number of household individuals, available detached kitchen space, type of available cookstove (other than the ECOCA), used fuel and stated access to electricity (Table 2). Despite the small sample size of this study, the profile of the households may be indicative of the conditions of the settlement considering the households are located across 8 distinct villages. For example households V005 (non-ECOCA) and V009 (ECOCA).

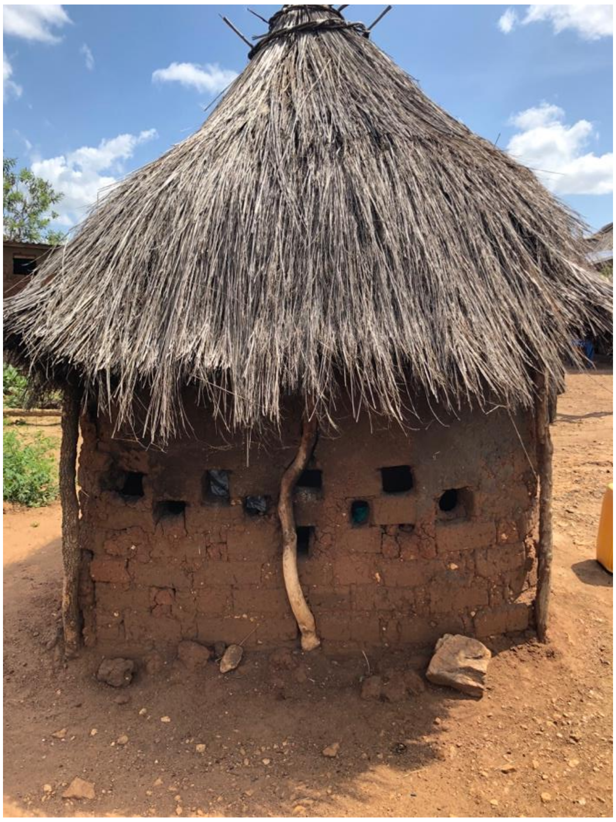
Table 2. *Household characteristics between, research sample.*

Household ID	Household type	No. of adults	No. of children	Detached Kitchen (Y/N)	Ventilation (i.e. holes on walls)	Type of stove (not including ECOCA)	What fuel do you normally use for cooking?	Do you have access to electricity?	Do you cook inside or outside?
V001	ECOCA	3	2	Y	No	Open Fire	Firewood	No	Inside
V002	Non ECOCA	2	4	Y	No	Surrounded fire	Firewood	No	Inside
V003	ECOCA	2	0	Y	Yes	Open Fire	Firewood	No	Inside
V004	Non ECOCA	2	6	Y	No	Surrounded fire	Firewood	No	Outside
V005	ECOCA	6	4	Y	No	Improved single pot stove	Firewood and charcoal	No	Inside
V006	Non ECOCA	3	5	Y	No	Surrounded fire	Firewood	No	Inside
V007	Non ECOCA	2	3	Y	No	Improved single pot stove	Firewood	No	Inside
V008	ECOCA	2	5	Y	No	Improved multiple pot stove	Firewood and charcoal	No	Inside
V009	Non ECOCA	6	4	Y	Yes	Open Fire	Firewood and charcoal	No	Inside
V010	ECOCA	2	9	Y	Yes	Surrounded Fire	Firewood and charcoal	No	Inside
V011	Non ECOCA	2	7	Y	No	Surrounded Fire	Firewood	No	Inside
V012	ECOCA	6	18	Y	No	Improved multiple pot stove	Firewood	No	Outside
V013	ECOCA	5	2	Y	No	Improved multiple pot stove	Firewood and charcoal	No	Inside
V014	ECOCA	6	5	Y	No	Surrounded Fire	Firewood and charcoal	No	Inside
V015	Non ECOCA	3	5	Y	Yes	Open Fire & Improved	Firewood	No	Inside

						multiple pot stove			
V016	Non ECOCA	4	3	Y	Yes	Surrounded Fire	Firewood	No	Inside
V017	ECOCA	8	4	Y	Yes	Surrounded Fire	Firewood	No	Inside
V018	Non ECOCA	8	5	Y	Yes	Open Fire	Firewood	No	Inside
V019	ECOCA	3	2	Y	Yes	Open Fire	Firewood	No	Inside
V020	Non ECOCA	1	6	Y	Yes	Improved multiple pot stove	Firewood	No	Inside

Most households (18/20) reported that they do most of their cooking inside, for a number of reasons, weather it is too hot outside, or the wind makes it dangerous and makes the flames to spread. However only 9 households mentioned to have dedicated ventilation on their place of cooking, suggesting that air ventilation for the purpose of dealing with smoke is prevalent across the interviewed households. Below (Graphic 3) there are two examples of the (A) typical ventilation mechanism on the place of cooking and (B) the place of cooking for a household that reported to do most of its cooking outside.

Graphic 4. *Ventilation for inside cooking (A) and typical place for outside cooking (B).*



A.

B.

In terms of costs, Table 3, provides the stated costs per bundle of firewood and charcoal, as well as the stated costs per mobile phone charge. Noting that fresh drinking water is free for all residents of the camp. Prices for firewood or charcoal depend on where residents purchase it, i.e. local Ugandans outside the settlement. For the ones without access to phone charging at phone, its either done through neighbours or local businesses, or at the camp's community centre.

Table 3. *Reported costs for firewood, charcoal and mobile phone charging.*

Firewood p/bundle (UGX)	Charcoal p/bundle (UGX)	Mobile phone charge p/charge (UGX)
1000-5000	2000-5000	300-500

Below we elaborate further on the household context, the lung function tests and air quality readings.

1.4 Understanding the household context

The questionnaire component of the research provided greater understanding of the impact and usability of the ECOCA cookstoves, as well as how these compared against non-ECOCA households. The total sample of interviews includes 13 ECOCA household respondents, and 10 non-ECOCA. Table 4 shows a breakdown on the participants (R001…R023) and according to the household. When available more than one participant per household was interviewed.

Table 4*. Overview of research participant.*

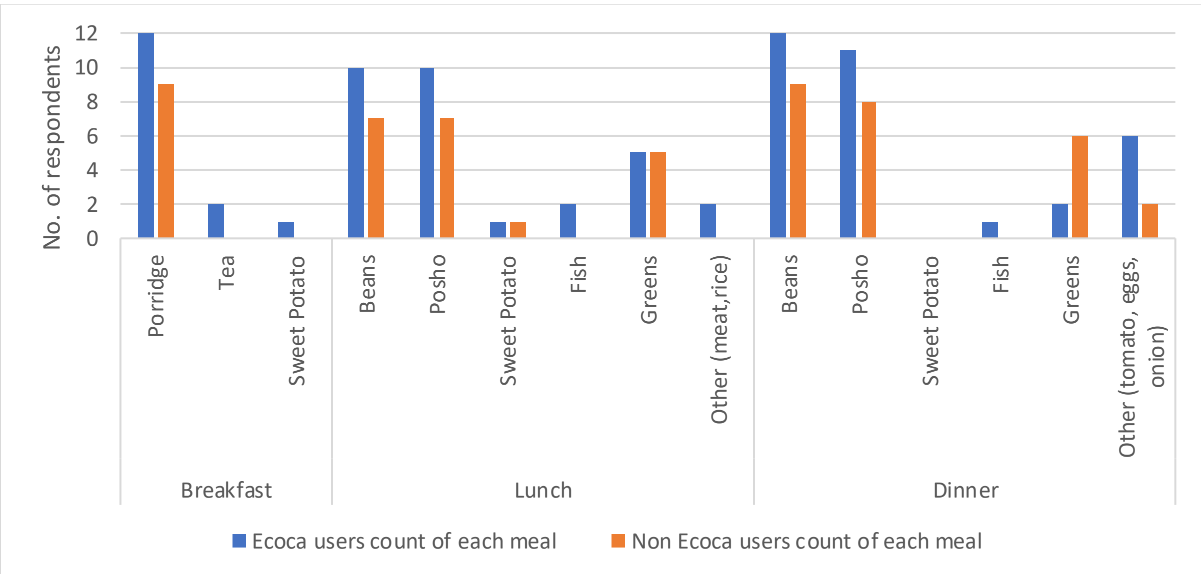
Participant ID	Household ID	Household type	Age of participant	Gender	Level of education	Income/ employment
R001	**V001**	ECOCA	25	Female	Senior	None
R002	V001	ECOCA	31	Male	Secondary	Employed
R003	**V002**	Non ECOCA	33	Female	Senior	None
R004	**V003**	ECOCA	70	Female	None	None
R005	**V004**	Non ECOCA	23	Female	Primary	None
R006	**V005**	ECOCA	28	Female	Secondary	None
R007	**V006**	Non ECOCA	36	Female	Primary	None
R008	**NA***	ECOCA	29	Male	Secondary	None
R009	**V007**	Non ECOCA	37	Female	None	None
R010	**V008**	ECOCA	63	Female	Primary	None
R011	**V009**	Non ECOCA	60	Female	Primary	None
R012	**V010**	ECOCA	35	Female	Primary	None
R013	**V011**	Non ECOCA	30	Female	None	None
R014	**V012**	ECOCA	29	Female	Primary	None
R015	**V012**	ECOCA	39	Male	Secondary School and Diploma	Yes
R016	**V013**	ECOCA	23	Female	Secondary	None
R017	**V015**	Non ECOCA	32	Female	None	Yes
R018	**V014**	ECOCA	33	Female	Primary	None
R019	**V016**	Non ECOCA	19	Female	Primary	None
R020	**V018**	Non ECOCA	19	Female	Primary	None
R021	**V017**	ECOCA	31	Female	None	None
R022	**V019**	ECOCA	45	Female	None	None
R023	**V020**	Non ECOCA	40	Female	None	None

*Respondent R008 lives in an ECOCA household which could not be included for spirometer and air quality testing..

Theoretically speaking using the solar powered ECOCA cookstove should not produce any emissions and therefore reducing one's exposure to harmful particulate matter (PM) and pollutants like carbon monoxide (CO) (World Health Organisation, 2018). This concept would mean the ECOCA falls into Tier 4-5 according to MTF, not requiring ventilation of any time spent collecting firewood (The World Bank, 2018). However, through field investigation the research shows limitations in the level of peak power and the charging performance with the ECOCA. In order to reach boiling point and sustain this heat level to cook a meal, the ECOCA needs to be plugged into the solar panel (receiving some sunlight). Some of the respondents claimed that after cooking particularly heavier meals such as beans, the battery is drained of energy. Further, since needing to be plugged into the panel, relying on sunshine, means that the cookstove cannot be used to cook a meal after dark, even if the battery is fully charged, as the additional power provided from the solar panel is required. This results in ECOCA households being able to cook a maximum of 2 meals per day with the solar cookstove. While this research revealed that most households tend to cook only twice per day, there were still a few who explained that they must use firewood to replace their cooking needs where the ECOCA could not. However, some families did also note that they would only cook twice per day, meaning they would consume what was left over from lunch and therefore not needing to cook again. Consequently, as the fieldwork showed, the ECOCA is used sparingly resulting in the partial capturing of benefits of a 100% solar cookstove. This is further detailed in the sections of lung function and air quality testing.

For understanding the usability of the cookstove, it is important to understand the types of food that families tend to cook in the camp. The food rations at the Bidibidi Settlement are distributed by the World Food Programme to families at the distribution centre located within the camp. As Figure 1 shows, families typically cook porridge for breakfast, with posho (maize) and beans for lunch and dinner. Families tend to eat the same dish in the evening as they had cooked for lunch with few variations across households.

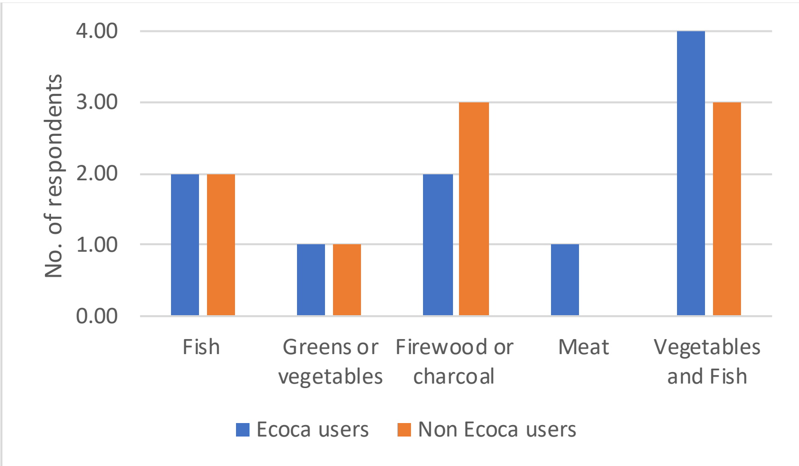
Figure 1. *What kind of food do you cook? (which dishes for breakfast, lunch and dinner).*



Note: The total sample of respondents here includes 12 ECOCA users and 9 non-ECOCA users. 2 respondents did not provide a detailed breakdown of daily cooking patterns.

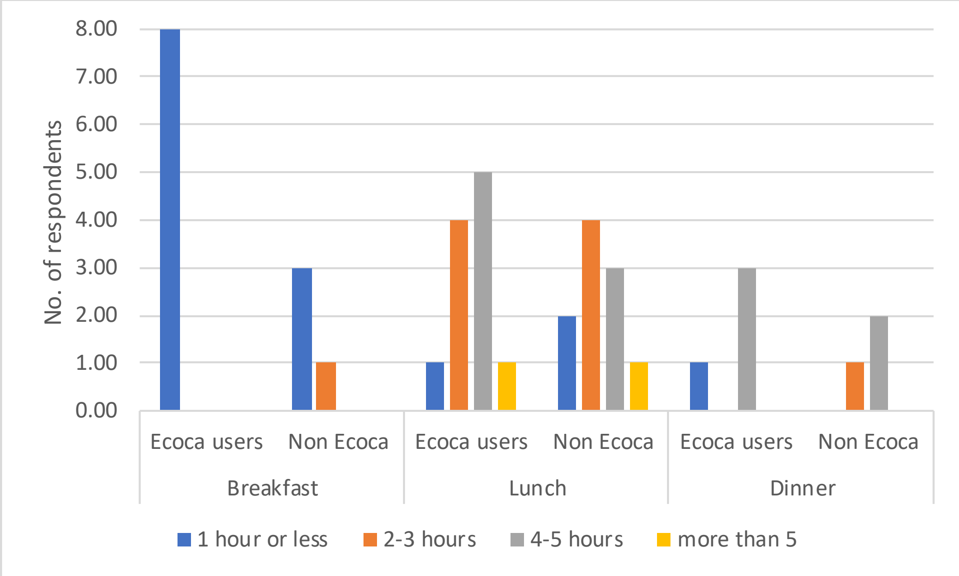
When asked if respondents tend to exchange or sell their food rations, (with the outcome of gaining firewood, charcoal or different food types) responses were relatively equal considering the size of the sample (Figure 2). Having food options that are outside of the WFP food rations, is an important element for households, as revealed in the interviews, where families could exchange maize for other food items either at the local distribution centre or between neighbours, providing them with a more diverse diet, often greens, meat and fish.

Figure 2. *What do you exchange/ sell your food rations for?*



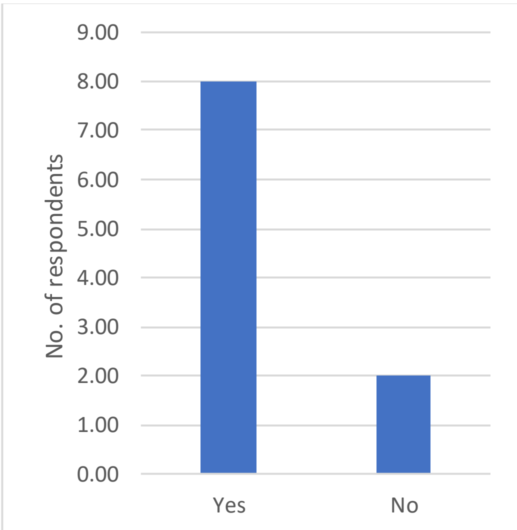
When looking at the average time spent on cooking meals comparatively, the majority of ECOCA respondents expressed that they now spend less time cooking their meals as the ECOCA cooks their meals much faster, even harder dishes like beans, compared to cooking over firewood or charcoal. Although, upon further investigation, as seen on Figure 3, the main reported difference is during breakfast, as mentioned, ECOCA households typically cook porridge in the morning, but 5 (out of 11 ECOCA participants that responded) mentioned it takes them up to 5 hours to cook lunch. This may imply that the perception of cooking with the ECOCA is faster, deriving from an easiness of cooking as compared with the effort pf intensive fuel burning cooking method, that starts with fire collection and preparation, to then proceed with cooking, as well as the physical impacts from smoke and heat.

Figure 3. *How long do you spend cooking an average meal?*



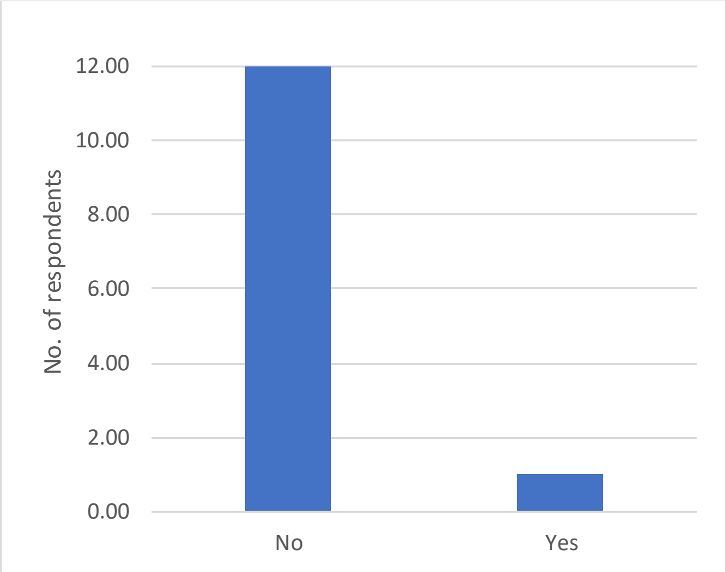
Given the understanding of cooking and dietary habits, the research wanted to understand how applicable the ECOCA cookstove is for meeting household cooking needs. For this purpose, when asked if the ECOCA was able to cook the most common dish cooked, a majority of the respondents (8 out of the 10 than responded) answered yes, that they can rely on the ECOCA (Figure 4). The two respondents who answered no, explained that they typically use the ECOCA for softer foods like sweet potato or eggs as the ECOCA was not able to properly cook beans.

Figure 4. *Can you cook your most common dish with the ECOCA?*



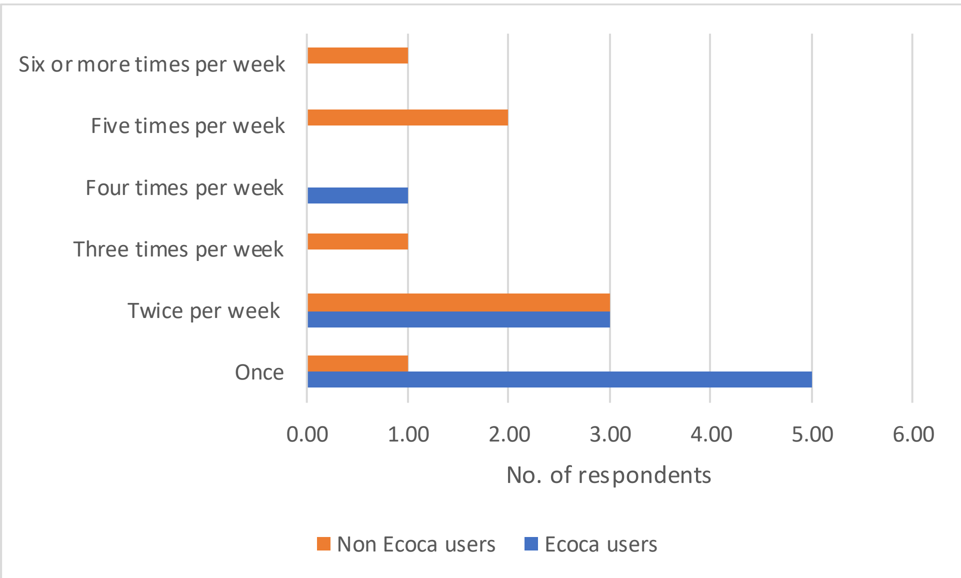
The research also considered the temporal aspect of cooking and investigated the uses after hours of the ECOCA (Figure 5). Here, many respondents expressed that they could not cook at night as the battery was not strong enough to reach boiling point and sustain this temperature long enough to fully cook a meal, unless it was plugged into the solar panel (and receive sunlight) whilst cooking. Although the majority of respondents said that they mainly cook two times per day (breakfast and lunch) there were still many who said that they indeed cook their dinner in the evening and therefore need to use firewood.

Figure 5. *Do you cook with the ECOCA at night?*



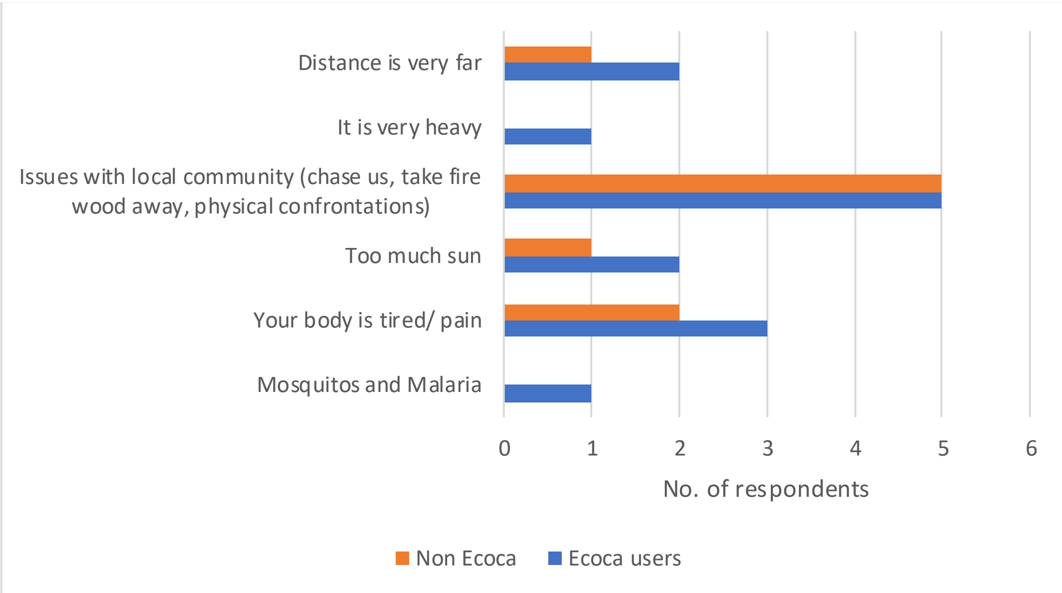
A key impact of the ECOCA, resulting in potential layered benefits such as improved physical health and wellbeing, mainly for women, is a reduction in firewood collection. In comparing ECOCA households with non-ECOCA households, households without an ECOCA reported to spend more time collecting fuel. As seen in Figure 6 show that ECOCA households typically collect firewood only 1-2 times per week, whereas non-ECOCA households even noting as much as six fuel collection trips per week.

Figure 6. *How many times a week do you collect firewood?*



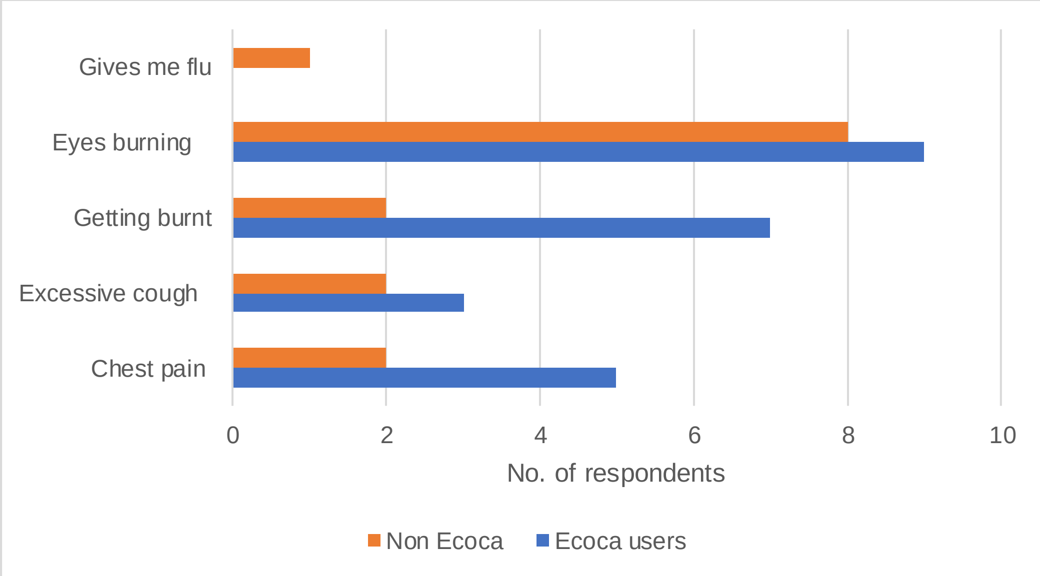
Interestingly, when asking ECOCA households how they perceived fuel collection and the time spent on the activity since receiving the ECOCA, almost all respondents said their trips were reduced. One respondent noted that she only has to collect firewood if its cloudy, meaning the ECOCA will not be able to fully charge. Reducing time spent collecting firewood is of significant importance when impacting health. This fact is that it is difficult to quantify as each respondent had their own experience and the difficulties are often traumas they face when collecting fuel (Figure 7). The time spent collecting food ranged between 2-6 hours per trip, which women explained that they would still have to cook and take care of children when they get home. Only 1 women explained than her husband would collect firewood, the rest all said that it is a task they must do themselves. Even though there are more ECOCA households collecting firewood just once per week, since the overall time spent collecting is longer than 4 hours, the stove falls into tier 1-3 since households that tier 4 requires that households with 'primarily with a clean fuel stove, spend 0.5–1.5 hours a week acquiring and preparing cooking fuels' (The World Bank, 2018).

Figure 7. *Are there ever any problems collecting fuel?*



There were a number of expressed concerns about cooking with fire, as it was remarked that dealing with the smoke is the hardest thing one deals with. Many women explained that the smoke burns their eyes so badly that they cannot sleep at night due to the pain of closing their eyes lids, and that since it is a daily activity (Figure 8). Notably, the questionnaire asked the ECOCA users if they had felt any change to their overall health since using the ECOCA. All the respondents said that they felt better, namely a reduction in headaches, eye pain and coughing less. Therefore when comparing samples, it was notable that ECOCA users mainly explained the ways they felt better since receiving the ECOCA, whereas non users focussed on the issues that had every day.

Figure 8. *Do you worry about your health when you cook with this fuel?*



Finally a common factor that appeared regarding health was also psychological. The research made a point to ask the women if they worried about running out of firewood, cooking with firewood and collecting firewood. The psychological aspect revealed that many women lose sleep over worrying, and explained they are sometimes afraid to go and collect firewood because the distance is so far and arduous. They worry that after taking the long journey collecting wood, a local resident will catch them and take their firewood away, meaning they must return home with nothing.

Many of the respondents explained that if they do not have firewood, it simply means that they cannot cook. One of the questions concluded, what 'What happens if you run out of firewood' to which many replied, they would go without eating. While all respondents answered they do worry if they run out of firewood, even ECOCA users who said they can still use their cookstove to supplement, running out is still a concern for them.

1.5 Looking at lung function

The study conducted in total 21 spirometer tests, including 11 respondents of ECOCA households and 10 respondents non-ECOCA Households. Noting that 2 prospective ECOCA respondents did not take part due to either personal preference or a medical condition, and one non-ECOCA respondent's test did not meet the criteria for evaluation. The tests followed the guidelines from the European Respiratory Society (Society, 2010). the American Thoracic Society (Miller, et al., 2005) and the World Health Organization (WHO) (World Health Orgsanization, 2017). In doing so it measured the maximal volume of air exhaled with maximal expiratory effort (FVC) and the maximal volume of air exhaled in the first second of a forced expiration (FEV) (Miller, et al., 2005).

Due to the small sample size of spirometry data, this project does not claim any statistical differences when comparing ECOCA households with non-ECOCA households. Largely because the results of lung capacity testing are dependent across several components such as age, ethnicity, height, and the contextual background of the participant across her/his life.

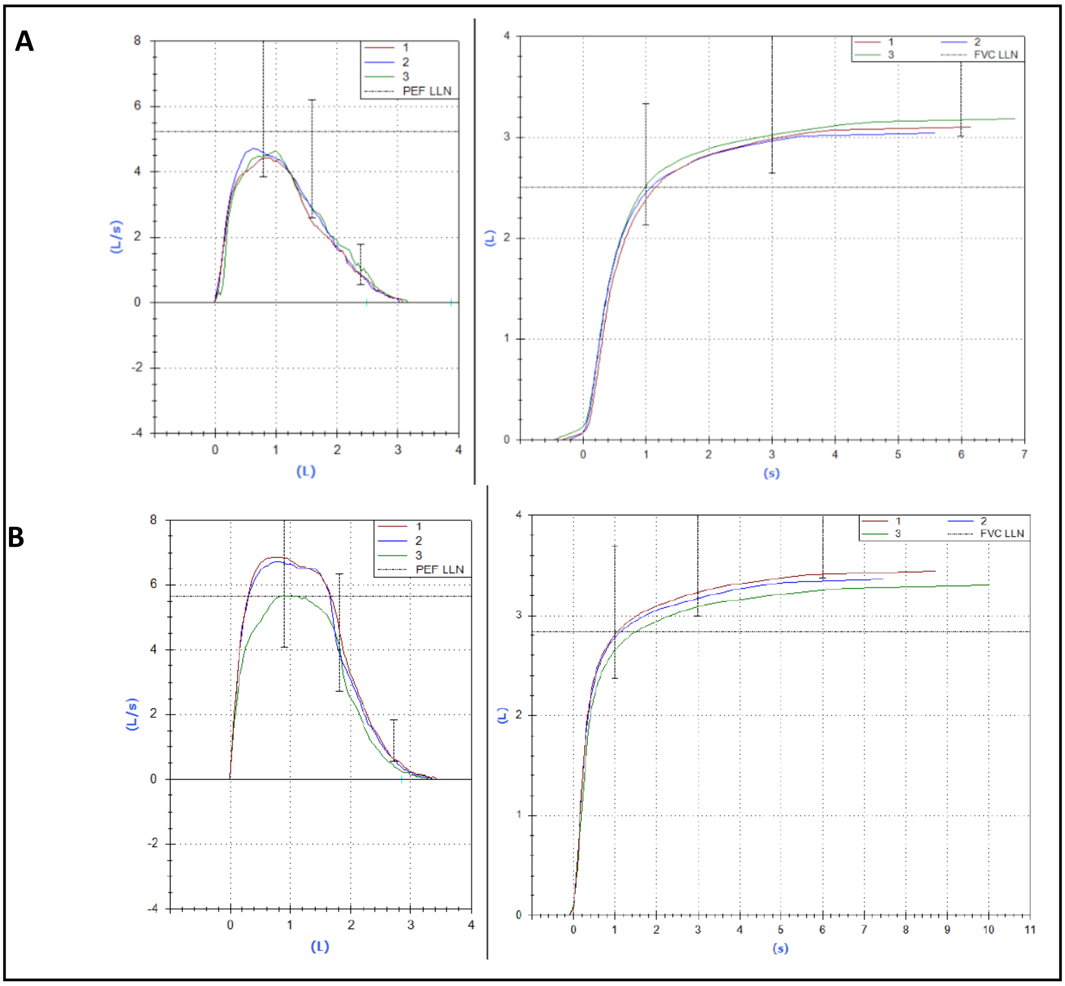
With this in mind, the project data shows on average slightly higher FVC and FEV values for non-ECOCA households (Table 5).

Table 5. *Comparing ECOCA and non-ECOCA respondents*

	Age (years)	**FVC (L)**	**FEV (L)**
Typical ECOCA respondent	39	2.80	2.27
Typical non-ECOCA respondent	31	2.99	2.45

To exemplify the comparison of tests, Figure 9 shows the test of an FVC and FEV curve of two female respondents (ages 24-32) for an ECOCA (A) and non-ECOCA (B) household. Noting an FVC curve (left) for the non-ECOCA household respondent.

Figure 9. *Comparing the FVC (right) and FEV (left) between an ECOCA (A) and non-ECOCA (B) households*



In turn, the tests do offer valuable insights when conducting spirometer studies on similar populations, namely, refugee settlements. Moving forward when preparing lung capacity research at a larger scale for further research, this project suggests conducting lung capacity examinations across a longitudinal design and with longer term exposure (and use) of the clean cookstove. For example, tests would be conducted prior to receiving improved cookstoves, with subsequent initial tests 1 year after, followed by a longer timeline of 3, 5, or 10 years (where available) in order to assess possible improvements to lung capacity and therefore overall possible health impacts. This is considering that the lung capacity of an individual is affected by physical and contextual factors such as age, ethnicity, height, weight and lifestyle.

It was important to have screening questions for spirometry tests, to identify eligible participants for health and safety reasons. For example, in the question 'do you notice blood when you cough?' one participant answered 'yes'. This would not only be potentially dangerous for the participant if they have issues with their lungs that could be exacerbated through forceful exhalation during the test, but also risk contaminating the spirometer, affecting future participants. Even though single-use one-way mouthpieces were used to avoid sampled individuals contact with each other, and having a new mouthpiece will be use on each test. The challenge comes considering the context in which tests take place, that includes vulnerable populations such as lack of access to health care, or language barriers between researchers and the participant. Even when considering local interpreters and engagement volunteers of Caritas Denmark through its local teams in Uganda liaised all interactions.

From observational position, when guiding the process of the spirometry test, being overly enthusiastic and encouraging the participant to exhale by cheerful actions like stomping feet and clapping while the person was exhaling, then cheering once complete, would yield more consistent and acceptable results. As encouraged by the local interpreters, the researchers found this as a way to overcome shyness of the participant creating a relaxed and inclusive environment while conducting the tests. This is an attribute already mentioned in spirometry testing, encouraging participants to exhale deeply (Miller, et al., 2005).

1.6 Measuring air quality

The results of air quality measurements in the in the Bidibidi settlement show two main insights. The first is that while there was a perceivable difference in the total measured particulate matter emissions (~10% less) and carbon oxide (~27% less) parts per million between ECOCA and non-ECOCA households, such difference is not as stark as conceptually considered. This alludes that ECOCA households do experience harmful emissions since fuel burning is still a predominant activity for cooking and lighting; with the consideration of the relatively small size of this study. The second insight is that while air quality readings are relatively comparable, when an ECOCA household exclusively or largely uses the ECOCA for cooking and lighting activities the ECOCA has the potential to considerably benefit the household and its members.

Air temperature during field work remained steady with an average maximum of 36.9C and minimum of 24.7, as well as humidity peaking just under 70% and a low of 46% (Table 6). However when looking at individual readings the highest air temperature recorded reached as high as 46 degree Celsius, showing the extreme conditions individuals face in the settlement. Especially considering the field trip was undertaken in December and local residents indicated that temperatures peak in January-February.

Table 6. *Temperature and humidity during air quality readings*

	Air temperature (C) average	Humidity (%) average
Max.	36.9	69.1
Mean	28.9	61.7
Min.	24.7	46.0

When looking more specifically at the typical household curves, Figure X shows the recorded daily curve for particulate matter (µg/m3) between ECOCA and non-ECOCA households. Evidently, while the non-ECOCA houses in total recorded 10% more PM, the ECOCA curve (blue) shows times where the recorded PM are considerably higher than non-ECOCA houses; indicating that individuals that own a functioning ECOCA still used fuel burning methods Figure 10). This was confirmed by ECOCA household members noting that even under the best weather conditions the ECOCA was used for two out of three meals per day. Particularly used in the morning to cook porridge or for softer foods like sweet potato and eggs, as communicated during the interviews. Thus, alluding that individuals do use their ECOCA for the meals that deem its performance acceptable, but also that the first version of the ECOCA did not perform well enough to becomes the primary or solely cooking method.

Figure 10.*Typical ECOCA vs NonECOCA household 24hr PPM (est.)*

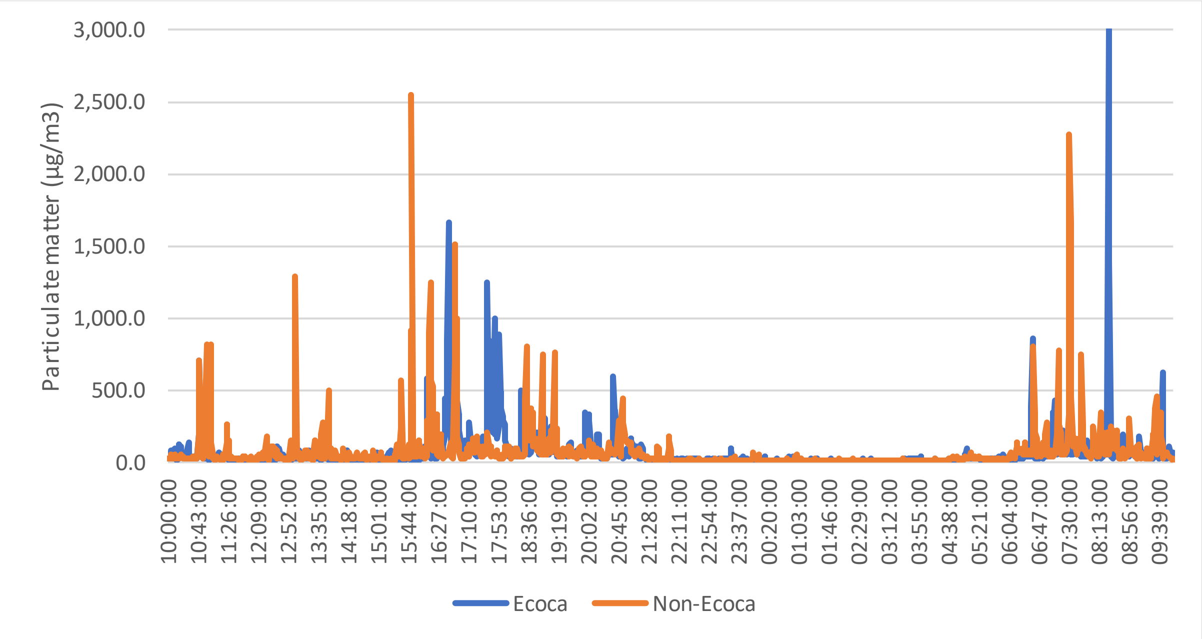
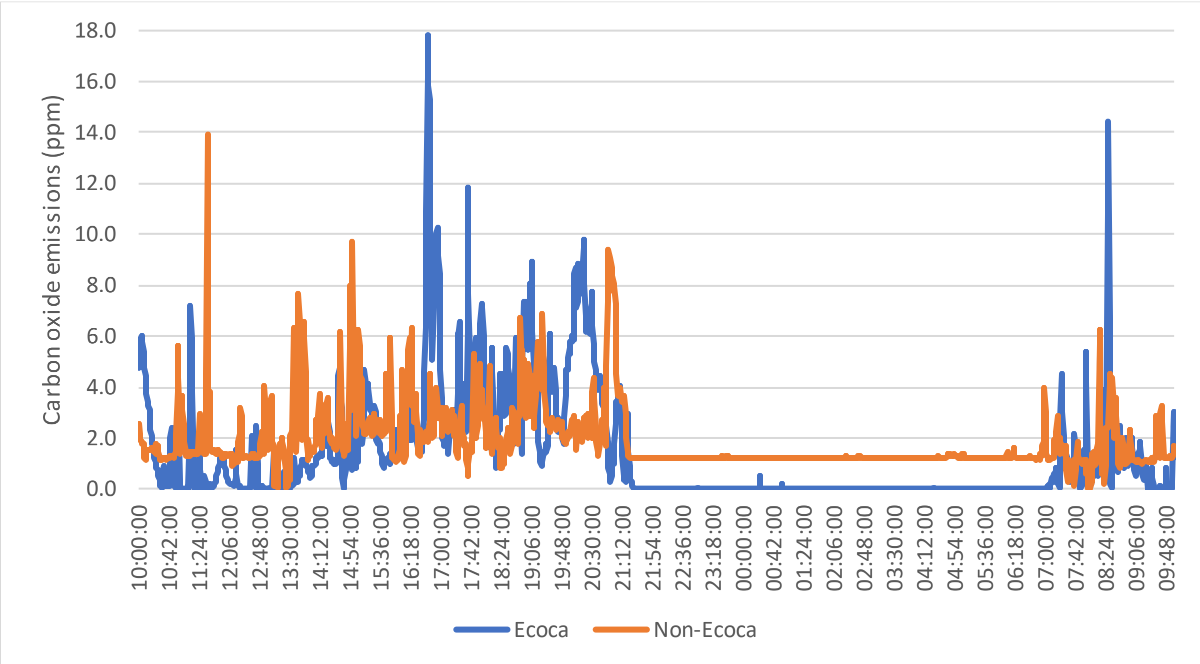


Figure 11 shows the recorded daily typical curve for ECOCA and non-ECOCA household carbon oxide emissions (ppm). While the EOCA households show higher values between 16:30-21:00, the total recorded emissions are 27% higher from Non-ECOCA users. In part this difference occurs at night, where these households show constant emissions during the night. Interestingly, one could argue that the emissions linger during the night for non-ECOCA households because the place of sleep with either the same room when the main cooking occurs or in closer proximity and lack of ventilation. Although this is a broader result independent of the ECOCA and more on the type of households. As such, on this study there was no perceivable difference on the type of household between ECOCA and non-ECOCA households, and would require further investigation on night time user practices.

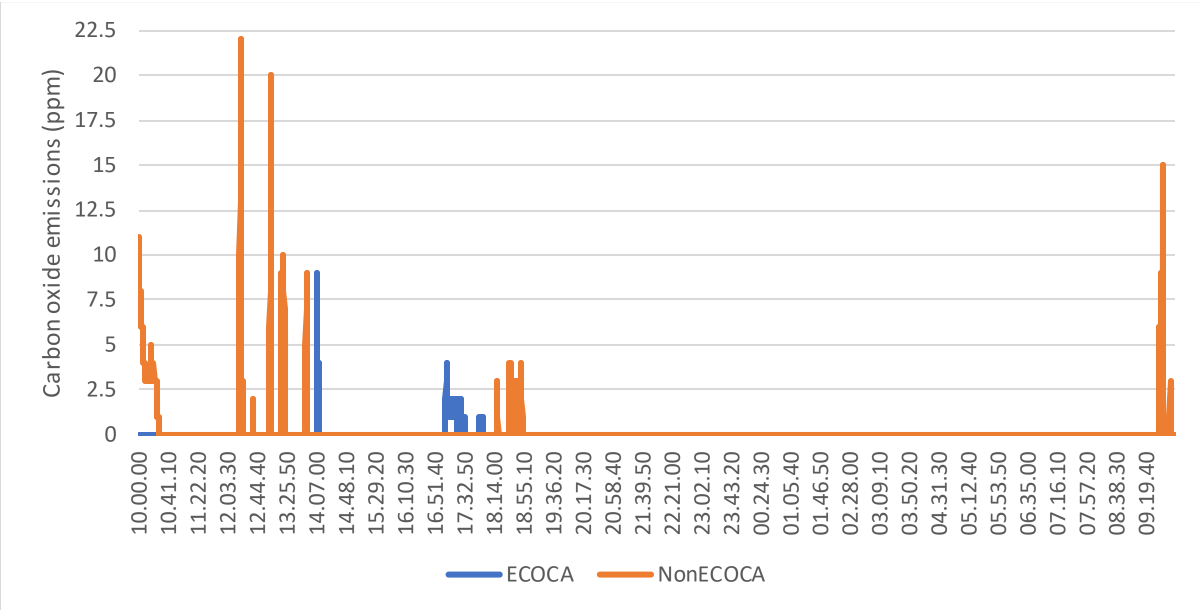
Also notable are morning spikes on ECOCA households, which can be attributed to capability aspects of the current version of the ECOCA. For example, ECOCA household respondents reported to have used fire in the mornings to make tea, and at times other meals because of the single pot provided with the ECOCA creates 2 challenges: the pot is large so its perceived as taking longer to boil water for small servings, and at times there are traces of taste of previously cooked foods such as silverfish or onion.

Figure 11. *Typical ECOCA vs NonECOCA household 24hr CO (ppm)*



Notably the data of this study alludes at the potential benefits of the ECOCA, when used exclusively or largely for cooking and lighting activities, for the purpose of air quality. Figure 12 below shows the comparison between a household that reported a high usage of their ECOCA vs a non-ECOCA household, which noted normal levels of fuel consumption (i.e. using fire once or twice a day for cooking). The ECOCA household shows 86% less CO (ppm) emissions and 51% less particulate matter (ppm), a sharper reduction of emissions. The reminder emissions shown by the ECOCA household may arise from using fire sparingly or come in contact with second hand smoke from a close by neighbour (some houses are only a few meters from each other). However this alludes that when the ECOCA's performance fulfils the users' needs and expectations, the 100% solar powered cookstove is used almost exclusively and considerably reducing the personal exposure emissions.

***Figure 12**. High ECOCA household usage vs. 'normal' non-ECOCA household CO (ppm)*



Limitations of the innovation/approach/design/system

The project found limitations in the design, implementation and innovation when conducting field work, as well as on the process of conducting research in Uganda overall. This had direct implications on the project, particularly referring to the relatively small sample size (20 total households, with 10 ECOCA and 10 non-ECOCA) .

The first limitation to consider is on the research design and targeted sample, vulnerable populations, in this case, residents of the refugee settlement in Bidibidi, Yumbe, Uganda. The initial design included three types of users including new users, current users and non-users; however, this was later revised to two users (current and non-ECOCA users). The reason being, the project timeline for delivery was short considering the grant deliverables which restrict the time spent on the field, but also facing a lengthy process for research approval in Uganda that includes: approval from an authorised Research Ethics Committee and the Uganda National Committee for Science and Technology. Furthermore, the research design considered to engage with 2 adults, typically female and male per household resulting in a sample of 40 total individual engagements. However, upon implementation, the research team found that the second adult was typically not physically available for participation in the research, even when returning at a later time or pre-arranging the visits. This resulted in a total sample of 23 individual engagements.

From a performance standpoint, there are two main elements to consider which have layered impacts:

- Starting with the first piloted version of the ECOCA, as users would not consider it acceptable to conduct all their cooking and lighting activities. For example cooking heavier dishes for dinner in the late afternoon-evening was reportedly difficult or not possible, particularly without the ECOCA's solar panel capturing sunlight. This greatly impacts the results because it forces users to still use fire for cooking, and therefore creating harmful respiratory and environmental emissions.
- Secondly, while the first live pilot project of the ECOCA included 50 units deployed earlier in 2019, this project encountered only 10 fully functional ECOCAs at the time of fieldwork. This meant that the total sample was restricted to 20 total households (including 10 non-ECOCA).

The reason behind this limitation was found in the lack of supporting networks of the ECOCA, particularly for spare parts, maintenance and repairs; some of which would be reportedly a simple "repair task". For example, tools to restart the motherboard. While others might require replacing spare parts such as USB ports or lamps for lighting, which also creates the need for fuel burning for lighting at night. Therefore, while the ECOCA technology, for a first live pilot, reportedly performs well (allowing users to cook most their meals and providing the stated benefits shown on the results section) with the caveat of repairs, a larger role out of ECOCAs requires a robust support network to be developed. This is already in consideration and further elaborated on the next section Practical applications.

The performance and continuous improvement elements are a natural process in the creation of not only clean technologies but, technologies and innovations more generally, and the follow up version of the ECOCA is expected considerably address these limitations. For example, higher voltage to support higher boiling temperatures or frying.

Practical applications of the concept to the national cooking energy system (including costs)

Following the results of the air pollution test, at an individual comparison between ECOCA and non ECOCA household, there is an apparent distinction in personal exposure to pollutants and particle matter. However, as shown above, individuals that use the ECOCA for the majority of activities are still susceptible to second-hand emissions from nearby neighbours using firewood for their cooking and daily needs.

For this purpose, one of the considerations is to design a measurement project that addresses the second-hand emissions. This suggests that the amount of cookstoves in one space needs to be upscaled in order to measure more generally the community-based impacts of the ECOCA. During the research, it became apparent that even when a beneficiary may be cooking with an ECOCA, neighbours who lives in close proximity that may be cooking with biomass fuels thus producing smoke, will still impact of the ECOCA household. Therefore, making clusters of ECOCA houses may be more practical for further research and overall health benefits.

Furthermore, for practical applications, Pesitho will be setting up a co-operative with Caritas Denmark. This is a result of understanding the innovation and the subsequent vision for larger deployments of ECOCA units on the field. For example in developing comprehensive support networks that are able to serve the ECOCA units. The Co-op model, would provide an operational unit where newer ECOCAS will be assembled and distributed and served. The concept will include hiring residents of the Bidibidi Settlement as well as the host community, further support community engagement and strengthening of relationships. Roles will include technicians, salespersons and managers among others such as data collectors. This will not only reduce the carbon footprint of the current supply chain logistic model, but also provide an income opportunity, as well as professional experience for the workers at the Co-op. Both men and women will be included, and a gender based framework will be established.

Next steps (e.g. beta or field testing and implementation; more development etc)

1.7 *Include the costs, time and resources required for next steps of development/implementation*

In terms of costs, the development of the ECOCA has four immediate streams:

First, costs associated with scalability and market penetration. These include the investigation and development of a bespoke supply chain model to optimise the delivery of ECOCAs into the Bidibidi settlement, and elsewhere. For example, exploring entry barriers, regulations, technical and non-technical challenges, such as import duties, tariffs and permits. Based on this scope a high level estimation is between 20,000-50,000GBP.

On the other hand, the development of the next iterations of the ECOCA looks to include, among other characteristics: remote access points/focal internet point via Bluetown, Motherboard development for better monitoring, and continued improvement of the current pot, and development of subsequent types of pot to support local practices.

Further, investigate and develop the ECOCA to consider gender dynamics. This would include not only iterations on the ECOCA system itself, but more importantly models of adoption and diffusion supporting gender equality. For example, the inclusion of both men and women in the local assembly, distribution, usage and promotion of the ECOCA. A high level estimation to develop such models would be 20,000-50,000GBP.

Finally, a stream dedicated to furthering the investigation and analysis presented on this report with a larger sample that allows for statistical validation, and enquiry of the benefits of the ECOCA. Such project is estimated at ~50,000-80,000GBP.

1.8 *Note any funding planning to apply for such as EU, Innovate UK etc.*

The ECOCA has shown it can attain the proposed benefits, in particular when used as the only cooking and lighting option in the household. For this reason further funding its actively sought at an EU level. The first grant pool is the next phases of the MECS-ECO. Other funding opportunities may include grants from bodies such as Danida (Denmark) and DFID (UK).

1.9 *Note any partnership developments, new investors engaging with etc.*

Pesitho will be setting up a cooperative based outside of the Bidibidi Refugee Settlement in Uganda which will be used for assembling and managing the local sales of the ECOCA. This will be in partnership with Caritas Denmark and Uganda.

Dissemination Plan

1.10 *Discuss the dissemination measure done already – provide link for where on the internet the report is published by you, what journals you have plans to publish, conferences attending to publicise the research etc*

The research dissemination plan refers in particular to a prospective publication agenda. The project is looking to publish a minimum of three research articles journals such as Nature Energy, Applied Energy, Energy and Energy Policy. In particular this agenda includes

- Paper 1: Cleaning the air through cooking: evaluation of emissions between renewable electricity powered and fuel-based cooking technologies
- Paper 2: Energy service units: an exploration of spin-off business opportunities using solar-powered cookers in refugee settlements.
- Paper 3: In what ways do clean cook stoves impact gender roles, particularly for women in cooking and everyday life activities.

Conclusion

The overall aim of this research project was to assess the air quality, health and well-being impacts associated with cooking using solid biomass fuels compared to cooking with the solar powered ECOCA. Methodologically, the research adopted 3 approaches; monitoring the personal exposure to air pollution of the main cook in the household across 24 hours, lung capacity testing using a hand-held spirometer and semi-structured interviews with ECOCA and non-ECOCA households. Due to small sample size (20 households) and time scale of the project, statistical significance of results is not claimed. However, the study highlights key insights on the impact of the current piloted version of the ECOCA reflected on the daily lives of the studies households in the settlement.

Considering the reported technical limitations of the piloted ECOCA, not being able to consistently cook heavier meals when the weather is not optimal, the ECOCA is used sparingly across daily cooking needs, mostly covering morning meals like porridge. This was further evidenced throughout the 24 hours air quality measurements, as differences between personal exposure to pollutants of households were lower than conceptually considered. Meaning that the sampled ECOCA households continue to experience exposure to harmful emissions since fuel burning is still a predominant activity for cooking and lighting.

From observation, when conducting personal exposure monitoring, it proved to be difficult to control what pollutants were present from the participants own cookstove, given that households within the camp were within close proximity of the other, meaning that smoke from a neighbours cookstove can directly impact the participant, even if they were not cooking with fire at the time. Further, the differences between the participants day to day activity was more likely to change throughout the week, and across seasons. Therefore, monitoring air quality across longer measurements, such as 72 hours and across seasons would provide greater insights into personal exposure to pollutants. Admittedly, there were no differences in the lung function tests between ECOCA and non-ECOCA household participants. However, no statistical validity is claimed due to the sample size, but also as lung capacity testing are dependent across several components such as age, ethnicity, height, and the contextual background of the participant across her/his life. Therefore, having had access to the ECOCA for only a few months would conceptually have minimal impact in the lung capacity of its users.

While statistically it was not possible to draw assumptions of overall impact of change to household's health using the ECOCA cookstove, comments made during the responses of semi structured interviews, allowed for greater insight into the health impact of participants. ECOCA users mainly explained the ways they felt better since receiving the ECOCA, whereas non users focussed on the issues that had every day. As part of the semi structured interviews, different aspects of health were measured including physical and mental. Respondents were able to reflect on both outlooks, with ECOCA households explaining they no longer coughed as much, felt pain in their chest and slept better from lack of stinging sensation in their eyes from cooking with smoke. Non-ECOCA households mentioned they get pain in their chest and still feel pain in their eyes, particularly pain associated with collecting firewood such as headaches, dizziness and feeling tired. Psychological aspects from ECOCA households included worrying less about having to collect firewood the following day, and what it would mean if they could not produce adequate firewood in order to cook for the family. For non-ECOCA households, the worst-case scenario responses were 'we do not eat'. Comparatively, ECOCA households all answered, that they could use the ECOCA. Although small scale data, there were apparent differences clearly documented throughout the research. It was not possible to provide comparative analysis with regards to gender impacts since almost none of the male family members within households were present to take part in interviews.

Therefore, considering the studied ECOCA was the first live piloted version, this study shows potential benefits to be captured, and the already stated positive impact in the lives of residents of the Bidibidi Settlement. Noting that when an ECOCA is able to be used exclusively or largely for cooking and lighting activities, emissions can be greatly reduced. Even with this early version of the ECOCA, users reported multi-dimensional benefits such as reduction of firewood usage and collection, reduced exposure to smoke and improved overall health. Suggesting for the ECOCA to continue to be developed and implemented.

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