Babington Stoves Field Test in Pugnido Refugee Camp
School Feeding Program
Gambella, Ethiopia

Final Report

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Project Gaia, Inc., Gaia Association &
Horn of Africa Regional Environment Center & Network (HoAREC&N)

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Executive Summary

1. Background

Securing a clean energy supply to meet the cooking needs of households, schools and institutions in Ethiopia continues to be a major challenge. The refugee camps in Ethiopia are also facing similar challenge to meet refugees' energy needs. To address this, the United Nations High Commissioner for Refugees (UNHCR) country office endorsed a national energy plan in early 2015 to solve the energy crisis in the refugee camps by introducing selected clean cooking and lighting technologies. As part of this wide effort, Project Gaia established a consortium of partners that includes Gaia Association, Babington Technologies, Horn of Africa Regional Environment Center & Network (HoAREC&N), UNHCR and the Ethiopian Government's Administration for Refugee and Returnee Affair (ARRA) to introduce a revolutionary new technology into the camps designed mainly to meet institutional cooking needs (e.g., for hospitals, schools, canteens, etc.). The new technology will eventually be adapted and modified by Babington Technologies to meet household cooking needs in the refugee camps as well as in other humanitarian and commercial settings.

The partners planned to introduce and test the Babington technology at Pugnido refugee camp in the Gambella Region of Ethiopia. The technology is capable of burning any liquid fuel, e.g., distillate fuels such as kerosene and diesel, ethanol, bio-fuels from plant oils, and even waste oils. It burns these cleanly and efficiently without smoke, soot or the production of carbon monoxide, based upon tests conducted in U.S. Government laboratories. The introduction of this highly efficient, clean burning technology into refugee camps and into the commercial market in Ethiopia will create opportunities for greater energy access and more sustainable energy use and should have a dramatic positive impact on institutional cooking problems in refugee camps.

Prior to the introduction of the Babington technology at the camp, the partners conducted a baseline study of the Pugnido camp's School Feeding Program during April 2015. Between November 06 and November 20, 2015, the Babington technology underwent pilot testing at Pugnido camp for two weeks. The tests were conducted by trialing four different Babington cooking appliances all fitted with the same Babington Airtronic burner. The pilot test identified which were the most appropriate appliances and what modifications would be necessary to meet the specific cooking needs of the School Feeding Program.

We noted that the cooks managed to adapt quickly to the new appliances. We would have liked to extend the length of the trials; however, we were limited by the lack of electricity connection and the necessity of relying on a diesel generator for power. The diesel generator we were using for the trials was withdrawn by HoAREC&N for use elsewhere and no replacement generator

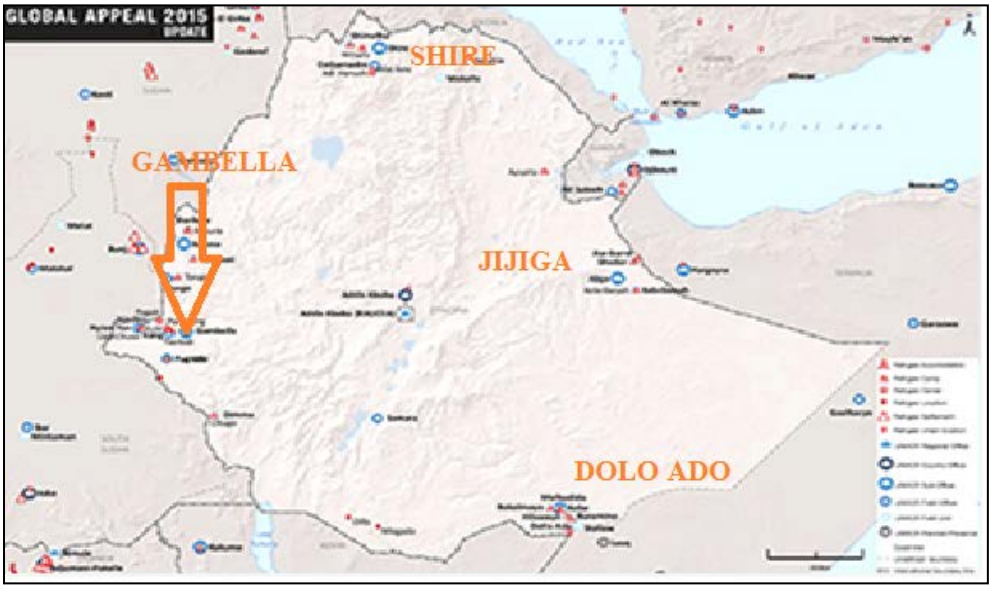
was available. no budget for diesel fuel was available. We concluded that a solar charged battery, solar collectors and an inverter could serve in the future as a replacement for the diesel generator.

Following the pilot, it is anticipated that modifications will be made to the Babington burners, based on these initial trials, and that additional Babington stoves will be trialed in Pugnido or in other camps. Because of the difficulty of supplying power to the Babington stoves in Pugnido, ARRA has recently decided (as of January 2017) to move the Babington stoves used in this trial to another camp.

This report presents the results of the baseline study and the first pilot studies conducted on the Babington technology at the Pugnido camp school kitchens.

2. Pugnido Refugee Camp

UNHCR operations in Ethiopia host more than 780,000 refugees from troubled neighboring countries in 25 camps. Pugnido camp is one of the five camps UNHCR operates in Western Ethiopia to host some 300,000 South-Sudanese refugees. The camp is located 900 km from Addis Ababa city and 110 km from Gambella town (the major town of the region). Pugnido camp was established in 1986 and is one of the first refugee camps in Ethiopia. At present, the total refugee population in Pugnido camp is estimated to be about 62,836. Over the years, UNHCR and its implementing partner organizations have developed camp infrastructure that includes but is not limited to administrative quarters, schools, clinics, social service centers, market areas, and distribution centers.



UNHCR Refugee Camps in Ethiopia (Source: UNHCR, 2015)

As in many of the other refugee camps of Ethiopia, firewood is widely used in Pugnido camp for both household and institutional cooking. Institutional cooking in the refugee camps is mostly

done at schools, hospitals and in cafeterias of agencies running refugee programs. The cooking at the camp's schools is part of the World Food Program (WFP) global initiative to provide meals to school children. At present, Pugnido camp is the only camp with a school feeding program in the Gambella-area refugee camps, since the other camps are only recently reopened following a new influx of refugees from South Sudan. Pugnido camp has four separate kitchens at each of four schools that are running school feeding programs. These programs serve meals to 10,303 students. All of the school kitchens are using semi-improved firewood stoves to cook Corn-Soya Blend (CSB) meals for the students, consuming 740 kg of firewood per day.

Firewood use for cooking in these UNHCR refugee camps is causing health problems, deforestation and environmental degradation, not to mention the tension that is created between refugees and the host communities. Efforts by the UNHCR and partners to reduce firewood dependence in some of the refugee camps of the country have shown significant improvements in the lives of refugees by lessening exposure to indoor air pollution, time spent in cooking and firewood gathering, and conflict with host communities. These efforts have shown significant results with regard to increased school attendance by the children of the camps. Reduced deforestation and land degradation have also been demonstrated in various programs.[1]

3. The Babington Institutional Cooking Technology

The innovative institutional cooking technology tested at Pugnido camp is designed and manufactured by Babington Technologies, which is based in the US, with its manufacturing facility in Rocky Mount, NC. The cookstove burner uses a unique fuel atomization technology that allows it to burn any liquid fuel, including heavier fuels like kerosene and diesel, and biodiesel, at near stoichiometric combustion (e.g. with complete air mixing). The burner comes in relatively small burner sizes yet the burners are powerful because they operate at very high combustion efficiency. The Babington burner atomizes liquid fuel to a very fine particle mist, which burns almost completely—approaching 95% combustion efficiency. The fuel burns much like a gas and produces no smoke, odor and very low carbon monoxide. This enables a wide range of high-efficiency, multi-fuel, portable heating and cooking applications, thus far deployed for group cooking use. Based on a simple engineering principle, the Babington technology developed a unique low-pressure, air atomization method, which sprays liquid fuel particles so fine that they are 1,000 times smaller than droplets produced by conventional spray nozzles.

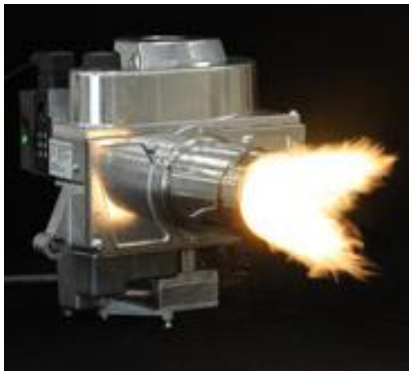
[1] Boiling Point, A Practitioner's Journal on Household Energy, Stoves and Poverty Reduction, Issue 68, accessed December 22, 2016, http://www.hedon.info/BP68_EthiopianJigjigaRefugeeCamps?bl=y

Patented Babington principle of atomization: jet of air is shot through a film of fuel

Produces an ultra-fine spray of sub-10-microns in size

Burns any liquid fuel like a gas

Atomizing liquid fuel in this manner permits the fuel to be ignited instantaneously and burn cleanly like a gas. The advanced vaporization effect leads to smokeless performance and near perfect (stoichiometric) combustion at variable heat outputs, which are able to be sized and adjusted between 450 to 105,000 BTUs/hr (1.3 to 30 kW). Thus, the clean burning technology can be delivered on almost any scale, in the form of small, energy efficient cookstoves to larger, more powerful institutional appliances.



Babington-Airtronic Burner

The burner in Babington appliances today is the Babington Airtronic burner, which atomizes and burns the fuel. The Babington Airtronic burner is capable of burning most liquid biofuels, both heavier fuels like biodiesel and lighter fuels like ethanol. . When there is an insufficient supply of biofuel, the burner can burn diesel or kerosene fuel. Babington's US military appliances are operated with diesel fuel.

Babington is developing small, simplified burners for use in household, institutional and commercial appliances in markets where alternatives to solid fuels are needed, such as in Africa where Project Gaia and HoAREC&N are active. This study is designed to support this R&D work. The new burners will operate at lower heating power, operate with manual controls, be cheaper to manufacture, and require DC rather than AC power.

For this pilot study, the partners selected four different Babington institutional cooking appliances to test at Pugnido refugee camp. All of the appliances are fitted with the same Airtronic burner and automatic controls that simplify operation of the appliances. Each appliance requires up to 140Watts of electric AC power to run the fuel pump and air compressor inside the Airtronic burner as well as to power the automated control box. The following Babington appliances were selected and pilot tested at the camp:

Tray Ration Heater (TRH): This is a double-walled cooker with a 60 liter cooking vessel inside. It has excellent thermal transfer and outside insulation that keeps the water jacket and food at high temperatures for an extended time period.

Corn-Soya Blend Cooker (CSB): This is a double-walled cooker especially designed for CSB cooking at refugee camps. The CSB Cooker can cook up to 250 liters of food at a time. Babington developed this cooker especially for these field trials.

Multi-Function Cooker (MFC): This is a simplified design of a larger appliance built for military use, designed to meet multiple cooking needs in institutional settings using large pots. The MFC has a grill and oven that can be placed on the burner. The stove is mounted on a sled for mobility. The Airtronic burner shoots a flame laterally into the firebox beneath the burner. Hot combustion gases are expelled from the top of the firebox. No flame is discharged from the firebox. Small holes in a grill at the top of the firebox spread heat uniformly.

Powered Multi-Function Burner (PMB): This is a simplified design of the MFC created to meet the needs of institutions for large pot cooking. Like the MFC, it consists of the Babington Airtronic burner mounted on a heating sled. The clean, odorless flame produced by the burner discharges into the firebox. The final stage of combustion is completed in the firebox. Only heat and not flame is discharged from the perforated surface at the top of the firebox. The small holes in the top of the firebox serve as a means of spreading the heat uniformly as the hot exhaust gases are expelled from the firebox.

Technology Installation

i. **Burner testing:** At Pugnido Camp, all of the burners in the stoves were dismantled, tested and serviced prior to commencing the field tests.


ii. **Installation**: In the kitchen, the stoves were placed at suitable locations for safe operation and to avoid interference with the activity patterns in the kitchen.


iii. **Test run & training of the cooks on how to use the stoves:** The burners were fitted back into the cookers and test runs were completed. Water was heated to boiling (±90ºC) during the test run and comments from the cooks on the temperature (readiness for cooking) were taken as reference. After the water heating test, the cookers were used for actual food preparation. The prepared food was tested by students for comment.

Training was provided to all of the cooks in the kitchen and to cooks in all shifts. Every cook learned how to use the stoves. They were able to open, close, turn on and off, and tell when the CSB was cooked and ready to serve.



iv. **Cooking trials:** The CSB cooker was able to replace two of the kitchen's 150-liter pots used on the fuelwood stoves. The TRH cooker was only able to cook 60 litters of food. The 150 liter pot was used on the MFC cooker but the PMB cooker was not able to accommodate any of the pots used in the kitchen. Therefore, a pot rest modification was designed and fabricated for the PMB. Data was collected while the cooking was done. Cooking routinely starts at 7:00 am in the morning. All the stoves are used to prepare food to be ready at 10:00 am for students. Information like amount of water added, starting time, time for water boiling, temperature, amount of fuel used, time of cooking, etc., were all recorded.

Pugnido Camp Cooking Trials

4. Test Methodology

The camp's schools run two cooking sessions each day, one in the morning and another in the afternoon. The CSB meals are served to schoolchildren at their breaks, at 10:00 am in the morning and at 4:00 pm in the afternoon. The school kitchens use similar semi-improved firewood stoves. Each kitchen uses seven of these stoves. The schools are open five days per week, ten months of the year. A tractor trailer load of firewood is supplied by ARRA every week and woodchoppers at the school kitchens prepare and provide wood in pieces to the cooks.

Pugnido Camp School Kitchen *Wood Chooping at School Kitchen*

CSB is the only food cooked for schoolchildren at the camp schools. The CSB is prepared using 120 liter volume pots in all of the kitchens. The CSB is cooked by first boiling 60 liters of water followed by mixing 15 kg of CSB and 3 kg of sugar in 40 liters of cold water. The CSB and the

sugar are measured by the Center Cooking Supervisors while the water is measured by the cooks during each cooking session. The CSB and sugar mixture is poured into the water once it is boiling and continuously stirred until the CSB is ready. The boiling water and CSB-sugar mixture are cooked for 30 minutes to make it ready for consumption. Therefore, cooking time is the time to boil 60 liters of water and cook the CSB for 30 minutes at a boil.

CSB Cooking Ingredients Measurement

The study team, comprised of Gaia, HoAREC&N and ARRA, observed the stoves and the cooking and conducted the evaluation. Camp and zonal officers of UNHCR and ARRA visited the pilot study.

Officials from ARRA and UNHCR visited the pilot study and observed the cooking trials

Operation and maintenance training was provided to the staff of ARRA to facilitate further experiments and trials of the Babington appliances by ARRA.

Operation and Maintenance Training to ARRA Staff

4.1 Baseline Methodology

- The Controlled Cooking Test (CCT) protocol from the Global Alliance for Clean Cookstoves was used. Two kitchens were selected for the CCT, assuming that all of the camp school kitchens are quite similar with regard to the type and amount of food cooked as well as the pots, stoves and fuel used. The firewood prepared and provided to the cooks was measured as well as its moisture content.

4.2 Pilot Test Methodology

- The Controlled Cooking Test (CCT) protocol from the Global Alliance for Clean Cookstoves was applied. As in the baseline study, the pilot test was conducted in two kitchens. Stove use training was provided and sufficient time was allowed for the cooks to become familiar with the stoves. Similar amounts or a proportional quantity of CSB and water was measured and cooked with the new stove. Fuel consumption measurements and cooking times were registered. Data was also collected by the following methods:
    - Survey questionnaire to 7 cooks,
    - Focus group discussion (FGD) with 11 cooks, and
    - Observations.

5. Results

5.1 Results of Baseline Study

Table 1: (following page)

Table 1

Test Site	Number of Students	Number of Test Rounds	Number of Test Stoves	Average Result of Measured Parameters					
				Weight of CSB cooked (in Kg)	Weight Sugar mixed (in Kg)	Volume of Water used for cooking (in lit)	Cooking Time (in min)	Weight of firewood used (in Kg)	Firewood moisture content (%)
Site-1	2894	**5**	**5**	**15**	**3**	**100**	**78**	**14.9**	**17.4**
Site-2	2524	**4**	**5**	**15**	**3**	**100**	**75**	**14.6**	**17.1**

On average, each stove consumes 14.8Kg of firewood and takes 76.5min to cook CSB. The results show that 740Kg of firewood is consumed each day by the four kitchens and 25 stoves that cook in two shifts. This is estimated to be 163ton of firewood consumption annually for 10 months the schools are open each year.

School Kitchens' Semi-Improved Firewood Stoves

5.2 Results of Pilot Study

5.2.1 CCT Result

Table 2:

Test Site	Type of Appliance	Number of Test Rounds	Average Result of Measured Parameters				
			Weight CSB cooked (in Kg)	Weight Sugar mixed (in Kg)	Volume of Water used for cooking (in lit)	Cooking Time (in min)	Fuel Consumption (in lit/hr)

Site 1 & Site 2 (5,418 students)	**CSB Cooker**	**8**	**30**	**6**	**200**	**150.5**	**1.44**
	TRH	**6**	**10**	**2**	**65**	**91.5**	**1.38**
	MFC	**9**	**15**	**3**	**100**	**81**	**1.41**
	PMB	**4**	**15**	**3**	**100**	**78**	**1.38**

The Babington stoves have an average diesel fuel consumption of **1.4 liters per hour** while it takes an average of **78 minutes** to prepare a 120 liter pot size CSB.

Cooks Using Babington Stoves and ARRA Staff Supervising

5.2.2 Result of Survey Questionnaire and FGD

The school kitchen cooks stated that they are facing daily problems because of the semi-improved firewood stoves they are using. The cooks explained they suffer from skin burns, low-blood pressure, less sleep, eye problems and even perceive the stoves to have a negative effect on their reproductive health. Moreover, cooking with large pots and firewood is challenging. In addition, the pots are burned, which makes cleaning very difficult and time consuming.

The Firewood Stoves Burned the Pots

The cooks stated they were happy with the new technology introduced and the cooking experience because the stoves:

- ✓ “burn cleanly”
- ✓ “do not have a burning flame”
- ✓ “are easy to wash since they do not burn the food”
- ✓ “do not require their constant attention; easy to cook with.”

Both the survey and FGD show similar results regarding appliance preference ranking:
The CSB-Cooker is ranked first, the MFC second, the PMB third and the TRH fourth.

The women stated that they are generally pleased with the different Babington appliances and that the differing sizes of the stoves influenced their rankings. The CSB-Cooker was favored because it can reduce the need for two large pots, reducing this to one. They reported that, unlike the firewood stove, which requires a cook’s attention for each large pot, a single cook using the CSB-Cooker can cook two large pots of CSB. The TRH is preferred least because of its smaller size. The cooks found using the new technology to be easy, but pointed out that more training is necessary.

The cooks believed that switching to the new cooking technology would improve their health and make their jobs easier because is the stoves burn cleanly and it do not require constant attention. They pointed out that they could attend to other duties since the new technology requires minimal attention.

6. Summary and Recommendations

The study team observed that cooking with firewood for the school feeding program is a difficult and arduous task that exposes the women to high levels of carbon monoxide and particulate matter. Although the cooking time for the firewood stove is reasonable, lighting the firewood stoves and cleaning burned pots are time consuming tasks. Cooking with the firewood stoves requires the full attention of the cooks to ensure that the fire is burning well and to continuously stir the pots in order to minimize CSB burning at the bottom of the pots.

Dependency on firewood for cooking consumes a significant portion of ARRA's financial and logistical resources given the need to identify sources for firewood and to collect, haul and supply the kitchens with firewood. It was beyond the scope of this study to quantify ARRA's problem with firewood but it is well known that the volume of firewood required is large and the costs are difficult for ARRA to bear. Moreover, the reliance on firewood contravenes government policy. We would recommend that more study be given to describing and quantifying this problem. This would place in better perspective the benefits that the Babington stoves could provide.

The pilot study showed that the Babington technology is well suited for cooking CSB for the school children and is preferred by the cooks over the firewood stoves. The cooks found the new stoves to be easy to cook with and to clean. They observed that the stoves do not burn the CSB and do not require their constant attention, freeing up time for other meal preparation activities. The clean burning stoves and the ability to prepare a larger volume of meals in the same amount of time were highly valued by all of the cooks. The CSB Cooker was the appliance favored by all of the cooks as well as by the supporting staff of the school feeding program. The study team concluded that it is able to replace two firewood stoves. The MFC and PMB were also well liked and found to be suitable stoves for the schools' CSB cooking, as one-to-one replacements for the firewood stoves. The technology replacement strategy should consider the cost of the CSB Cooker versus the cost of the MFC and PMB to determine the best strategy for replacement.

Although there were no major challenges faced during the pilot trial, the study team recommends that the following technical issues be addressed before introducing the next round of Babington appliances into the camp:

- Despite the minimal electrical power requirements of the stoves, a reliable off-grid power supply is vital to successfully operating the Babington stoves. The pilot was conducted using a diesel-fired electrical generator, which created some challenges for the cooks to

run the stoves smoothly. This generator also consumed diesel fuel, offsetting the savings of fuel achieved in the highly efficient burners. Moreover, any electrical generator requires tuning and maintenance. Supplying electrical power to the Babington stoves using a solar-powered system, requiring solar panels, storage batteries and an inverter, would make the stove operation easier, more reliable and more energy efficient.

- The Babington Airtronic burner is fitted with sensors and programmed automated controls, making it safe and easy to use. However, the team observed that it was challenging for the camp cooks to manage the functions and especially the automatic shutdown of the burners. As a result, it is recommended that the burner control system be made to operate manually within the limits of safety, in order to facilitate easy operation by the cooks. It is possible that the control boxes were not functioning properly. They appeared to be unduly sensitive and to cause unnecessary shut downs of the burners.
- The MFC and PMB pot seats should be modified to accommodate the 120 liter pots of the camp kitchens so that better energy efficiency can be achieved than what was observed during the pilot test.
- Diesel fuel purchased in Gambella and used in the camp is observed to have higher impurities than normal, requiring a fuel filter for the Airtronic burners that can withstand clogging and repeated cleaning.

The study team suggests the following steps be taken for successful introduction of Babington stoves into the refugee camps:

- Integrating a Solar PV system as the electric power source for the burners. Solar power is the preferred off-grid source in Ethiopia. This would also reduce the consumption of diesel fuel.
- Equip the burners with a less automated operating system, for example, replacing most automatic controls with manual controls.
- Pot-rest modification to be able to accommodate pots with 60 cm diameter bottoms but also with a design that will seat pots as small as 30 cm in diameter.
- Modify the burner fuel flow system to be less sensitive to impurities in the fuel, and design a fuel filter system so that it will continue to operate despite the accumulation of impurities in the filter. The fuel used in the pilot was purchased from a fuel station at Gambella and is typical of what is available. We filtered the fuel first before putting it in the stove fuel tank. But we continued to face the problem of burner shut down when the filter became clogged.
- Conduct further tests with the burners using ethanol, biodiesel, plant oil, used cooking oil, used motor oil and mixes of these to respond to the Ethiopian government's emphasis on promoting liquid biofuels and the utilization of waste to energy.

Our take-away is that the introduction of this clean-burning liquid fuel technology could successfully replace the use of firewood, thereby reducing the health hazards to the cooks, the arduous labor associated with institutional cooking, and also reduce the negative environmental impacts of firewood collection and the costs incurred by ARRA and the UNHCR in fuelwood purchase and handling. The overall energy efficiency in camp cooking operations would be substantially improved.