Feasibility study for the dissemination of improved cookstoves among Cherara Cooperative members in Kericho County, Kenya

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Testing and recommendations

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Final report

February 2021

Executive summary

SalvaTerra and its Kenyan partner Dr. Kinyua Gitau - bioenergy researcher, currently consulting with World Agroforestry (ICRAF), have been hired by PUR Projet to conduct a feasibility study for the dissemination of improved cookstoves (ICSs) among coffee producers' part of the Cherara Cooperative in Kericho County, Kenya.

The objective of the study is to provide recommendations to PUR Projet, in order to disseminate the promising ICSs and to coordinate this activity with the agroforestry ones. After a field and desk study to understand the baseline situation on ICSs and fuels at national and local level, three promising ICSs have been identified and tested:

- The chimney stove - Brighter Communities: this locally made ICS is made of bricks fixed with a clay and mud mortar, and a chimney. It has one inlet and allow cooking with two pots simultaneously: one pot is heated directly by flames from the burning wood and the second receives the heat from the smoke driven outside through the chimney. It has been promoted by the non-governmental organization" Friends of Londiani and Kipkelion" since 2009 in Kericho County;
- BURN Kuni Okoa: this portable stove is made by a Kenyan company BURN Manufacturing. It is light and portable, and allows important fuel reductions, but some acceptability challenges remain;
- The clay liner stove – 2 pots: made of two clay liners fixed in a sand and cement mortar and additional bricks to hold liners in position. This ICS has two inlets and no chimney. It fits local population uses and addresses the issue of stability while allowing most of cooking operations.

A combination of qualitative and quantitative methods has been used: Controlled Cooking Tests (CCT) allowed to measure specific fuel consumption for each ICS and a complementary Focus Group Discussion (FGD) was held to assess users 'satisfaction.

Kuni Okoa clearly appears to be the most fuel-efficient stove, twice more efficient than the three other stoves (two other ICSs and traditional stove - Koitama), enabling 56% fuel economy compared to traditional stove. The clay liner stove and chimney stove have not shown significant results in terms of fuel savings compared to Koitama; they are considered equivalent in term of fuel consumption. The clay liner stove generated smoke all along the cooking process, due to the absence of chimney, and once the stove reached its full heating capacity, the flames rose high to the point where they protruded beyond the pot sides, which proved to be risky and dangerous to the cooks as it could burn their hands. The chimney stove performed without generating any smoke and enabled to cook 14% faster than the traditional stove.

FGD revealed a strong preference for the chimney stove, which fits all pots and offers great stability and safety. Kuni Okoa was declared very satisfactory for light cooking, with a hot and strong flame consistent once the stove is well lit. All heat is directed to the pot, which is good especially for rapid cooking tasks. However, it is considered less suitable for cooking for large families with large pots. Both stoves were appreciated for their low smoke emissions. The clay liner stove was less appreciated on almost all criteria.

When asked if in the case stoves would be taken back, they would be willing to buy it and keep it, most participant answered they would. Opinions were, however, quite divided according to household profiles: for some, Kuni Okoa was well suited to their uses (small households, need to prepare meals quickly) in combination with Koitama, for others less so (large families). The latter would be more willing to invest in a clay liner stove or a chimney stove. Participants who were ready to invest in the respective ICS declared being willing to pay around 500 KES for a Kuni Okoa (i.e. 20% of the total price of the stove), between 500 and 1500 KES for a clay liner stove (i.e. between 10% and 25% of the total price of the stove) and until 2500 KES for a chimney stove (i.e. until 50% of the total price of the stove).

On one hand, the Kuni Okoa is the type of ICS that would make it possible to save a lot of firewood and time spent collecting it, but it would have to stacked with the traditional stove for larger families. Its adoption would enable HHs to save up to 92 kg of firewood per month (i.e. 1,1 t/year) and would free up to five hours a week spent by women, representing in total two working days a month. On the other hand, the chimney stove did not perform as well as expected since no fuel economy was demonstrated during the CCT but shows a great social acceptance. Therefore, the dissemination of several models can be envisaged in order to cover a variety of needs identified in the area: the project could initially propose the Kuni Okoa for small families, and work in parallel to improve the chimney stove model that will suit bigger families 'needs as well. This would require some prototyping work, not necessarily very long, on the basis of the existing model.

For a first dissemination campaign, the number of orders will have to be adapted according to local demand, and therefore probably a mix between Kuni Okoa (or Pro 100 if suitable – more stable, wider inlet, bigger capacity) and the improved chimney stove. Considering the high range order, 300 Kuni Okoa models would cost a maximum of 819,000 KES, i.e. around 6,200 euros. In the same spirit, the chimney stove would cost in total 5,000 KES to build (i.e. 38 euros per unit), including material, labour and transportation, 1,500,000 KES (i.e. 11,300 euros) in total.

It is then recommended to follow a two steps approach for dissemination:

- Offer a subsidy directly to the consumer, in order to build up a solid base of satisfied users of the product and introduce a change of habits. According to the surveys, the users would be willing to pay the equivalent of 20% of the stove price. On the basis of Kuni Okoa's price, 2,230 KES per stove would thus remain to be paid by PUR Projet. As for the chimney stove, HHs were willing to pay until 50% of the stove price. Considering an average contribution to up to 30% of the stove price, i.e. 1,500 KES (all HHs would not be able to contribute up to 2,500 KES), 3,500 KES per stove would thus remain to be paid by PUR Projet. As an example, a scenario where 25% of the ICS disseminated would be Kuni Okoa (and 75% would be chimney stoves) would represent a total cost of 955,000 KES for the project, i.e. around 7,200 euros.
- Enable the establishment of a durable company by providing technical, administrative and financial support to the chimney stove manufacturer. This will also ensure sufficient production capacity to meet the dissemination objectives of the project. It is important to point out that there is no interest for BURN to train competitors, all the more so as the manufacture of the proposed model requires the creation of a manufacturing unit for clay liners, metal workshop etc.

Another option to consider is the upcoming introduction of the new BURN model on the market. With a maximum capacity of 100l per pot, this ICS is in fact much more stable, has a wider inlet which allows the use of large pieces of wood and would allow to use bigger pots. The manufacturer is still in testing process and expects to launch the product on the market in mid-2021. This model should be tested as well to evaluate its ability to meet the HHs needs.

A study of agroforestry projects in Kenya led to recommendations for potentially suitable companion trees in coffee agroforestry systems in the project area. A participatory approach is advised for the selection of species to be prioritised, in order to avoid the adoption difficulties. Among those species, *Commiphora zimmermannii, Grevillea robusta Croton megalocarpus, Cordia Africana,* and *Markhamia lutea* appear to be promising trees providing for good quality shade and allowing continuous pruning for firewood.

Finally, monitoring and evaluation protocols are suggested to assess the medium- and long-term impacts for the ICS dissemination, based on both qualitative and quantitative indicators.

Summary

Figures

Acronyms

CCT	Controlled Cooking Test
FGD	Focus Group Discussion
FOLK	Friends Of Londiani and Kipkelion
GACC	Global Alliance for Clean Cookstoves
GIZ	*Deutsche Gesellschaft für Internationale Zusammenarbeit* (German technical cooperation)
HH	Household
ICRAF	World Agroforestry
ICS	Improved Cookstove
KES	Kenyan Shilling
NGO	Non-Governmental Organization
SFC	Specific Fuel Consumption
TSOF	Three Stone Open Fire
WTP	Willingness To Pay

1. Introduction

1.1. Context of the study

PUR Projet is a French Non-Governmental Organisation specialized in the development of forestry, agroforestry and agro-ecological projects. In Kenya, PUR Projet is currently supporting coffee producers, part of Cherara Cooperative members in Kericho County, mostly promoting agroforestry implementation, the adoption of arabica coffee good agricultural practices, and the promotion of income-generating activities. It also aims to disseminate Improved Cookstoves (ICSs) among the coffee farmers' households (HHs). Its objective is to install 300 ICSs in 2021.

SalvaTerra and its Kenyan partner, Dr. James Kinyua Gitau (bioenergy researcher currently consulting with World Agroforestry - ICRAF), have been hired to conduct a feasibility study for the dissemination of ICSs among these coffee producers' HHs. Dr. Mary Njenga (Bioenergy research scientist at ICRAF) also contributed to this study.

The preliminary study of the national and local market has shown that a multitude of entrepreneurs are active throughout the territory, particularly around urban areas where the market is the most developed. Among active entrepreneurs: the biggest producers (BURN manufacturing, Envirofit, etc.) are implanted around the capital, whereas most of the informal production is done in Kisumu County and Muranga County, western and central Kenya respectively, where clay is readily available. There is a multitude of projects at the national level, often funded by carbon finance mechanisms. In the project area, some initiatives have been implemented at HH level. The technology of ICSs is therefore known to the population, but none of these projects directly involves the villages benefiting from PUR Project activities.

In the project area, the stove used is the local traditional mud stove called Koitama, based on three stove open fire (TSOF), with room for only one pot (cf. Figure 1). HHs rely completely on fuelwood for which they spend on average 5 hours collecting each week. The study of cooking habits leads us to think that the promoted ICS will have to be able: i) to generate both high intensity heat to boil water and fry, and low intensity heat for slow cook, ii) to be stable, allowing preparation of dishes that require vigorous stirring like Ugali (maize flour boiled in water and agglomerated into a ball), iii) to adapt to a variety of utensils used, iv) to last long with less requirement for maintenance-durability and, v) to run on fuelwood, which is the most commonly source of energy used locally.

After an assessment and diagnosis of the market situation and cooking habits at the local level, three ICSs were selected to be tested among the members of the cooperative (Salvaterra, 2020)[1]. This report presents the outcome of the second and third phase of the study, i.e. ICS tests results and recommendations for successful dissemination of the ICS selected and coordination with PUR Projet agroforestry activities in the area.

1.2. Stoves technologies tested

			
Koitama • Traditional mud stove • Three stones fixed in a mud mortar • One pot	**Kuni Okoa** • Portable wood stove; • One fire inlet; • Clay liner with metal cover	**Clay liner stove** • Consists of two clay-fired liners built *in situ;* • Two firewood inlets, each for one liner; • No chimney.	**Brighter communities chimney stove** • One firewood inlet; • Two pots; • Mud, bricks and clay stove; • Chimney.

Figure 1: ICSs tested (Authors, 2021)

[1] Salvaterra 2020. Overview of ICS market at the national and local levels in Kenya. Feasibility study for the dissemination of ICSs among coffee producers' part of the Cherara cooperative, Kericho County, Kenya. 21 p.

2. Methodology

In order to evaluate ICSs both technically and from a user feedback perspective, two types of analysis have been carried out:

- Controlled Cooking Tests (CCT) were conducted to assess the performance of the ICSs compared to the traditional stoves: three HHs experimented three ICSs during two weeks each, and then followed CCT protocol.
- Focus Group Discussions (FGD) were held to gather and debate users' opinions on the technologies tested: representatives (main HH cooks) of the 18 HHs that tested one of the proposed ICS participated in the discussions.

2.1. Controlled Cooking Tests

The CCT allows stoves comparison as they perform a standard cooking task that is representative of actual cooking habits of the local people. The quantity of wood used, as well as ignition and cooking time are measured in order to analyse Specific Fuel Consumption (SFC) for each stove. The tests are designed in a way that minimizes the influence of other factors and allows for the test conditions to be reproduced (Global Alliance for Clean Cooking (GACC) 2004)[2].

- Experimental design and stove introduction: Four stoves (the traditional stove and three ICSs) were to be tested by three HHs. For logistical reasons (small kitchens that could not accommodate three ICSs and rotation of testing teams), three neighbouring HHs from the list of participants to the HHs survey were selected and one ICS issued to each. After a six-week familiarisation period during which each cook tested all ICS models, each HH performed a test with each stove (including the traditional stove Koitama). Tests were repeated three times to ensure statistical significance. **All 36 tests (four stoves, three HHs, three repetitions per stove) were conducted in a four days period** (see schedule and templates in Annex 1 and 2).

- Standard cooking task & time: In Kenya, according to the initial stove users' habits survey and national experts, dishes regularly eaten in the community include Ugali (maize flour boiled in water and agglomerated into a ball) and vegetables. The selection of these dishes for CCT allows us to check, among other things, the compatibility of ICS with vigorous stirring. Raw food and corresponding ingredients were purchased before the tests and weighed into similar portions then distributed to the respective HHs. All cooking operations took around two hours per test.

- Representativity and homogeneity of fuel used: the firewood, *Grevillea robusta,* was air dried with an average moisture content of 13%. The selected dry wood from the pile was tied into bundles then distributed to the participating HHs. Each test used one bundle of firewood then discarded after the final measurements. A new bundle was provided for the subsequent test.

2.2. Focus Group Discussions

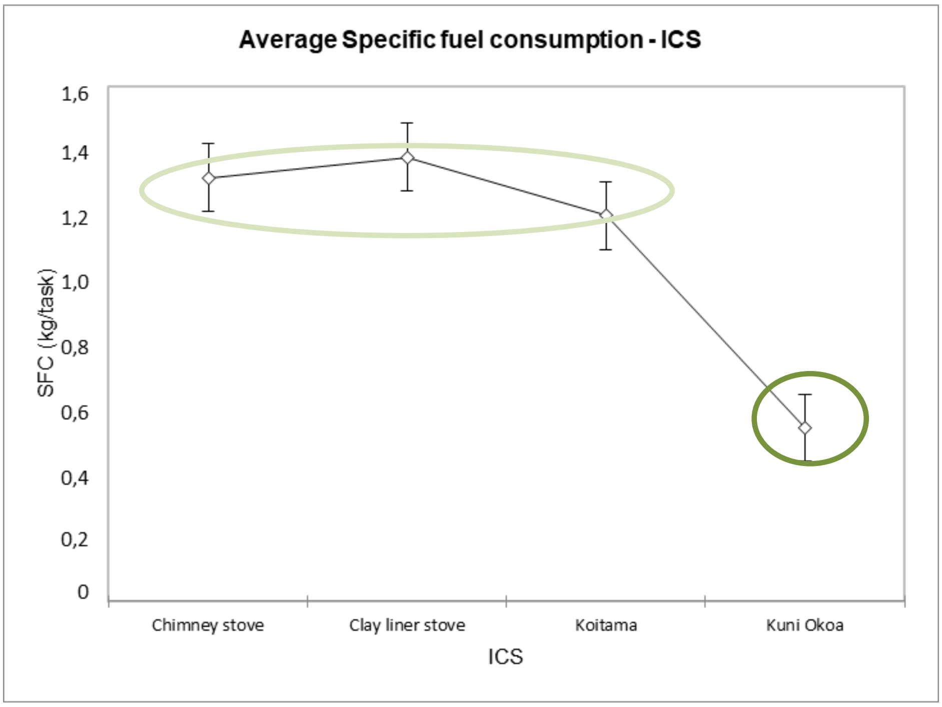
A FGD was undertaken with beneficiary farmers inviting them to share perceptions on the ICS models tested in comparison to the traditional stove Koitama regarding a number of criteria such as smoke emissions, safety, fuel consumption and stove performance (see FGD guidelines in Annex 3). As an ice-breaker, the participants were asked to rank the performance criteria of the three ICS models according to preference. Participants could then share their point of view according to the different criteria.

FGD took place on the last day of the mission, to comply with HHs availability, and had an attendance of 17 cooks over the 18 who tested one of the three ICSs distributed. Three groups of five to six cooks were interviewed in turn, to respect government restrictions. The diversity of ICSs tested was represented in each group to ensure to allow the comparison of uses and the expression of points of view. Two villagers asked to be allowed to witness the discussions, but were not allowed to contribute to the debate.

[2] GACC 2004. Controlled Cooking Test (CCT) Protocol. 8 P. [Available Online]: https://www.cleancookingalliance.org/binary-data/DOCUMENT/file/000/000/80-1.pdf

3. Results

3.1. CCT



ICS	Average (SFC (kg/task)	Statistical Groups (confirmed by ANOVA & Fisher test)	Fuel consumption efficiency	99% significance (p value<0,0001)
Traditional stove - Koitama	0,338	a	0%	Yes
Chimney stove	0,377	a	0%*	Yes
Clay liner stove	0,381	a	0%*	Yes
Kuni Okoa	0,149	b	**56%**	Yes

NB: ANOVA - statistical method that enables to study the behaviour of a quantitative variable to be explained as a function of one or more qualitative variables; Fisher test - statistical test used to determine if there are non-random associations between two categorical variables; A p-value is a measure of the probability that an observed difference could have occurred just by random chance: a 99% significance means that results are not linked randomly.

Figure 2: CCT results – Specific Fuel Consumption (Authors, 2021)

From the analysis of the amount of firewood consumed per cooking task (i.e. SFC) one of the stoves stands out significantly from the other three, with a 99% reliability:

- **Kuni Okoa clearly appears to be the most fuel-efficient stove**, twice more efficient than the three other stoves. Using Kuni Okoa enables 56% fuel economy compared to the traditional stove. It emits little smoke at lighting and cooling down stage.
- In spite of their great potential, **the clay liner stove and chimney stove have not shown significant results in terms of fuel savings compared to Koitama**. Chimney stove and clay liner stove show slightly higher consumption results than the Koitama in the data set, however these results are not statistically representative. They are therefore considered to be statistically equivalent to the Koitama.

- **The clay liner stove generated smoke all along the cooking process**, due to the absence of chimney, and once the stove reached its full heating capacity, the **flames rose high to the point where they protruded beyond the pot sides**, which proved to be dangerous for cooking.
- **The chimney stove performed without generating any smoke emissions**, as expected. It also enables to cook dishes 14% faster than the Koitama.

3.2. FGD

After the relative ranking of one stove versus the others according to the pre-established criteria grid, participants were invited to discuss the performance of each ICS and to express their preferences. Below is a summary of the discussions:

Fuel consumption: Users reported **lower wood consumption for the three ICSs compared to the Koitama.** It should be noted that there is a perception bias here, which can be partly explained by the shorter cooking time allowed by the chimney stove and the possibility of cooking two dishes at the same time. For Kuni Okoa, they note that **the use of thin pieces of wood is required, which implies a slightly longer wood preparation time, but allows a finer adjustment of the quantity of wood to be burnt**.

In the clay liner or the chimney stoves, any kind of wood can be burnt without increasing the wood preparation time. Some cooks even found **chimney stove to be more polyvalent in terms of wood types**, compared to Koitama, since some thinner pieces of wood can be used that does not usually work well with the Koitama.

Speed/power: **Kuni Okoa was declared very satisfactory for light cooking, with a hot and strong flame consistent once the stove is well lit.** All heat is directed to the pot, which is **good especially for rapid cooking tasks**. However, Kuni Okoa is **less suitable for cooking for large families** with large pots. **Clay liner stove also performed well**, although users note that **flame intensity decreases when fresh fuel is added**, and rises up again when combustion starts. They also highlighted that the stove **needs more tending to maintain a high level of combustion, and requires more frequent reloading.** Users declared the **chimney stove to be highly suitable for local cooking practices, diffusing a hot a long-lasting flame.** Heat is retained a lot longer in the chimney stove, and the stove does not need tending once it is lit, which was really appreciated. One tester noticed that the chimney stove has slightly less firepower than the Koitama, point of view that was not shared by the rest of the users.

Smoke emissions: A point of view shared by all participants - **Kuni Okoa and chimney stove produce less smoke than Koitama.** Kuni Okoa emits no smoke during cooking period, but smokes at lighting stage and when the burning wood is pulled out for quenching after cooking. Chimney stove does not smoke at all, as long as the cooking places are covered at ignition stage. It is important to point out that users can adopt two methods to light the stove, from above or directly through the inlet. The first method causes the smoke emissions, but that could be corrected by advising users on the most appropriate method to use in a user's guide. The clay liner stove, on the other hand, emits a lot of smoke.

Design: Users declared being **impressed by the attractive design of the ICSs they received** (It is worth highlighting that some of the mud-based stoves have been customised by users with soot and clay designs in different colours). Although appreciated for its modern look, users have concerns about the stability of the Kuni Okoa, especially with the use of larger pots. On the other hand, they **enjoy its portability, that enables to cook outside or to gather with other cooks** for ceremonies for example. The **clay liner stove's design was less appreciated** by cooks because, despite the possibility of cooking two dishes at the same time, **liners were too large and pots rests were not holding the pots properly hence. Pots were not as stable as required to stir vigorously** Ugali, for example. An additional metal piece was added to stabilize the pot. Chimney stove met all the users 'needs: it is compatible with all pots and cooking operations. When cooking with very small pots on chimney stove, a metal piece was also added to hold the pot in position.

Safety: Kunio Okoa **is considered safe, since the flames are covered and directed toward the pots** which reduces risks of burns. However, **concerns have been expressed about its stability**. Indeed, the low weight of the stove leads to a risk when cooking dishes which requires stirring. Some participants also mentioned that the metal cladding was getting hot, which required the cook attention when cooking to avoid any burns. No incident was reported while using Kuni Okoa. **The clay liner was considered quite dangerous** because of the **naked flames** that often protruded beyond the pot sides, causing burns to the cooks' hands, especially when cooking dishes that require the holding of the pot. Moreover, **pieces of wood protruding from the inlet have also been reported as potentially dangerous** to children. On the other hand, the **mortar does not get hot, which limits risk of burn from the outer part** of the stove. **Chimney stove was considered very safe**: i) the stove and pots are stable, so there is no risk of spilling food or burning hands, ii) the firewood is entirely inside the body of the stove, so there is no risk of tripping and iii) the outside of the stove does not get hot, which limits the risk of burns as well.

Cleaning/Maintenance: **All participants declare cleaning operations to be easy**. Regarding Kuni Okoa and clay liner stove, users expressed their **concerns regarding maintenance, that would necessarily be done by a skilled artisan**, therefore **generating extra-costs**. **Kuni Okoa was considered more solid than clay liner stove**. However, these concerns were not raised for the chimney stove since it is closer to their traditional stove in terms of design and materials. They feel more capable of repairing it themselves using locally available materials like ash, dung, mud, etc. **The participants also expect to have to make regular repairs; they are aware of the fragility** of this stove compared to the Kuni Okoa for example.

Willingness to pay (WTP): When asked if in the case stoves would be taken back, they would be willing to buy it and keep it, most participant answered they would. Opinions were, however, quite divided according to household profiles: for some, Kuni Okoa was well suited to their uses (small households, need to prepare meals quickly), for others less so (large families). The latter would be more willing to invest in a clay liner stove or a chimney stove. Participants who were ready to invest in the respective ICS declared being willing to pay around **500 KES for a Kuni Okoa (i.e. 20% of the total price of the stove), between 500 and 1,500 KES for a clay liner stove (i.e. between 10% and 25% of the total price of the stove) and until 2,500 KES for a chimney stove (i.e. until 50% of the total price of the stove)**. It should be noted that one of the lower income HHs stated that they could invest only 500 KES regardless of the model.

User satisfaction regarding the determined criteria:

Criteria	Chimney stove	Kuni Okoa	Clay liner stove
Fuel saving	Medium	High	Poor
Smoke emission	High	Medium	Poor
Saved cooking time	High	Medium	Medium
Fuel preparation	High	Medium	Medium
Stove maintenance	Medium	High	High
Ease of lighting	High	Medium	Medium
House warming	Medium	Medium	High

Figure 3: Overview of criteria discussed regarding the ICSs tested (Authors, 2021).

4. Recommendations for ICS dissemination

4.1. ICS to be promoted

Basing on CCT results, the Kuni Okoa is by far the most effective stove in term of fuel consumption selected. It emits relatively little smoke compared to the Koitama. It is easy to maintain and clean, and warm the house well. From the FGD, the three criteria identified that present challenges in terms of social acceptance are: i) the stove is not suitable for the preparation of meals for large families (especially for lunch and dinner), ii) fears have been raised about its stability, and iii) fuel preparation takes slightly longer than for the other stoves. **Provided that the Kuni Okoa is adopted, it would enable HHs to save up to 92 kg of firewood per month (i.e. 1,1 t/year).**

In addition, its use **would free up to five hours per week for women, representing in total two working days a month** (56% of 9 hours spent collecting firewood per week). This is without counting on the additional time savings that sustainable agroforestry practices could allow (source of firewood through the pruning of shade trees and which is carried out also by men, proximity of agro-forestry plots to wood sources, etc.). For reference, a study carried out in Ethiopia shows that agroforestry plot owners spend on average half as much time collecting wood as those who collect from local shrubs and forest, thus freeing up 88 hours per year per woman (Tadele et al. 2020)[3]

So, on one hand, the Kuni Okoa is the type of ICS that would make it possible to save a lot of firewood and time collecting it, but it would have to be used alongside the traditional stove for the larger families.

On the other hand, the chimney stove did not perform as well as expected since no fuel economy was demonstrated by the CCT results but shows a great social acceptance: i) it meets all cooking needs of the HHs, ii) it shows safety and stability, and iii) most importantly, it emits **no smoke and would enable to reduce time spent**

[3] Tadele M., Birhane E., Kidu G., G-Wahid H., Rannestad M., 2020. Contribution of Parkland Agroforestry in Meeting Fuel Wood Demand in the Dry Lands of Tigray, Ethiopia. Journal of Sustainable Forestry. 39:8, 841-853, DOI:10.1080/10549811.2020.1738946. 14 p.

cooking by 14%. One possible explanation for the stove's poor performance is excess draft due to the chimney. The first option to explore to improve the stove would be to add a door to control the effect of the chimney, which would add an estimated maximum of 1,000 KES to the global budget for one stove. The reduction of the combustion chamber is also an interesting possibility to improve the efficiency of the stove, since the larger the combustion chamber, the higher the wood consumption will be. This would require some prototyping work, not necessarily very long, on the basis of the existing model. (pers. Com. Dr. J. Guitau – Jan 2021).

Many projects go through a prototyping phase since very often there is no ready-made improved cook stove model available that adheres 100% to the specific requirements of the local conditions (*Deutsche Gesellschaft für Internationale Zusammenarbeit* - GIZ, 2013)[4]. For the improvement of the chimney stove, some key steps will be: 1) Consultation of manufacturers and field operators (at least FOLK and local manufacturers) with ICS experts (ICRAF researchers, in particular) in order to consider the changes to be made to increase the efficiency of the stove according to the set performance threshold, 2) Laboratory testing phase on several prototypes and performance validation, 3) Testing phase in situation in the project area (through CCT and possibly other tests, such as indoor-air pollution measurements) and performance validation, and 4) Dissemination of the improved model.

In this case where no "turnkey" solution appears, dissemination of several models can be envisaged in order to cover a variety of needs identified in the area: the project could **initially propose the Kuni Okoa for small families, and work in parallel to improve the chimney stove model that will suit bigger families' needs as well.**

Another option that could be interesting, although for the moment uncertain, would be to consider testing a new model of ICS that is not yet on the market: the BURN pro 100 (no images are available yet, those found on the manufacturer's website correspond to the pro 300 model). With a maximum capacity of 100l per pot, this ICS is in fact much more stable, has a wider inlet which allows the use of large pieces of wood and would allow to use bigger pots. The manufacturer is still in testing process and expects to launch the product on the market in mid-2021.

4.2. Financial and technical options to disseminate ICSs

From a technical point of view, disseminating BURN's ICS would be quite an easy task, since the manufacturer delivers quickly after order and makes sliding scale prices according to the number of pieces ordered. **Considering the high range order, 300 Kuni Okoa models would cost a maximum of 819,000 KES, i.e. around 6,200 euros** (2,730 KES/stove).

The chimney stove costs in total **5,000 KES** to build (i.e. 38 euros per unit), including material, labour and transportation. Considering also a high order range, i.e. 300 ICSs, the overall cost would be around **1,500,00 KES, i.e. 11,300 euros.**

Below is the ICS costs breakdown for the chimney stove:

Materials	Unit	Quantity	Approx. price/unit (KES)	Final Costs (KES)
Bricks	brick	70	15	1050
Clay	bag	1	200	200
Chimney	tube	1	1,000	1,000
Labour	installation	-	2,000	2,000

Figure 4: Chimney stove costs breakdown (Authors, 2021)

In order to build the chimney stoves for the feasibility study, a single manufacturer was hired. The manufacturer was trained by the NGO Friends of Londiani and Kipkelion (FOLK), as many other women and men in the area. Several

[4] GIZ HERA 2013. GIZ HERA Cooking Energy Compendium. A practical guidebook for implementers of cooking energy intervention. Berlin, Germany. [Available Online]: https://energypedia.info/index.php/GIZ_HERA_Cooking_Energy_Compendium

other manufacturers can thus be mobilized locally, in order to launch a larger production and train new artisans. One manufacturer can build one stove per day, two stoves per day with an assistant.

The advantage of this stove lies in its ease of access: in just a few weeks of training with skilled artisans, women can learn how to build and repair their stove themselves. It could therefore be envisaged, insofar as the demand on the local market is confirmed, to form a team of manufacturers on-site, whether or not associated with the cooperative.

For a first dissemination campaign, the number of orders will have to be adapted according to local demand, and therefore probably a mix between Kuni Okoa (or Pro 100 if suitable) and the improved Chimney stove.

When it comes to choosing a business plan for effective dissemination of ICSs, two approaches can be adopted (Gaul, 2009):

1) The use of direct subsidies to bring down the selling price of stoves (partially or totally). Direct subsidies will often take the form of buy-down grants to reduce product price directly, either by paying the producer for every system installed or providing the money directly to the customer.

2) The use of indirect subsidies to help establish a market through activities such as subsidised training, product promotion, business reinforcement, etc.

Based on the literature (Gaul, 2009) and lessons learned from the various ICS dissemination projects in Kenya, several points of attention are to be taken into consideration when it comes to planning the dissemination of ICS:

- Avoid 100% direct subsidies;

- Adopt a market driven approach as much as possible, i.e. when there is a secured market in the area;

- Do not neglect after-sales service and maintenance (access to spare-parts, skilled artisans, etc.);

In this case, it is recommended to combine the two approaches. In the first instance, **it seems appropriate to offer a subsidy directly to the consumer, in order to build up a solid base of satisfied users of the product and introduce a change of habits.** According to the surveys, the users would be willing to pay the equivalent of 20% of the stove price. On the basis of Kuni Okoa's price, 2,230 KES per stove would thus remain to be paid by PUR Projet. As for the chimney stove, HHs were willing to pay until 50% of the stove price. Considering an average contribution to up to 30% of the stove price, i.e. 1,500 KES (all HHs would not be able to contribute up to 2,500 KES), 3,500 KES per stove would thus remain to be paid by PUR Projet. As an example, **a scenario where 25% of the ICS disseminated would be Kuni Okoa** (and 75% would be chimney stoves) **would represent a total cost of 955,000 KES for the project, i.e. around 7,200 euros.** The WTP has been evaluated without communicating the quantified benefits of the use of ICSs (wood saved, time saved, etc.). Depending on consumer awareness, WTP can increase significantly.

As a second step, **the manufacturer could be supported to structure her business, train and hire other manufacturers. Technical** (manufacturing process, supply of materials, etc.), **administrative** (accounting, etc.) **and financial support** could be provided in order to sustain her activity. Assuming that **a stove is built in one day by an artisan,** over six months (considering 100 days worked), **a team of three manufacturers should be able to ensure the construction of 300 ICS models.** This shall ensure sufficient production capacity to meet the dissemination objectives of the project.

It is also recommended to associate users when developing/improving a stove model; the appropriation of the stove's functioning will reinforce its acceptability to the target population.

Specific measures can also be taken to strengthen cost coverage for HHs considered very poor, depending on the objectives and targets of PUR Projet. This could take the form, for example, of minimum contribution asked, or payments spread over the year, whereas other better-off HHs could be asked to make a larger contribution. The contribution amount should be adjusted with the help of the cooperative in order to further refine the subsidy allocation model.

It also appears relevant to work with the cooperative to develop partnerships with local banks and micro-credit organizations to enable HHs to access credit to cover their share of the stove's price. This approach has been successful for some ICS promotion projects.

4.3. Wood fuel management of the agroforestry-based coffee plantations

Tree species identified in Kericho County included *Grevillea robusta*, *Markhamia lutea, Eucalyptus spp, Croton megalocarpus,* among other trees grown for fruits such as avocados, macadamia nuts, mangos, etc.

Lamonds *et al*, (2016)[5], founds that the most common trees used for both shade and firewood provision in coffee farms were *Grevillea robusta, Commiphora zimmermannii, Bridelia micrantha, Eucalyptus spp., Croton megalocarpus, Cordia Africana, Markhamia lutea, Cyprus spp., Eriobotrya japonica* and *Mangifera indica.* Three of this species at least are also found locally. The study found out that by incorporating those trees in their coffee systems, farmers were ensuring alternative livelihood strategies in the face of market fluctuations. According to farmers' knowledge, at high elevation, *Bridelia micrantha* can attract pests on the coffee bushes. Farmers also tended to ban *Eucalyptus spp.* from their coffee plots considering they where responsible for drying up the land. One of the main criteria cited when selecting tree species is low competition with coffee bushes (rooting system), and *Commiphora zimmermannii* was particularly appreciated for that regard. It is also highlighted that *Grevillea robusta* is the only specy that has been recommended to provide shade by coffee factories in the area.

Holding et al. (2006)[6] confirms the heavy reliance on *Grevillea robusta* to respond to demand for firewood and timber. Authors also note a shift from planting trees for functional uses (such as soil and water conservation) to commercial marketing of wood products as firewood grows scarce. For instance, 42% of farmers were engaged in commercial marketing of tree products in coffee production systems in Mount Kenya area.

Therefore, the most promising species for potentially suitable companion trees in coffee agroforestry systems in the project area include *Commiphora zimmermannii, Grevillea robusta Croton megalocarpus, Cordia Africana, Eriobotrya japonica* and *Markhamia lutea*. Multipurpose trees should also not be neglected, such as *Mangifera indica* who provides also a non-negligeable amount of firewood according to Holding et al. (2006). A participatory approach is advised for the selection of species to be prioritised.

Few recent studies assessed the amount of firewood that could actually be sustainably collected from coffee plots in Africa. Rice (2008)[7] found out in Guatemala and Peru that non-coffee products account for up to a third of the total value realized from the coffee agroforestry system, of which 35% to 52% of the total value generated is derived from firewood. The amount of firewood harvested from the Guatemalan and Peruvian coffee area farm represents 3,500 and 2,100 kg/ha harvested, respectively over two years. In both cases, wood is pruned yearly or on a biennial basis from shade trees as well as from the coffee shrubs themselves. Kalanzi (2015)[8] highlights that abrupt removal of trees should be avoided as much as possible to limit shocks on coffee plants, and is also not suitable for sustainable firewood production.

A study carried out in Embu County in 2015 (Njenga *et al.* 2017)[9] found that *Grevillea robusta,* grown for timber, is the main source of firewood in the area. Grown in agroforestry systems, Grevillea spp. were pruned biannually (once every two years) to enhance the quality of timber. The pruning was carried out by young boys between the ages of 10 and 17 years of age, whereas girls were in charge of carrying wood for relatively short distances between the base of the pruned trees and the woodshed where the wood is then dried under shelter. HHs got up to 750kg of firewood from 16 mature trees. Considering that in the project area, HHs use an average of 2 t of firewood per year with the Koitama, it would cover 40% of the HHs needs with traditional stove and more than 65% of the needs with Kuni Okoa.

In addition, because canopy pruning and firewood collection are gender-specific activities, traditionally assigned to men and women respectively, the division of labour will need to be considered (Sebulime G., et al. 2018)[10] to ensure a regular

[5] Lamonds G., Sandbrook L., Gassner A., Sinclair. F. 2016. Local knowledge of tree attributes underpins species selection on coffee farms. Expl Agric. (2019), volume 55 (S1), pp. 35–49. Cambridge University press. 15p.
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[9] Njenga M., Mendum R., Gitau J., Iiyama M., Jamnadass R., Watson C. 2017. Trees on farms could satisfy household firewood needs. Miti. The tree farmers magazine for Africa. 6p.
[10] Ssebulime G., Nyombi K., Kagezi G.H., Byabagambi S., Tushemereirwe W.K., Kubiriba J., Karamura E.B., Satver C. 2018. Canopy management, leaf fall and litter quality of dominant tree species in the banana agroforestry system in Uganda. African Journals online. Vol. 18. No 1 (2018). 17 p.

supply of wood from agroforestry systems. For example, additional time could be saved for women if men in charge of pruning prepare the firewood when working in the plots.

4.4. Medium to long term Monitoring of ICSs impacts

In order to set up an effective monitoring and evaluation (M&E) of the project once ICSs are being disseminated, performance and social indicators, both qualitative and quantitative, will be closely tracked during the project duration.

Social Impact and fuel use monitoring

Social impact monitoring will help measuring if and how the adoption of clean and efficient cookstoves induced a shift in HH finances, changes in the time spent cooking and collecting fuel, shifts in workload for women. The GACC and the International Center for Research on Women (ICRW) (2017)[11] recommend a two-step monitoring approach: 1) to establish a baseline dataset when the stove is installed to capture the habits with traditional stoves; 2) to complete the diagnosis six months to one year later.

The baseline questionnaire used for this feasibility study (cf. SalvaTerra 2020) may be rolled out to new users to establish the situation prior to installation regarding: HHs economic stability (schooled children, poverty level etc.), adoption and cooking time (first and second most used cooking device, time spent cooking every week, etc.), cooking habits (persons involved in cooking, time spent cleaning the kitchen, multitasking, etc.) fuel consumption and firewood sourcing (fuel used, time spent collecting and preparing firewood, etc.), health and safety (injuries, safety risks etc.).

HHs will be interviewed again after a sufficiently long period of use (more than six months) on the basis of this questionnaire, supplemented by a few additional modules in order to understand:

- What needs are not covered by the ICS (in case they keep using the traditional stove)?
- How users are using saved time (if any)?
- ICS's adoption impact on social status (if any);
- How users are using saved fuel (if any)?

Outcome Indicators:

- **Firewood saved, avoided deforestation/carbon emissions (fuel consumption before/after ICS adoption);**
- **Time saved and opportunities generated;**
- **Users' satisfaction.**

Distribution/sales tracking

In the first stage of dissemination, ICS installation should be closely monitored to quickly identify potential problems related to the installation (defects, potential cracks, etc.).

FGD should also be organised to make sure the subsidy model adopted suits HHs income level and allow for its adaptation if necessary.

In order to limit monitoring costs, a system of feedback to the project coordinators within the cooperative could be set up, for example by taking advantage of the cooperative meetings or events to conduct FGD or semi-structures interviews with the users.

Outcome Indicators:

- **Adoption rate and trends;**
- **Users satisfaction;**
- **Dissemination patterns (word-to-mouth, etc.).**

Emissions monitoring

Although measurements were not carried out for this study due to the absence of dedicated budget, it seems important to measure small particles emissions ($PM_{2,5}$) and monoxide (CO) levels in kitchens when the ICSs are being used to cook. Indeed, although this does not have a direct effect on deforestation, it could allow measuring the other most important benefit of this ICS model, namely the significant improvement of air quality and the beneficial consequences for the health of women and children. These measures do not require a large investment, and national institutions such as ICRAF, which possesses the required equipment and master the protocols can undertake the monitoring. Using a "before and after" design is recommended. Importance of dry wood well must always be emphasized since no matter

[11] GACC and IRCW 2017. Measuring social impact in the clean and efficient cooking sector: a how-to guide. 122 p. [Available Online]: https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/489-1.pdf

how efficient a stove is, when used with wood which is not well dried (above 20% moisture content), it will generate a lot of smoke.

Outcome Indicators:

- **Indoor air pollution (emission concentration levels below or within the WHO recommendations)**
- **Reduced smoke generation rates (compared to traditional stove or initial ICS).**

Fuel consumption

A new set of CCT can also be run after improving the stove (if a door is added for example). A comparison between the ICS with door and without door can be made by selecting a standard cooking task to be cooked, measuring the weight of wood used for cooking in order to determine the SFC.

Outcome Indicators: Fuel consumption of the improved ICS compared to traditional stove (or initial ICS).

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Annex 1. CCT Schedule

Monday 14/12	am	Travel - Training of technicians		
		ICSb	ICSc	ICSa
	pm	ICSa	ICSb	ICSc
		Trad. Stove	Trad. Stove	Trad. Stove
Tuesday 15/12	am	Focus group discussions sub-sample 2		
	pm			
Wenesday 16/12	am	ICSa	ICSb	ICSc
		ICSc	ICSa	ICSb
	pm	ICSb	ICSc	ICSa
Thusrday 17/12	am	Trad. Stove	Trad. Stove	Trad. Stove
		ICSa	ICSb	ICSc
	pm	ICSc	ICSa	ICSb
Friday 18/12	am	ICSb	ICSc	ICSa
		Trad. Stove	Trad. Stove	Trad. Stove
	pm	ICSc	ICSa	ICSb

HH1	HH2	HH3

As an example, On the first day, HH1 tested ICS b, while HH3 tested ICSc and HH2 tested ICSa. HHs then moved to another house to test a different ICS and so on until they completed twelve tests each.

Annex 2. CCT Template

Template for field based cooking test			Test number:	
Date:	Name of cook:			
Fuelwood/ type :	Type of stove (Circle):	Smokeless stove 6-Brick	ILF rural woodstove TSOF (trad)	
Fuelwood Moisture content:				

Data of field based performance		
PARAMETERS	Units	Measurm.
Weight of pile of firewood used (W1)	g	
Start time to light the stove T1	time	
Time when fuel is well lit T2	time	
Start time to cook dish 1 T3	time	
Time when dish 1 is ready T4	time	
Start time to cook dish 2 T5	time	
Time when dish 2 is ready T6	time	
Weight of fuel remaining in the pile W2	g	
Weight of fuel withdrawn from fire (if any) W3	g	
Calculations on time spent		
Time taken to light stove fire (T2-T1)	min	
Time to cook dish 1(T4-T3)	min	
Time to cook dish 2 (T6-T5)	min	
Calculations on firewood consumption		
Weight of fuel used (W1-W2-W3)=(W4)	g	

Data of food cooked		
Dish 1 : fried rice		
	Ingredients	Amount (g)
1		
2		
3		
4		
Weight of the pot (g) (w1)		
Weight of pot plus dish 1 (g) (w2)		
Weight of the dish 1 (g) (w3= w2-w1)		
Dish 2 : Cabbage		
	Ingredients	Amount (g)
1		750
2		76
3		8
4		
5		269
6		81
7		
Weight of the pot (g) (w4)		
Weight of pot plus dish 2 (g) (w5)		
Weight of dish 2 (g) (w6= w5-w4)		

Complementary Questions/observations (circle/complete)		
1. After cooking, do you normally:	A.	withdraw the unburned and store for next cooking session
	B.	or you leave it to continue burning for other purposes (heating, etc.)
2. Status of door when cooking?	A.	open
	B.	closed
3. Status of the window(s) when cooking?	A.	open
	B.	closed (or no window)
4. Is the pot covered during cooking?	A.	covered
	B.	not covered

Comments :

Annex 3. FGD guidelines

After 6 weeks of testing, these focus group discussions aim at identifying the users' perceptions on various criteria, including wood fuel saving (also quantified through Kitchen Performance Tests (KPT)) but also by more qualitative criteria.

Methodology**: I**n a focus group, the discussion is free, but organised and structured in a flexible way. A focus group will gather between 6 to 10 participants and last at maximum a couple of hours. **The expert will act as facilitators and rapporteur** (using flipcharts and markers), **ensuring the opportunity for all the respondents to participate and to give their opinions.** The results of all the focus group discussions will be synthetized, criteria per criteria (design, maintenance, etc.).

Before starting, make sure to identify the HH and ICS they have been testing. For each ICS, at least two users should participate (2 HH for ICSa, 2HH for ICSb, 2 HH for ICSc = 6 pers. minimum). For each parameter, make sure opinion is given on each type of ICS.

Since ICS have been distributed among different villages, a central place to gather must be decided ahead of the meeting.

If possible, the use of a recording device could help collecting all the data without missing arguments or single voices that may not appear in the discussion's summary.

Main steps should be as follow:

1) Introduction: Presentation of the objectives of the discussion and rules of the focus group

   Context: This pilot phase aims at testing and selecting one ICS that suits best to cooperative members' needs and that improve cooking practices without breaking habits. After that phase, implementation at a larger scale will occur.

   Objectives: The objective of this session is to help us find the ICS that will match best users 'expectations and will present the best performances in terms of smoke emissions and fuel consumptions.

   Ground rules of the focus Group:

   Participation in the focus group is voluntary

   All responses are valid—there are no right or wrong answers.

   Please respect the opinions of others even if you do not agree.

   Speak as openly as you feel comfortable.

   Questions: Allow time for questions, and then ask participants to introduce themselves

2) Performance: Assessment of change on the three different parameters speed, smoke reduction and fuel consumption they perceive in comparison with their previously used stove (Koitama for Kericho households)):

   Fuel: Did you notice changes in your fuel consumption? (quantity/size of sticks)

   Smoke: Did you notice any decrease in the amount of smoke inside your cooking area/kitchen?

   What could you recommend to be done to decrease the amount of smoke (add a chimney, add ventilation in the kitchen, etc.)?

   At what stage of stove use was smoke produced higher? (at lighting stage, when fresh fuel was added to the stove, when simmering, when done with cooking and quenching the burning wood etc)

   Speed & power:

   Did you face any difficulties lighting the stove?

   Is the rise in flame temperature fast enough?

   Is the flame temperature hot enough to cook according to your habits/practices?

3) Assessing users' satisfaction regarding compatibility with cooking habits and preferences

   Design:

   What was your first impression when you received the ICS?

   Does the ICS meet your needs? Did you face any difficulties using the stove?

   Is the ICS adapted to the local pots and pans (including clay pots)? What would you recommend to be changed in the design of the stove to better suit your cooking needs?

   Do you plan to continue using the ICS?

If yes, do you plan to use it alone or alongside (stack) with TSOF?

Do all cooking forms do well with the ICS?

If No, which cooking does well on the ICS and which ones do not?

<u>Safety:</u>

Did any incident occurred while using ICS?

Is the stove stable enough?

How is the safety of the ICS when children are around?

<u>Maintenance:</u>

Did you face any difficulty in terms of cleaning?

Any fear regarding the robustness (e.g. cracks appearing on mud stoves)?

Would you pay for the stove maintenance or rather do it yourself?

Have you observed any faults with the performance of the ICS?

4) Willingness to pay (WTP):

Would you recommend the ICS you received to you neighbours and relatives?

Would you be willing to buy the ICS you tested?

What is the maximum price you would buy the ICS?

Among all ICS discussed today, which one would you choose if you had to buy one? Why?

5) Conclusion: Summarize key information using for example a table such as:

	ICSa	ICSb	ICSc
Criteria 1 (e.g. fuel consumption)			

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