Feasibility study for the dissemination of improved cookstoves among members of the Rwenzori Farmers' Co-operative Union (RFCU) in Kasese/Fort Portal area, Uganda

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Testing and recommendations

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February 2021

Executive summary

SalvaTerra and its Ugandan partner, the Centre for Research in Energy and Energy Conservation (CREEC) have been hired by PUR Projet to conduct a feasibility study for the dissemination of improved cookstoves (ICSs) among coffee producers' part of the Rwenzori Farmers' Co-operative Union in Kasese / Fort Portal area, Uganda.

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 ILF rural wood stove: it is two clay-fired liners built *in situ* for 2 pots, with an ash chamber which also act as air inlet, with two firewood inlets, each for one liner, without chimney. It was promoted by International Lifeline Fund and then Humankind;
- The smokeless wood stove: built *in situ*, it has only one firewood inlet that power two cooking fires and a chimney to evacuate the smoke out of the kitchen. It seems promising, but there are few references attesting to the effectiveness of this technology;
- The six bricks shielded wood stove: portable, composed of six burnt bricks enclosed in a metal cover, this stove can accommodate only one saucepan at a time. Numerous references attest to its effectiveness, as it has been promoted by Aid Africa for years in rural areas.

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.

All three ICSs performed better than the traditional three stone open fire (TSOF): The 6-Brick wood stove performs the best, proving to be 43% more effective than TSOF. However, it took the longest time to light, probably because of its small and the narrow combustion chamber (corresponding to the cylinder where the combustion takes place) as well as the firewood inlet (i.e. the opening through which the wood is loaded into the ICS). "Smoke Free Energy Saving" stove came second allowing to save more than 30% firewood compared to TSOF. Lighting time is similar to TSOF, generating a bit of smoke at lighting stage but then quickly evacuated outside thanks to the chimney. Finally, the ILF rural wood stove saved up to 20% of firewood.

FGD revealed a strong preference for the "Smoke Free Energy Saving" stove, declared very satisfactory both in term of fuel consumption and smoke emission by users. It also allows simultaneous cooking and provides a safe use thanks to its stability and high height which puts it out of the reach of children, and limits the risk of accidents. Six brick and ILF stoves were less appreciated, mainly due to rather high smoke emission and less safe design.

When asked if in the case stoves would be taken back, they would be willing to buy it and keep it, they all answered yes. Participants declared being willing to pay around 60,000 UGX for a "Smoke Free Energy Saving" stove (i.e. over 20% of the total price of the stove), 40,000 UGX for an ILF rural wood stove (i.e. over 10% of the total price of the stove) and 10,000 UGX for a Six-bricks stove (i.e. over 10% of the total price of the stove).

Basing on the CCT and FGD results, the "Smoke Free Energy Saving" stove seems to be best suited to the local context while guaranteeing a good level of performance, ensuring an energy efficiency of more than 30% compared to TSOF. The chimney allows to reduce considerably the level of indoor air pollution, the design reinforces safety and provides for multiple uses. The possibility of cooking with two pots at the same time matches the wishes expressed by the cooks, and will undoubtedly save cooking time, in addition to saving wood. The estimated savings are 30 kg of wood per month per household and an average of 3 hours freed per week for women. To give an idea of the savings in financial terms, if the wood was purchased, this would correspond to about 30,000 UGX saved per month.

The stove can either be made of cement - with a cost of 300.000 UGX per stove including labour, material and transport – or made from clay and other locally available material, that could easily be sourced by beneficiaries. If the raw material is provided by the producers, the installation costs of 150.000 UGX per stove (labour and materials not available locally such as the chimney) would remain to be covered by the project. If the raw material is not provided, a contribution may be requested from the beneficiaries to cover these costs. Most of the raw material is available on site: clay, sand, gravels and bricks. According to the surveys, the users would be willing to pay the equivalent of 20% of the stove price, either in financial form or as a contribution in building materials. Therefore, the installation of the 300 ICSs would cost 45 million UGX (150.000 UGX per stove), i. e. around 10,500 euros for labour costs.

A study of agroforestry projects in Uganda 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, *Albizia coriara, Ficus natalensis* and *Cordia Africana* 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
CREEC	Centre for Research in Energy and Energy Conservation
EnDev	Energizing Development Partnership Programme
FGD	Focus Group Discussion
GACC	Global Alliance for Clean Cookstoves
GEF	Global Environment Facility
HH	Household
ICS	Improved Cookstove
ICRW	International Center for Research on Women
MFI	Microfinance Institution
SNV	*Stichting Nederlandse Vrijwilligers*
TSOF	Three Stone Open Fire

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 Uganda, PUR Projet is currently supporting coffee producers, part of the Rwenzori Farmers' Co-operative Union - Kasese / Fort Portal area, 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.

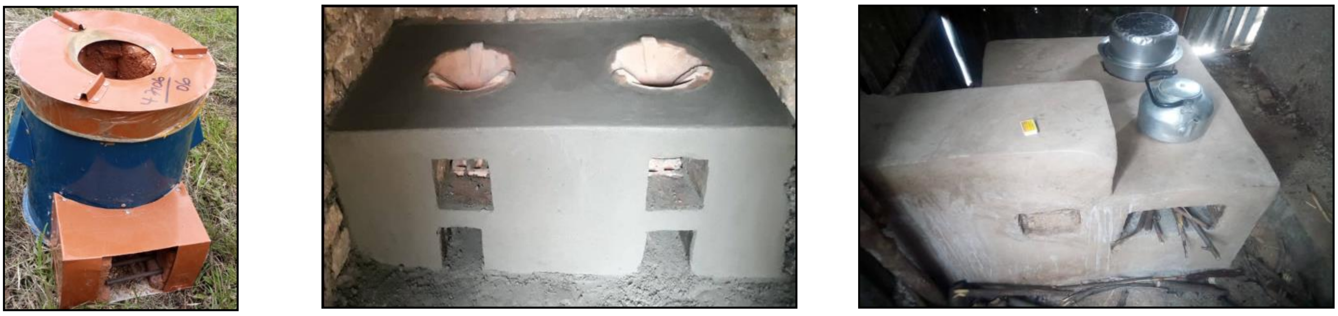
SalvaTerra and its Ugandan partner, the Centre for Research in Energy and Energy Conservation (CREEC), have been hired to conduct a feasibility study for the dissemination of ICSs among these coffee producers' HHs.

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. While most producers have a low production capacity, a few larger groups stand out, such as Ugastove limited or the production units set up by the International Lifeline Fund (ILF), which produce several thousand pieces per month. However, the distribution networks for these ICSs are limited, not allowing for the availability of ICSs in the most remote and hard-to-reach areas of the country. In the project area, especially around Kasese, some initiatives have been implemented at household and institutional level (institutional stoves in schools). Two local companies are currently active in Kasese, offering two types of ICS that have been selected to be tested in this study.

In the project area, HHs rely mostly on traditional stoves: three stone open fire or traditional mud stoves are the two commonly used cooking methods. Although it is admitted that these stoves are fuel consuming, emit a lot of smoke and increase the risk of accidents, users are unable to access the ICSs technology on the local market. Women and girls spend an average of 9 hours a week collecting firewood, report numbers of serious health problems due to smoke exposure and often encounter difficulties while collecting wood: scarcity, conflicts with landowners, risk of accidents and injuries, etc. Therefore, the two most important criteria when considering the acquisition of an ICS are smoke reduction and lower fuel consumption. The ability to cook several dishes at the same time is also very important to users, since the average time spent cooking per day is quite considerable (5.5 hours/day). The increase in income, the scarcity of wood and the inconveniences due to the use of traditional stoves encourage several families to consider acquiring an ICS in the near future.

After an assessment and diagnosis of the market situation and cooking habits at the local level summarized above, 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



Six-Brick Wood stove

- Portable wood stove;
- One fire inlet;
- Clay liner with metal cover;
- Certified by CREEC.

ILF rural wood stove

- Consists of two clay-fired liners built *in situ;*
- Two firewood inlets, each for one liner;
- No chimney.

« Smoke Free Energy Saving » stove

- One firewood inlet;
- Two pots or fireplaces;
- A chimney attached on the side.

Figure 1: ICSs tested (Authors, 2021)

[1] Salvaterra 2020. Overview of ICS market at the national and local levels in Uganda. Feasibility study for the dissemination of ICSs among coffee producers' part of the Rwenzori Farmers' Co-operative Union in Kasese / Fort Portal area, Uganda. 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 of the 18 households 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 attributed 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 three-stone open fire - TSOF). 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** in Kikokera village (see templates in Annex 1, and illustration of different steps in Annex 3)**.**

- Standard cooking task & time: In Uganda, according to the initial stove users' habits survey and national experts, dishes regularly eaten in the community include matooke. 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 used was *Grevillea robusta* with an average moisture content of 16%. To ensure adequate moisture content (under 20% was mandatory for the test), firewood was purchased during the second field mission and stocked for more than six weeks in a dry place. *Grevillea robusta* was chosen due to the scarcity of dry *Eucalyptus spp.* firewood because of high consumption during the rainy season, when the tests occurred. Both species are highly grown in the region. The selected dry wood from the pile was tied into bundles of four pieces with an average of 12 kg per bundle then distributed to the participating households. 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

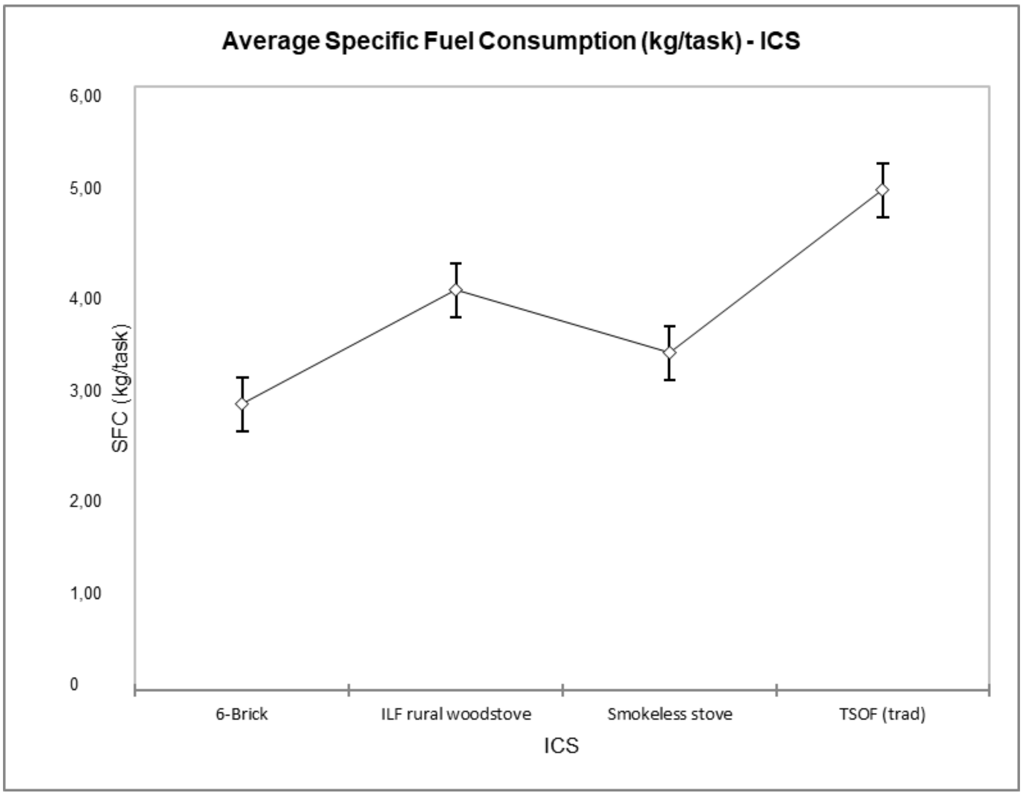
A FGD was undertaken with beneficiary farmers inviting them to share perceptions on the ICS models tested in comparison to the TSOF regarding a number of criteria such as smoke emissions, safety, fuel consumption and stove performance (see FGD guidelines in Annex 2). As an ice-breaker, the participants 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 final day of the field mission in the home of a beneficiary farmer within the community where the ICS stoves samples had been distributed months earlier and had an attendance of 14 cooks. Half of the group had tested one of the ICS models being experimented while the rest of the attendants had an opportunity to witness the performance of ICS models and expressed their desire and curiosity to listen to the discussion.

[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 results



ICS	Average (SFC (kg/task)	Statistical Groups (confirmed by ANOVA & Fisher test)	Fuel consumption efficiency	99% significance (p value<0,0001)
TSOF (trad)	4,975	a	0%	Yes
ILF rural woodstove	3,979	b	20%	Yes
Smokeless stove	3,352	c	**33%**	Yes
6-Brick	2,847	d	43%	Yes

NB: ANOVA - statistical method that separates observed variance data into different components to use for additional tests; 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

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

From the analysis of the amount of firewood consumed per cooking task (i.e. SFC), it is possible to clearly rank the ICSs that consume the least amount of wood, with a 99% reliability:

- The 6-Brick wood stove performs the best, proving to be 43% more effective than TSOF. However, it took the longest time to light, probably because of its small and the narrow combustion chamber (corresponding to the cylinder where the combustion takes place) as well as the firewood inlet (i.e. the opening through which the wood is loaded into the ICS), considered too narrow as well. On average, it took eight minutes to light the stove to a steady flame. Like the ILF wood stove, the absence of a chimney created a smoky environment and a discomfort tending to the stove;

- "Smoke Free Energy Saving" stove came second allowing to save more than 30% firewood compared to TSOF. Lighting time is similar to TSOF, generating a bit of smoke at lighting stage but then quickly evacuated outside thanks to the chimney.

- ILF rural wood stove did not perform as well as expected, although its use can still save up to 20% of firewood. It is possible that this poor performance is partly due to design errors with the firewood grate, as illustrated in figure 3 below. The large holes in the grate could not hold char to aid continuous burning of the wood. Once the char was formed, it would fall through the grate to the air inlet below, thus implying the use of more firewood to maintain sufficient temperature.

Figure 3: ILF rural wood stove conception defaults (Kaweesa, 2021).

The absence of a chimney resulted into more smoke around the cooking environment especially during lighting phase and when adding firewood into the combustion chamber. Despite of such flows, the stove performed better compared to the baseline stove in terms of fuel saving and heat retention.

3.2. FGD results – "Smoke Free Energy Saving" stove preferred

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:

- Overall performance (fuel consumption/smoke emission/heat power): All users reported feeling that the **ICSs were more efficient than the traditional TSOF in terms of wood consumption, smoke emissions and cooking time.** According to the users, the **"Smoke Free Energy Saving" stove meets all the expectations by its cooking speed, very low smoke emissions and the fire power that allows all cooking operations** (except for roasting, which requires the use of an additional metal grill). Although performing well in terms of heat retention, the **ILF rural wood stove produces smoke and design flaws have resulted in an increased fuel consumption. Six-bricks stove was reported to be very efficient on the main criteria, but ignition difficulties (the draft is not sufficient to maintain the initial flame, so it is necessary to make several attempts to light the stove) did not allow for optimal use.**

- Design: **General aspects of the three ICS were appreciated**. All three ICS fit different types of pots and utensils used locally, and enable almost all cooking practices (with additional grill). Although they **enjoyed portability of the Six-bricks stove**, drawbacks mentioned in the above and below sections did not convince the cooks. For the other two ICSs, the **possibility of cooking two dishes at the same time was very much appreciated** by the users. However, they emphasized **their preference for a one inlet only system**, i.e. the "Smoke Free Energy Saving" stove.

- Safety: The **"Smoke Free Energy Saving" stove was declared very safe** by all users, who appreciated the fact that **the inlet is raised above ground level**, thus avoiding possible injuries due to pot spilling etc. Although the **ILF rural wood stove is considered safe**, some users reported a risk of injury to children, and therefore the need for adult attendant to avoid possible burns. It should be noted that the latter and the "Smoke Free Energy Saving" stove are at the same height and therefor present theoretically the same risks for users. It is reasonable to consider that any kind of stove should not be used without adult supervision. **The six-bricks stove has caused more reticence** on the part of users: they noticed a **major instability** when used on non-levelled grounds causing risks to topple over. Moreover, the **cladding becomes hot** when stove is in use, sometimes causing burns.

- Cleaning/Maintenance: **No difficulties were mentioned regarding the cleaning of the stoves.** Users did not express any particular concern regarding the robustness of any of the stoves, since the finishing is either metal or sand and cement mixture that is unlikely to crack. They stated they were **willing to repair the stove themselves if provided with skills**, and some even declared being **ready to pay small amounts for maintenance by a specialized artisan**.

- 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, they all answered yes. Participants declared being willing to pay **around 60,000 UGX for a "Smoke Free Energy Saving" stove** (i.e. over 20% of the total price of the stove), **40,000 UGX for an ILF rural wood stove** (i.e. over 10% of the total price of the stove) and **10,000 UGX for a Six-bricks stove** (i.e. over 10% of the total price of the stove).

Relative ranking of the stoves was as follows:

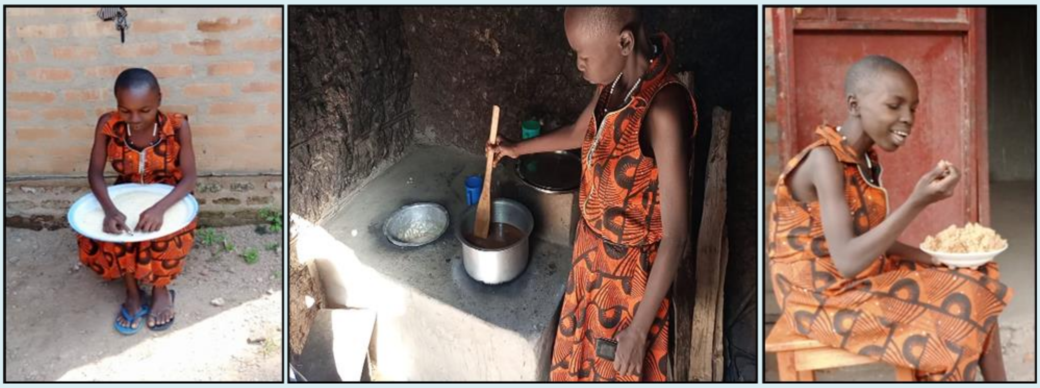
Criteria	"Smoke Free Energy Saving" stove	Six-bricks stove	ILF rural wood stove
Fuel saving	**1**	3	2
Smoke emission	**1**	2	3
Saved cooking time	**1**	2*	2*
Flame power	**1**	3	2
Fuel preparation	**1**	3	2
Stove maintenance	**1**	2	3
Ease of lighting	2	3	**1**
House warming	**1***	2	**1***
Safety	**1**	3	2
Taste of food & water	**1**	2	3
Simmering	**1**	3	2
Kitchen cleanliness	**1**	2	3
Heat retention	**1**	3	2

*****classified ex-aequo*

Figure 4: Relative ranking of ICS tested (Authors, 2021).

Focus – Experience of a "Smoke Free Energy Saving" stove user

Mrs. Eliza's daughter, who suffers from heart disease, was never allowed cooking because of breathing difficulties caused by smoke emitted by the TSOF. After testing the "Smoke Free Energy Saving" stove distributed to the HH, she stated "*I am able to participate in cooking as required of a girl in our culture because the new stove does not emit smoke that is bad for my health*".



Eliza's daughter sorting rice, cooking it by herself and enjoying her meal.

Figure 5: Experience of a "Smoke Free Energy Saving" stove user (Kaweesa, 2021).

4. Recommendations for ICS dissemination

4.1. ICS to be promoted & enhancement suggestions

Basing on the CCT and FGD results, **the "Smoke Free Energy Saving" stove seems to be best suited to the local context while guaranteeing a good level of performance, ensuring an energy efficiency of more than 30% compared to TSOF. The chimney allows to reduce considerably the level of indoor air pollution, the design reinforces safety and provides for multiple uses. The possibility of cooking with two pots at the same time matches the wishes expressed by the cooks, and will undoubtedly save cooking time, in addition to saving wood.**

From the HH survey (SalvaTerra, 2020), the equivalent of 25,000 UGX (around 25 kg) is allocated to firewood each week. Considering a wood saving of 30% per week, this would be **equivalent to saving about 30,000 UGX per month**. However, it is important to remember that most HHs do not buy wood directly but collect it (64% collect it, as opposed to 36% who buy or buy and collect). **The benefits of adopting this ICS would therefore be either in the form of cash savings or in the form of time saved on collection, thus to be spent on other potentially income-generating activities.**

Adopting this ICS **could free up an average of 3 hours per week for women, or a full working day per month** (30% of 9h 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 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]

When it comes to fuel consumption, the stove came in second place to the 6-brick wood stove, allowing more than 30% fuel saving compared to TSOF. Indeed, the introduction of chimney to a stove introduces additional draft that sucks more air into the system which, when more than required, disrupts combustion and thus overall efficiency. Manufacturers mention that **a door can be added to further improve the performance of the stove**. The addition of a door would make it possible to better control the draught effect of the chimney, and to modulate the combustion depending on the cooking intensity, for example. A door, foreseen in the original design, had finally been removed for the sale of this already expensive model, in order to reduce costs for the consumer. It can be added again for a budget of 50,000 UGX per stove.

The addition of a grilling mesh was also suggested by FGD participants to overcome the impossibility of grilling food on the stove. Quite easily affordable, this accessory would complete the range of cooking possibilities.

4.2. Financial and technical options to disseminate ICSs

From a technical point of view, the manufacturers have a **team of 20 trained technicians** who can be mobilized for the construction of the ICSs in the project area. They estimate the **construction speed of one stove per day/team of two technicians in good weather conditions**, and anticipate a period of **six to seven months for the installation of 300 ICSs** given the remoteness of the area. The installation of stoves should preferably be carried out during dry season, since heavy rains make the roads very difficult to access in wet season and therefore, transport of material very complicated. It should be noted here that an installed ICS requires almost a ton of material if built from cement. If built from local materials, on a clay basis, manufacturers would provide for material that is not easily accessible locally, such as the chimney. As a first step, before thinking of training local craftsmen, it seems appropriate to **entrust the company with the installation of the first stoves**.

The stove can either be built from cement of clay, and the budget will vary accordingly.

[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.

Figure 6 : "Smoke free energy saving stove" built from clay (left) or cement (right)

The estimated lifespan of the stove is about 10 years, according to manufacturers. However, repairs will be necessary as the stove is used. These are normally handled by the manufacturers as an after-sale service, in easily accessible areas close to the company's headquarters. In the context of the project, **the manufacturers propose to train a team in each community, or the users themselves, to repair and maintain the ICSs thus ensuring the longevity of the installed model.** After one year of use, the "pot-hole" circular areas can be damaged and therefore need to be replaced/fixed. When built out of local material, the manufacturer trains the beneficiaries on the ratios and process of mixing materials (e.g. clay, sand, dry chopped grass and water) to plaster the stove. Once the technique has been acquired, common repairs come at no costs for users.

Raw materials would have to be provided by the producers according to the following list:

Materials	Unit	Quantity
Sand	Wheel barrow	2
Gravels	Wheel barrow	4
Clay*	Wheel barrow	4
Dry chopped grass	Wheel barrow	1
Water	litter	200

Figure 7: ICS's locally sourced materials (Authors, 2021)

Bricks can either be baked or dried in situ. If backed, 200-250 small bricks would have to be provided by local shops at the extra cost of 150 UGX per unit. Another option is to make bricks from clay and to let them dry on site, which would reduce the total cost of the stove.

In order to reduce costs as much as possible, in terms of time and energy, it is possible to propose the mutualisation of efforts to extract materials within the village community.

When it comes to choosing a business plan for effective dissemination of ICSs, two approaches can be adopted (Gaul, 2009) [4]:

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.

[4] Gaul M. 2009. Subsidy schemes for the dissemination of improved stoves. Experiences of GTZ HERA and Energizing Development. Eschborn, Germany. 33p.

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 Uganda (ESMAP, 2019)[5], 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 the case of the study area, it seems appropriate in the first instance 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**, either in financial form or as a contribution in building materials. As mentioned above, it would be possible, for example, to group search and extraction of materials in order to reduce the overall cost. 1**50.000 UGX per stove would thus remain to be paid by PUR Projet. The implementation cost would therefore be a total of 45 million UGX, i.e. 10,500 euros.**

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 special assistance/subsidy in gathering materials, whereas other better-off HHs could be asked to make a larger contribution (effort or materials). This variable can 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 households to access credit to cover their share of the stove's price. This approach has been successful for some ICS promotion projects. As it stands now, the cooperative has already tried to provide farmers with credit facilities for vanilla crops but the recover was very poor since most farmers failed to pay back. Repayment solutions could be defined according to an in-depth analysis of the HHs economy and the new opportunities generated by agroforestry. Micro-credit institutions are established in Kasese, and could also be a source of funding for households, through partnerships and consultation with farmers, who are currently reluctant to engage with such institutions.

In the perspective to scale-up the dissemination, after a strict monitor and evaluation of the first stage, impact analysis on the local market, training sessions to set-up a local manufacturers team can be implemented. The company can provide six months courses to fully train technicians, preferably by group of ten persons. Once the training is completed, the technicians are autonomous and do not necessarily have to be part of the company. The company would charge 65 million UGX (around 15.000 euros) to set up the full training, i.e. around 1500 euros per trainee. This price, indicated by the manufacturer, is quite substantial and can probably be revised downwards if the option is considered.

ESMAP reports that "Demand-side ICS awareness is underestimated by shopkeepers, prompting ineffective sales tactics". Indeed, to ensure a wide dissemination of the ICS, awareness raising campaign will have to be carried out so that consumers have a homogenous and factual understanding of ICS benefits and share this understanding with others. So far, HHs of the targeted area have little knowledge about clean cooking technologies (SalvaTerra, 2020). This must be addressed in order to develop a sustainable local market, as word-of-mouth recommendations play a critical role in the ICS uptake (SNV, 2014)[6].

It should also be kept in mind that even though the installation of ICSs is usually done by men, they traditionally have little experience in the kitchen. Demonstrations and guidance on how to use the stoves properly should therefore primarily be conducted by women.

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

[5] ESMAP (Energy Sector Management Assistance Program) 2019. Uganda Clean Cooking Behavioral Diagnostic. ESMAP Paper. Washington, D.C.: World Bank. 86p.

[6] SNV (Netherlands Development Organisation) 2014. *Grassroots Solutions for Scaling Up Improved Cookstove Access in Uganda: A Last-Mile Community Market Intelligence Report*. Kampala, Uganda. 60p.

Particular attention should be paid to the tree species selected for introduction into coffee systems. Indeed, local preference is often given to *Eucalyptus spp.* which have the advantage of growing quickly, becoming de facto the best-selling firewood locally.

In the study by Gram *et al.* (2018)[7] carried out in eastern Uganda among coffee producers of Mt Elgon, producers were asked to rank tree species that were present in their agroforestry-based coffee plantations according to the ecosystem services (ES) they provide. When referring to fuelwood in mid-altitude zones (1400 meters above sea level – masl - to 1700 masl, which corresponds to the altitude of most RFCU plots), producers cited several tree species that were highly appreciated: *Cordia Africana, Ficus spp. (mucuso, sur, natalensis, ovata, sycomorus), Albizia coriara, Terminalia ivorensis, Milicia excelsa, Eucalyptus grandis, Vitex doniana, Gravillea robusta,* et *Markhamia lutea.* Among these species, only *Cordia africana* and *Ficus spp.* were also providing for other ES such as timber provision, weed and erosion control, temperature regulation and impacts on coffee yields.

In a similar study conducted in central Uganda by Bukumelo *et al.* (2017)[8], farmers found *Albizia coriara* and *Ficus natalensis* to be the most multipurpose trees, including fuelwood. *Grevillea robusta* was also mentioned as highly efficient in providing firewood and shade, but not providing for additional uses. Kalanzi (2015)[9] attests that *Ficus natalensis* was commended by the farmers for its high biomass production as well as sprouting ability and high tolerance to repeated pruning. This last criterion was declared very important by the farmers interviewed because of the constant need for fuel wood harvesting. In Godfrey *et al.* (2010)[10] study, farmers declares that *Ficus natalensis* and *Mangifera indica* were having good combustible characteristics such as production of quality fires and ability to burn for longer periods.

These species, *Ficus spp. (natalensis*), *Cordia Africana* and *Albizia coriara*, can therefore be studied as 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 difficulties encountered in some projects promoting firewood for charcoal production. As an example, the final evaluation report of the GEF's Green charcoal project (2019)[11] reports that a shift had to be made during the course of the project regarding the establishment of sustainable woodlots for charcoal production. Indeed, tree planters demanded the multi-purpose eucalyptus instead of the three local species that had been pre-selected for planting. This was partly explained by the high demand for eucalyptus in non-agricultural sectors (timber, building and electricity poles).

Few recent studies assessed the amount of firewood that could actually be sustainably collected from coffee plots in Africa. Rice (2008)[12] 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 3500 and 2100 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) 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.

[7] Gram G., Vaast P., Van der Wolf J., Jassogne L. 2018. Local tree knowledge can fast-track agroforestry recommendations for coffee smallholders along a climate gradient in Mount Elgon, Uganda. Agroforest Syst (2018) 92:1625–1638. 15 p. [Available Online]: https://doi.org/10.1007/s10457-017-0111-8

[8] Bukumeko H., Jassogne L. Tumwebaze S. Eilu G., Vaast P. 2017. Integrating local knowledge with tree diversity analyses to optimize on-farm tree species composition for ecosystem service delivery in coffee agroforestry systems of Uganda. Agroforest Syst (2019) 93:755–770. 16 p. [Available Online]: https://doi.org/10.1007/s10457-017-0172-8

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[10] Godfrey J., Okia C. Waiska D., 2010. Household firewood consumption and its dynamics in Kalizo Sub-county, Central Uganda. Ethnobotanical Leaflets 14: 841-855. 2010. 16 p. [Available Online]: https://www.researchgate.net/publication/268385659_Household_Firewood_Consumption_and_its_Dynamics_in_Kalisizo_Sub-County_Central_Uganda.

[11] Muthui V. N., Nuwakora C.B. 2019. Terminal Evaluation Report - Addressing Barriers to Adoption of Improved Charcoal Production Technologies and Sustainable Land Practices through an Integrated Approach. UNDP – GEF project. 97 p.

[12] Rice R. 2008. Agricultural intensification within agroforestry: The case of coffee and wood products. Agriculture Ecosystems & Environment 2008-12. 9p.

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 (Ssebulime G., *et al.* 2018)[13] to ensure a regular 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, 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)[14] 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);

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 of events to conduct FGD or semi-structures interviews with 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 in the absence of dedicated budget, it seems important to measure small particles emissions ($PM_{2,5}$) and monoxide (CO) levels in kitchens. 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

[13] 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.

[14] 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

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 CREEC, which possesses the required equipment and master the protocols can undertake the monitoring. Using a "before and after" design is recommended.

Outcome Indicators: Indoor air pollution

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

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Annexs

Annex 1- CCT template

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

Data of field based performance			Data of food cooked		
PARAMETERS	Units	Measurm.	Dish 1 : fried rice		
				Ingredients	Amount (g)
Weight of pile of firewood used (W1)	g		1		
Start time to light the stove T1	time		2		
Time when fuel is well lit T2	time		3		
Start time to cook dish 1 T3	time		4		
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 the pot (g) (w1)		
Weight of fuel remaining in the pile W2	g		Weight of pot plus dish 1 (g) (w2)		
Weight of fuel withdrawn from fire (if any) W3	g		Weight of the dish 1 (g) (w3= w2-w1)		
			Dish 2 : Cabbage		
Calculations on time spent				Ingredients	Amount (g)
Time taken to light stove fire (T2-T1)	min		1		750
Time to cook dish 1(T4-T3)	min		2		76
Time to cook dish 2 (T6-T5)	min		3		8
			4		
Calculations on firewood consumption			5		269
Weight of fuel used (W1-W2-W3)=(W4)	g		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 2 - 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 don't 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 (TSOF (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 don't?

<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)			

Annex 3 - Illustration of the different steps of the study

Measurement of firewood, moisture content and food

The ILF stove, 6-brick stove and “Smoke free Energy saving” stove in use

Focus group discussion done in the open due to Covid 19

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SAS SalvaTerra
6 rue de Panama
75018 Paris I France
Tél : +33 (0)6 66 49 95 31
Email : info@salvaterra.fr
Web : www.salvaterra.fr