Zanzibar Pilot Study Final Report
June 2015

UNIDO

PROJECT GAIA ENERGY REVOLUTION

This reported is submitted to UNIDO on June 16, 2015 in response to the ToR Small-scale demonstration of ethanol as an alternative fuel for clean cookstoves in Zanzibar, Tanzania.

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Our thanks also go to the large number of households who opened their doors to us.

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I. Executive Summary

In February 2014, UNIDO commissioned Project Gaia to complete an Ethanol as a Cooking Fuel Scoping Study for the island of Zanzibar. Following positive findings from the Scoping Study, UNIDO commissioned a Pilot Study for Zanzibar to test the adoption and potential benefits of ethanol fuel and stoves for household energy.

Ethanol has many benefits over traditional biomass fuels and other clean fuels. Ethanol can be produced locally or imported. In each case, new economic opportunities are created in the distribution of fuel and stoves, and farmers are given new markets. Ethanol fuel and the CLEANCOOK stove eliminate Household Air Pollution (HAP) when the stove is the only stove used. Ethanol reduces the need for firewood collection, deforestation, and families' reliance on dirty fuels. Families save time when using the CLEANCOOK stove and are able to dedicate more of their day to educational or economic opportunities. Ethanol is unique as a renewable, clean fuel since it can be produced locally, anywhere in the world, and can be transported easily in liquid form.

The 2014-2015 pilot study in Zanzibar demonstrated that ethanol is an ideal fuel for the Zanzibar household market. 95% of participating families believed that ethanol fuel and the CLEANCOOK stove were preferable to other fuels and stoves. 73% of families used the stove every day during the study. Families reported saving 2.1 hours each day on average by switching to ethanol. Ethanol was purchased in both urban and rural regions of Zanzibar, including Kisakasaka, a village where 100% of the families reported collecting firewood for fuel. The average particulate matter concentration in the kitchens tested was greatly reduced after the households began using the CLEANCOOK stove – from 575.4 to 109ug/m^3, a very significant improvement in household air quality. The CO concentration in households dropped to 3.5mg/m^3 during use of the CLEANCOOK stove, significantly below the World Health Organization guideline of 10mg/m^3. Households purchased 2-3 liters of fuel each week. Families purchased fuel for 1,600 TSH per liter throughout the study and continue to purchase fuel at this price. However, families stated that they would prefer to purchase fuel for 1,000-1,300 TSH per liter.

A Steering Committee made up of government officials from key ministries convened three times during the course of the study. The Steering Committee communicated updates from the pilot study back to their respective offices, gave recommendations for the continued distribution of fuel, and garnered government support and approval for ethanol fuel for household use.

Based on the positive findings from the pilot study and support from local government, Project Gaia recommends a commercial scale-up of the pilot project. Project Gaia has continued the supply of fuel from Zanzibar Sugar Factory to participating families and is working with local partners to develop a sustainable fuel and stoves business. Project Gaia recommends that fuel be imported from other East African countries at a lower cost than the locally produced fuel so that more consumers can afford to adopt ethanol. Project Gaia also recommends an educational piece on ethanol fuel efficiency as part of the marketing strategy for the stove and fuel.

II. Introduction

Overview of Zanzibar

Zanzibar is a semi-autonomous state of the United Republic of Tanzania. Two main islands, Unguja and Pemba, with a total land area of 2,654 square kilometers, constitute Zanzibar. Unguja is the largest island of the two, constituting 63% of the total land area and providing a home to about 70% of the population[1]. According to the 2012 Population and Housing Census, the population of Zanzibar is 1,303,569 with a growth rate of 2.8% per year. About 57% of the population lives in rural areas. The government administration of Zanzibar is divided into five regions, three in Unguja and two in Pemba, comprising ten districts.

Economy of Zanzibar

The Gross Domestic Product of Zanzibar for 2012 at market price was 1,354.2 billion TSH ($861 million USD) with a GDP per capita of $638 USD. The main economy of Zanzibar is based in the service sector, which accounts for about 52% of the GDP. The agriculture, forestry and fishing sectors contribute about 35% to the economy while the industry sector accounts only for about 13%. Main subsectors in the service sector are water and electricity utilities, trade and repair, and transport and communication. In the agriculture, forestry and fishing sectors, crop production accounts for two thirds of the value of these sectors. The balance of trade has always been negative for Zanzibar and the gap is continuously growing. In 2012, Zanzibar's export earnings were 67,390.5 million TSH while imports were 271,273 million TSH, with a negative trade balance of 203,882.5 million TSH. Vegetable products, mainly cloves, account for 94% of the total export earnings[2].

Energy Use in Zanzibar

In terms of energy consumption, the household sector makes up the lion's share from the total national energy consumption. The household sector accounts for about 84% of the total energy consumption in Zanzibar. All other sectors together consume only 16% of the total. Households almost entirely depend on biomass, mainly on firewood and charcoal, for cooking. The proportion of firewood to charcoal in the households varies by settlement type. Firewood is the main cooking fuel for the rural households while charcoal is the primary fuel used by urban households.

The major cooking fuels for urban and rural households in Zanzibar are charcoal and firewood. A cooking fuels consumption survey in 2010 showed that firewood is the primary cooking fuel for rural households while charcoal is the primary fuel for urban households. About 90% of the rural households and 43% of the urban households in Zanzibar depend on firewood for cooking. Findings in the Project Gaia baseline survey also confirm this data. Charcoal and paraffin are mainly present in urban areas, and only very few households use them for cooking. Preference for cooking fuels by household depends on the availability and price of the fuel and its relative convenience.

Despite scarcity of locally produced charcoal and its rising price, there is an apparent general trend of shifting from firewood to charcoal by both urban and rural households. Comparison of biomass cooking fuel consumption for 2004-2005 and 2009-2010 shows a shift by 5% from firewood to charcoal. The total national level charcoal consumption increased from 21.2% to 26.2% with a corresponding decrease of firewood from 75% to 70.8%. This perhaps is due to the preference of households for a cleaner fuel even

[1] Zanzibar Strategy for Growth and Reduction of Poverty (ZSGRP-I) 2007 to 2010, January 2007.
[2] Office of the Chief of Government Statistician, Socio-economic Survey of 2013, Statistical Report, Zanzibar, March 2013.

though it is more costly. It is also an indication that convenience of use is a governing factor that influences household choice of cooking fuels. However, price of cooking fuel also governs the choice that households make. The costs of paraffin and electricity have become prohibitively expensive for households to use for cooking. Kerosene usage for cooking declined from 2004/2005 to 2009/2010, from 2% to 1.5% while electricity use declined from 1.3% to 0.9%. This could indicate the limit that households are able or willing to pay for cooking energy[3]. When fuels become unaffordable, lower income households have little choice but to revert back to cheaper options. In one of the villages visited during the pilot study, Kisakasaka, due to the scarcity of hardwood species suitable for charcoal production, households in the village are no longer able to use charcoal as they once did; they now burn wood directly.

The Benefits of Ethanol Adoption

Figure 1.1: Hillary Njau distributes stoves to study participants at Zanzibar Sugar Factory.

Three billion people worldwide still burn wood, charcoal, dung, and coal in their homes and over four million people die each year from illnesses due to indoor air pollution. These deaths are highly concentrated in developing countries. In Zanzibar, the domestic sector accounts for 84% of Zanzibar's total energy consumption. Biomass fuels account for 82% of the total national energy supply, of which firewood contributes 53% and charcoal 25%.[4] Studies led by the World Health Organization (WHO) indicate that Household Air Pollution (HAP) is a major risk factor for many illnesses such as chronic respiratory disease among adults, pneumonia among children, tuberculosis, asthma, cataracts, low birth weight and prenatal mortality.

Improved wood and charcoal stoves cannot make sufficient improvements in air quality related to health for households experiencing extreme energy poverty. Ethanol, a clean liquid fuel that can be produced easily and affordably from renewable sources, burns cleanly and without smoke. Ethanol completely eliminates the HAP problems associated with biomass energy sources. Furthermore, the stove and ethanol fuel combination eliminates the two major disadvantages of LPG (liquefied petroleum gas) - safety and cost. This fuel is the ideal substitute for kerosene or bottled gas and for wood and charcoal.

[3] Household Budget Survey 2009/2010, Final Report, Office of the Chief Government Statistician, May 2012.
[4] Department of Energy and Minerals, Country Presentation on Energy Policy, Hahad Juma Baka, Zanzibar, May 2010.

The ethanol fuel and stove combination also positively impacts women's security and lives. In countries where PG has implemented projects, CLEANCOOK stoves and ethanol fuel eliminates the need for women to walk up to 10 kilometers and between 2-5 hours per day to gather fuelwood. The CLEANCOOK stove also grants significant timesaving over traditional and improved wood, charcoal, and kerosene stoves. The CLEANCOOK performs similarly to LPG. In PG's projects, families used this saved time for productive activities such as childcare, education, and developing skills to engage in income earning activities.

Ethanol fuel and stoves also have a significant positive impact on the local and global environments. In Zanzibar, the biomass exploitation rate has been so high that prime hardwood species for charcoal are not easily available. Zanzibar's biodiversity and resilience to climate change relies greatly on its mangrove resources. Switching to cleaner fuels can control black carbon, which is produced by burning biomass fuels. The CLEANCOOK stove surpasses WHO standards for carbon and particulate matter emissions. Tests of the CLEANCOOK showed a 94% reduction of particulate matter emissions and 79% reduction in carbon monoxide emissions from traditional firewood stoves.

Efficiency and convenience are among the most important indicators for stove adoption. In pilot studies in Ethiopia, South Africa, Nigeria, and Madagascar, Project Gaia has found that stove users are often most concerned with the ease of use of the stove and fuel, as well as cooking speed. The CLEANCOOK stove has proved to be clean, fast, efficient, and easy to use. Similar results have now been demonstrated in Zanzibar.

Pilot Study Design and Summary

Following the promising scoping study conducted in February 2014 by Project Gaia and Ethio Resources Group, the United Nations Industrial Development Organization (UNIDO) commissioned an ethanol fuel and cookstove study on the island of Zanzibar. The pilot study was a proof of concept; it was designed to test whether ethanol fuel and stoves are commercial options for the Zanzibar cooking market and whether they could benefit public health and the environment. The study included a baseline study, weekly user-acceptance surveys, Household Air Pollution (HAP) monitoring, and focus group discussions.

Figure 1.2: Bottles being filled at Zanzibar Sugar Factory (ZSF).

A total of 120 households were selected in four districts of Zanzibar including, Urban, Western, Northern A, and Northern B, and the village of Kisakasaka. Because of delays in clearing the stoves from customs and receiving the necessary permits to sell fuel, several households dropped out before the stoves were distributed. Another group of households were added to bring the total number of pilot study households up to 122 families with stoves, and a total of 144 households were interviewed for the baseline study. The study UNIDO commissioned was for 150 stoves initially. The study was reduced to 122

stoves so that UNIDO Dar es Salaam and government officials in Zanzibar could have sample stoves. Nine stoves stayed on the mainland with UNIDO and the following stakeholders each received one stove: Regional Administrative Officer (Northern Region), Director of Industries, Assistant Director of Industries, Director of Zanzibar Bureau of Standards, Director of Energy, Principal Secretary Ministry of Empowerment, Youth, Women, and Children, Director of Cooperatives, Principal Secretary 1st VPO, Assistant Principal Secretary 1st VPO, Principal Secretary 2nd VPO, Advisor to the President on Industries, Director of Environment, Minister of Environment, Acting Principal Secretary Ministry of Empowerment, Cultural Secretary Northern "B" District, Hamisi Mosi (ethanol distributor in Stone Town), Minister of Industries, Project Manager Hillary Njau, and one is in the Zanzibar office for display and demonstration.

Figure 1.3: Bottles being capped at ZSF.

Household selection was conducted with the aid of district offices. Officials were asked to select 30 households from their respective districts, and these households were invited to attend a demonstration and introductory meeting. Officials were asked to select households randomly; however, there is a disproportionately large Christian and government administrator population in the study as compared to the population of Zanzibar as a whole. Zanzibar is 98% Muslim, and the pilot study participants were 87% Muslim. In order to participate, selected households should have already been purchasing fuels for cooking and had to be able to pay a 15,000 TSH deposit for the stoves. The purpose of the deposit was to encourage families to take good care of the stoves. If they chose to keep the stove following the pilot study, they were asked to pay 60,000 TSH total with the deposit going towards this payment. If families chose to return the stove, they would be refunded in full as long as the stove was still in good condition. At the end of the pilot study, Project Gaia and UNIDO chose to sell the stoves for just the original 15,000 TSH deposit to encourage good will towards the project during the commercial scale-up phase. Each family was given three liters of fuel for free when they received their stove.

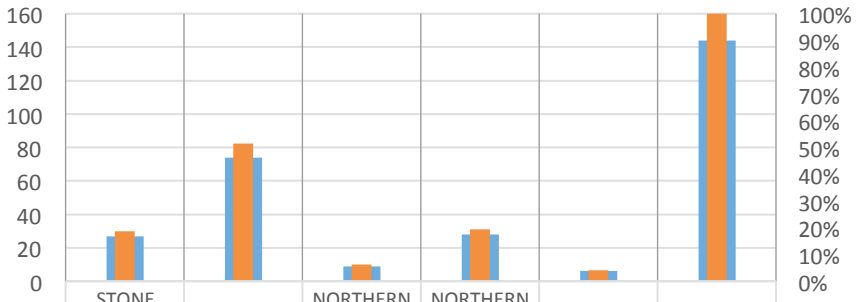
The baseline survey was conducted in November 2014, and again in January 2015 when the new group was added to the study. The weekly surveys ran from January 26 – March 23. Intensive surveys were to be administered to 40 families during the last four weeks of the study. These families were randomly chosen. Focus group discussions were conducted on March 12 and 14, 2015. These focus group studies help to give context to the data gathered in the surveys. Project Gaia has continued the supply of fuel to distributors since the completion of the study and has purchased another 3,000 liters of fuel from the Zanzibar Sugar Factory to continue the supply as a commercial scale-up is planned.

III. Baseline Study Summary and Analysis

A baseline survey was conducted in 144 urban households in five districts in Zanzibar in September 2014 to assess the cooking fuel supply and demand pattern, and households' cooking practices. The objective of the survey was to determine the type and amount of cooking fuels used by the urban households in Zanzibar. Ownership and use of cookstoves by the households were also important issues investigated by the survey. This information was intended for use to devise a strategy that best serves the adoption of clean and affordable ethanol fuel for cooking by the households in Zanzibar.

The survey was conducted in four districts including Urban (Stone Town), Western, Northern A, Northern B and the village of Kisakasaka. The distribution of samples is shown in Figure 3.1 below.

Figure 3.1 Distribution of sample households by district

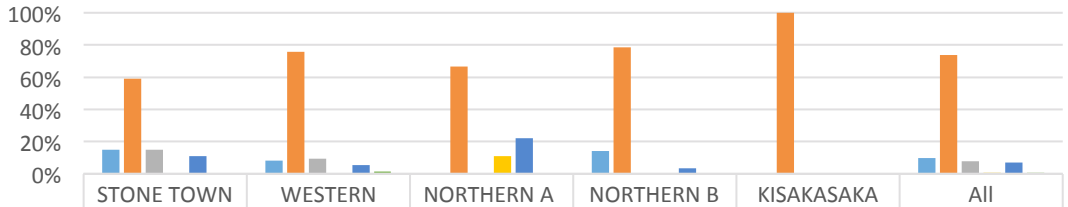


	STONE TOWN	WESTERN	NORTHERN A	NORTHERN B	KISAKASAKA	All
Distribution of Sample Households	27	74	9	28	6	144
Sample household %	19%	51%	6%	19%	4%	100%

Demographic and Socioeconomic Characteristics of the Surveyed Households

The respondents in the surveyed households were either the household heads or the spouses. All respondents were over 20 years old. The majority of them (53%) were less than 40 years old. Elderly respondents were very few (4%) in the households surveyed.

Figure 3.2 Distribution of households by marital status of the respondent

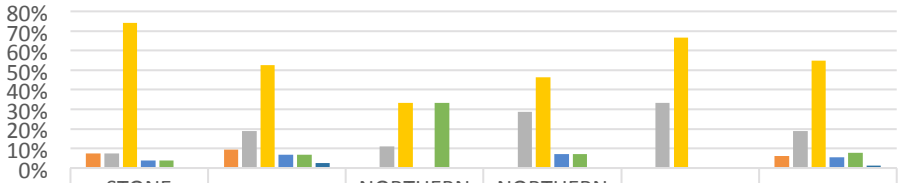


	STONE TOWN	WESTERN	NORTHERN A	NORTHERN B	KISAKASAKA	All
Single	15%	8%	0%	14%	0%	10%
Married	59%	76%	67%	79%	100%	74%
Divorced	15%	9%	0%	0%	0%	8%
Separated	0%	0%	11%	0%	0%	1%
Widowed	11%	5%	22%	4%	0%	7%
Not applicable	0%	1%	0%	0%	0%	1%

Most of the respondents (74%) were married. Marriage status of respondents in Stone Town was a little different than the other towns surveyed. Stone Town is the the capital of Zanzibar and the most urbanized of all the other towns. The percentage of divorced and singles were the highest in Stone Town. On the contrary, in Kisakasaka, 100% of the households surveyed were married. Kisakasaka is a rural town and was less urbanized compared to the other towns surveyed.

Most of the respondents (55%) completed secondary education. In Stone Town, the percentage of households that completed secondary education was about 74%. Only 9% of the respondents in all surveyed districts completed higher education.

Figure 3.3 Distribution of households by educational status of respondent



	STONE TOWN	WESTERN	NORTHERN A	NORTHERN B	KISAKASAKA	All
Some primary	7%	9%	0%	0%	0%	6%
Completed primary	7%	19%	11%	29%	33%	19%
Completed secondary	74%	53%	33%	46%	67%	55%
Completed high school or equivalent	4%	7%	0%	7%	0%	6%
Completed collage, pre-university or university	4%	7%	33%	7%	0%	8%
Completed post graduate	0%	3%	0%	0%	0%	1%

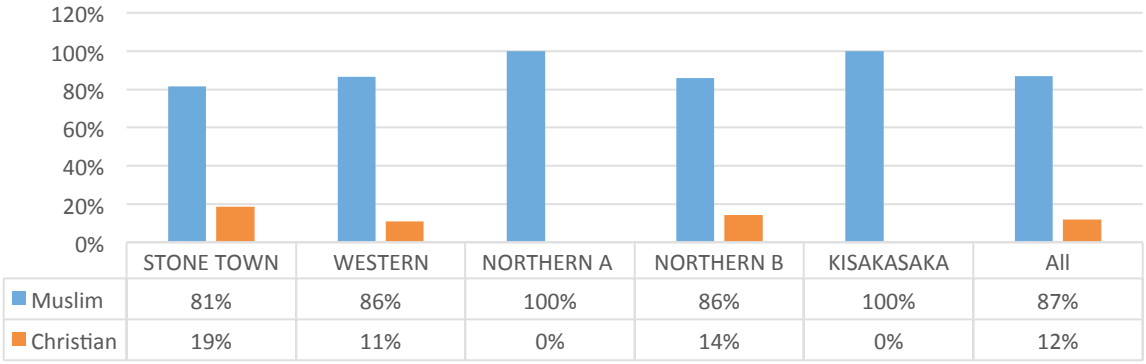
Major occupation of the surveyed households was self employment in small businesses (32%). Civil servants consituted about 22% of household heads. About 23% of the household heads were unemployed during the time the survey was conducted. Unemployment was the highest in Kisakasaka (33%) and was the least in Stone Town (11%).

Table 3.1 Distribution of households by type of occupation of the household head

Occupation	STONE TOWN	WESTERN	NORTHERN A	NORTHERN B	KISAKASAKA	All
Farmer	0%	5%	0%	11%	33%	6%
Teacher	7%	4%	0%	4%	0%	4%
Artisan	0%	0%	11%	0%	0%	1%
Office Worker	11%	8%	11%	0%	0%	7%
Civil servant	15%	18%	33%	39%	0%	22%
Self-employment/own business	52%	32%	0%	21%	33%	32%
Student/pupil	0%	0%	0%	0%	0%	0%
Unemployed	11%	27%	22%	21%	33%	23%
Not in labor force/ retired	4%	0%	0%	0%	0%	1%
Others	0%	3%	11%	4%	0%	3%

The majority of the surveyed households (87%) were Muslims while the remaining were Christians from Northern B and Stone Town (Urban). All the households surveyed in Northern A and Kisakasaka districts were Muslim.

Figue 3.4 Distribution of households by religion of the household head



	STONE TOWN	WESTERN	NORTHERN A	NORTHERN B	KISAKASAKA	All
Muslim	81%	86%	100%	86%	100%	87%
Christian	19%	11%	0%	14%	0%	12%

The average household size in the surveyed households is 6.4. There was slight variation between districts. There was a minimum household size of 5.4 in Stone Town while the maximum was 7.4 in Northern A district.

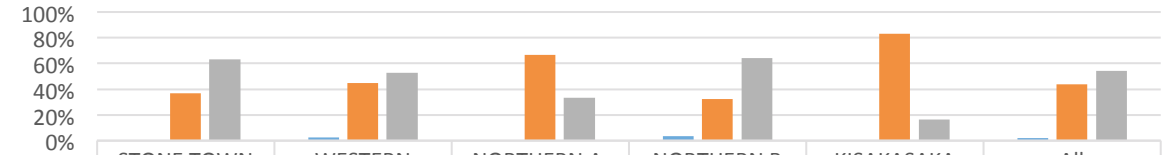
Table 3.2 Average household size in the surveyed districts

District name	STONE TOWN	WESTERN	NORTHERN A	NORTHERN B	KISAKASAKA	All
Average household size	5.4	6.5	7.4	6.8	6.5	6.4

Cooking Practices in the Surveyed Households

Cooking practices of households in the surveyed district were diverse in terms of the type of cooking fuel they used, the number of meals they cook and their expenditure for cooking fuels. The majority of the households in Northern A district (67%) and Kisakasaka (83%) cook two meals a day while the majority of the households in the other districts cook three meals. None of the households reported that they cook more than three meals a day.

Fig. 3.5 Distribution of households by number of meals cooked in a day

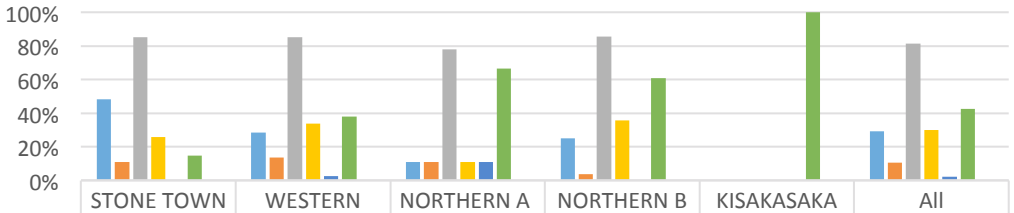


	STONE TOWN	WESTERN	NORTHERN A	NORTHERN B	KISAKASAKA	All
One	0%	3%	0%	4%	0%	2%
Two	37%	45%	67%	32%	83%	44%
Three	63%	53%	33%	64%	17%	54%

Cooking fuels that the households use also depend on availability of the fuel. In Kisakasaka, all households use firewood for cooking. Distribution of other fuels such as electricity and kerosene were limited in the district. With 81% of the households using it, charcoal was the most widely used cooking fuel in all the districts except in Kisakasaka. Next to charcoal, firewood was the second most important cooking fuel. About 42% of the households use firewood for cooking. However, firewood was not an important cooking fuel for the majority of the households in Stone Town. Nearly half of the households in

Stone Town use electricity for cooking. On average, about a third of all the surveyed households use electricity and kerosene for cooking. Only about 10% of the households use LPG for cooking.

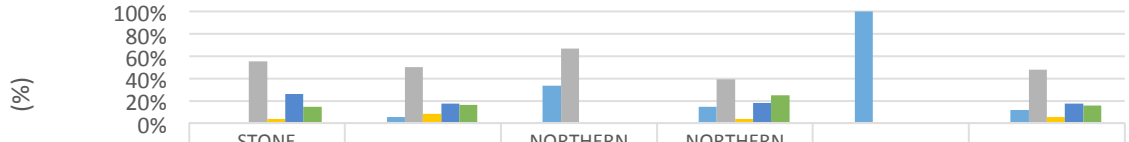
Fig. 3.6 Distribution of households by type of fuel used for cooking



	STONE TOWN	WESTERN	NORTHERN A	NORTHERN B	KISAKASAKA	All
Electricity	48%	28%	11%	25%	0%	29%
LPG	11%	14%	11%	4%	0%	10%
Charcoal	85%	85%	78%	86%	0%	81%
Kerosene	26%	34%	11%	36%	0%	30%
Agri-residues	0%	3%	11%	0%	0%	2%
Firewood (all types)	15%	38%	67%	61%	100%	42%
Other fuel	0%	0%	0%	0%	0%	0%

Even though the surveyed households used a variety of cooking fuels, their choice of a particular type of fuel, which determines the frequency of use of the fuel, depends on several factors including availability, affordability, accessibility, and convenience. The survey showed that charcoal was the most widely and most frequently used fuel. About 80% of the households that use charcoal use it daily. Firewood was also a frequently used fuel. About 80% of the households that use firewood for cooking use it on daily basis. Even though LPG was used by only 10% of the households, the survey indicated that almost all the households (93%) that use LPG use it on a daily basis. Kerosene and electricity were respectively used on a daily basis by 67% and 38% of the households that use the fuels. Most households purchased their cooking fuels; the rest freely collect. All the surveyed households in Kisakasaka and a third of the households in Northern A district collect their cooking fuel.

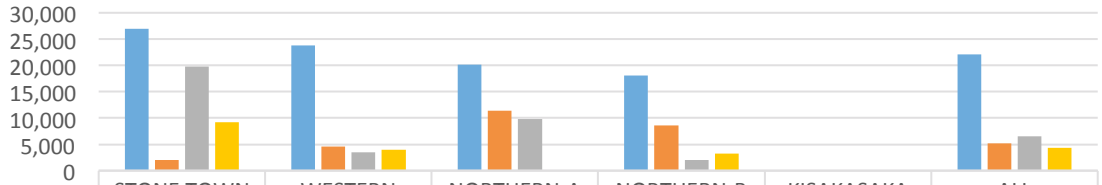
Fig. 3.7 Distribution of households by source of primary cooking fuel



	STONE TOWN	WESTERN	NORTHERN A	NORTHERN B	KISAKASAKA	All
From own source	0%	0%	0%	0%	0%	0%
Collect	0%	5%	33%	14%	100%	12%
Local vender/local shop	56%	50%	67%	39%	0%	48%
Door-to-door seller	4%	8%	0%	4%	0%	6%
Market	26%	18%	0%	18%	0%	17%
Other source	15%	16%	0%	25%	0%	16%

Households' expenditure on cooking fuel depends on the type and frequency of fuel they use. The survey showed that, on average, a household spends about 38,053 TSH per month for different types of cooking fuels. Households that use LPG, on average, spend up to 15,553 TSH per month for LPG alone, consuming between 6 to 14 kg.

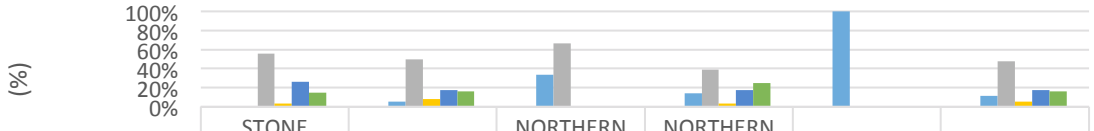
Fig. 3.8 Households' average monthly expenditure for cooking fuel (THS/Month)



	STONE TOWN	WESTERN	NORTHERN-A	NORTHERN-B	KISAKASAKA	ALL
Charcoal	26,963	23,805	20,111	18,071	0	22,060
Firewood	2,074	4,586	11,333	8,643	0	5,135
LPG	19,778	3,449	9,778	2,000	0	6,481
Kerosene	9,230	3,926	0	3,239	0	4,378

Households in Kisakasaka entirely depend on collected fuel. Percentage of households that collect their primary cooking fuel in Western, Northern A and Northern B districts were 5%, 33% and 14%, respectively. Nearly half of the households surveyed purchase their cooking fuels from local vendors. For half of the households, it took them less than 30 minutes to travel to their primary cooking fuel source.

Fig.3.9 Distribution of households by source of primary cooking fuel



	STONE TOWN	WESTERN	NORTHERN A	NORTHERN B	KISAKASAKA	All
From own source	0%	0%	0%	0%	0%	0%
Collect	0%	5%	33%	14%	100%	12%
Local vender/local shop	56%	50%	67%	39%	0%	48%
Door-to-door seller	4%	8%	0%	4%	0%	6%
Market	26%	18%	0%	18%	0%	17%
Other source	15%	16%	0%	25%	0%	16%

Households choose the place they purchase fuel for several reasons. Table 3.3 shows the main reasons why households purchase their cooking fuel from a certain source. The two main reasons given by 30% to 50% of the households were availability of retail purchases (the ability to purchase small amounts) and easy access to the fuel.

Reasons	*Charcoal*	*Kerosene*	*Firewood*	*Agri-residue*
Fuel is cheap	*10%*	*33%*	*22%*	*19%*
Fuel supply reliable	*0%*	*0%*	*13%*	*14%*
Retail possible	*45%*	*47%*	*44%*	*49%*
Easy access to fuel	*10%*	*33%*	*34%*	*23%*
Other reasons	*17%*	*20%*	*13%*	*12%*

Table 3.3 Reasons for choosing fuel supply source

Choice of Cooking Fuels

Choice of cooking fuels depends on several factors that are related to the attributes of the fuels that the households use for cooking. As can be seen in Table 3.4, the main reasons households chose their fuels were related to access to the fuel and its convenience to use. Results of the survey also showed that more than half of the surveyed households liked charcoal and firewood because they can be used to cook different types of food. Moreover, about 40% of the households also indicated that the availability of charcoal in smaller retail units and the fact that it does not need much attention or tending during cooking makes it a fuel of choice. Electricity and LPG are liked by more than half of the households that use them for their cleanliness.

High electricity tariffs and the high cost of the stove were the reasons for 69% and 50% of the surveyed households not liking to cook with electricity. In addition, about 40% of the households responded that electricity or electric cookstoves are undesirable because they can only be used for certain types of cooking. For about 77% and 97% of the households, smoke was reported as the main reason for dislike of kerosene and firewood, respectively.

Reasons	*Electricity*	*LPG*	*Charcoal*	*Kerosene*	*Firewood*
High cost of fuel	*69%*	*20%*	*47%*	*23%*	*20%*
High cost of stove	*50%*	*33%*	*15%*	*23%*	*0%*
Difficult to access fuel	*2%*	*0%*	*9%*	*0%*	*15%*
Supply not reliable	*2%*	*7%*	*12%*	*9%*	*7%*
Limited or no retail	*21%*	*27%*	*8%*	*12%*	*15%*
Not clean	*0%*	*0%*	*29%*	*26%*	*64%*
Smoky	*2%*	*0%*	*32%*	*77%*	*97%*
Not easy to use	*2%*	*0%*	*5%*	*5%*	*3%*
Not easy to light	*0%*	*7%*	*50%*	*2%*	*23%*
Requires more attention	*36%*	*13%*	*3%*	*42%*	*31%*
Not cook different food	*40%*	*0%*	*3%*	*51%*	*2%*
Other reasons	*7%*	*33%*	*14%*	*19%*	*13%*

Table 3.5 Reasons for households for not liking the fuel they use

Cooking Devices

Households use a range of cookstoves the price of which varies significantly. Electric cookstoves are the highest in price while firewood stoves are on the lower end.

Table 3.6 Average cookstove prices and number of burners per stove

Stove type	Electric	LPG	Kerosene	Improved charcoal	Traditional Charcoal	Improved firewood	Traditional firewood
Price (TSH)	115,345	70,000	11,116	21,016	18,967	6,500	1,619
Number of burners							
1	17%	54%	98%	97%	100%	80%	100%
2	46%	15%	0%	3%	0%	20%	0%
> 2	37%	31%	2%	0%	0%	0%	0%

Most of the cookstoves in the households were single burner except the electric cookstoves where two or more burners were observed in over 80% of the surveyed households.

Ownership of different types of cookstoves varies significantly from one district to the other. Improved cookstove ownership is the highest (64%). None of the households in Kisakasaka own any type of charcoal stove. Traditional firewood stoves (open fire) were ubiquitous in Kisakasaka.

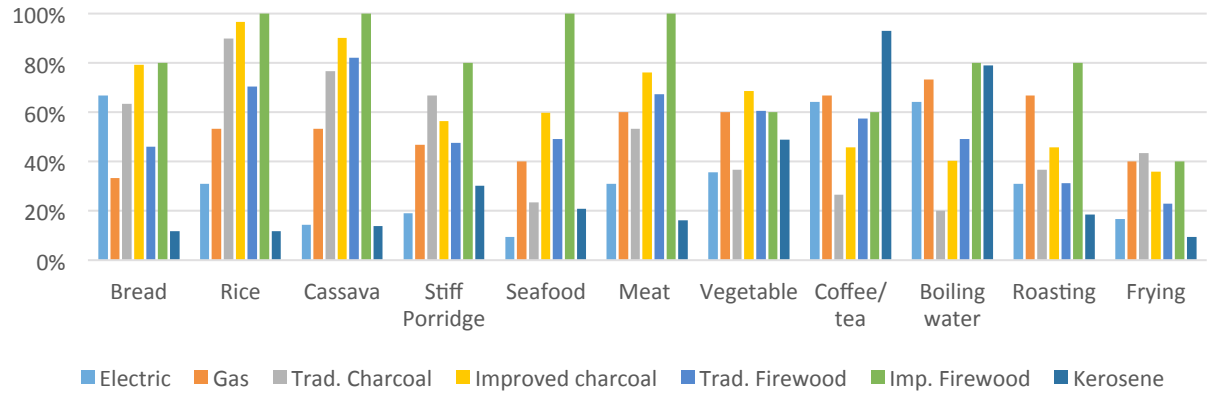
Reasons	*Stone Town*	*Western*	*Northern-A*	*Northern-B*	*Kisakasaka*	*All*
Electricity	37%	27%	0%	18%	0%	24%
Gas	15%	9%	11%	4%	0%	9%
Trad. charcoal	15%	22%	0%	36%	0%	21%
Impr. Charcoal	70%	69%	67%	57%	0%	64%
Trad. firewood	7%	24%	44%	43%	100%	29%
Imp. firewood	0%	3%	0%	7%	17%	3%
Kerosene	30%	31%	11%	39%	17%	31%

Table 3.7 Cookstove ownership by district

Cooking Devices and End-Uses

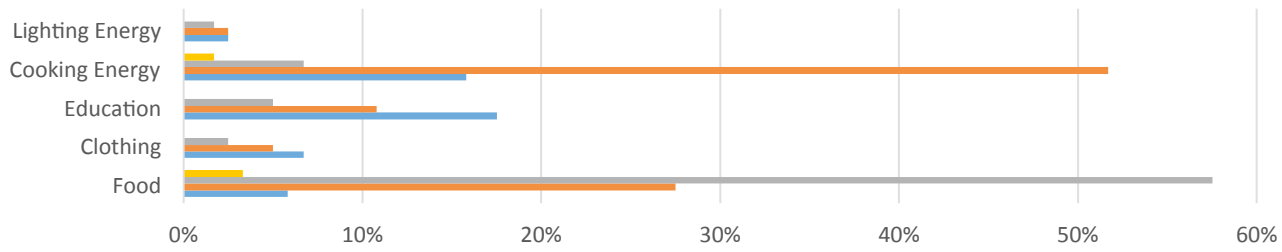
Cooking fuel and stove stacking was a common mechanism for the households to cope with the unreliability of the cooking fuel supply and price fluctuations. The other reason that the households kept different fuels and stoves was the convenience or preference of certain fuels for certain types of end-uses. The households were asked for their preferences for using the particular types of cooking fuels and stoves that they own for particular end-uses. Figure 3.10 shows the responses.

Fig. 3.10 Cookstoves that households like to use by end-use type



It can be observed from Figure 3.10 that electricity and kerosene do not seem to be highly preferred for cooking energy-intensive and time-consuming end-uses such as cooking meat, rice and cassava while charcoal and firewood were generally preferred for these end-uses. Kerosene was mainly preferred for boiling coffee/tea or water. It seems that households preferred to use cheaper fuels for end-uses that required higher energy consumption. Households are cautious about their fuel expenditures as it takes up a significant proportion of their income. After food, the greatest expenditure in the surveyed households was for cooking fuel. About 60% of the households spend over 10% of their income on cooking fuel.

Fig. 3.11 Proportion of households by expenditure type



	Food	Clothing	Education	Cooking Energy	Lighting Energy
>75%	3.3%	0.0%	0.0%	1.7%	0.0%
50%	57.5%	2.5%	5.0%	6.7%	1.7%
25%	27.5%	5.0%	10.8%	51.7%	2.5%
<10%	5.8%	6.7%	17.5%	15.8%	2.5%

After cooking fuel, house rent was the largest expenditure for the households. Average expenditure on house rent was about 22,289 THS per month. However, only about 13% of the surveyed households live in a rented house.

For the majority of households (94%), salaried employment was the main source of income. However, there are differences between the districts. For households in Kisakasaka farming is the major employment and main source of income.

Source of Income	*Stone Town*	*Western*	*Northern -A*	*Northern -B*	*Kisakasaka*	*All*
Employment	85%	97%	89%	100%	17%	94%
Business/trade	41%	28%	22%	25%	33%	30%
Farming	0%	8%	11%	14%	100%	12%
Others	15%	14%	11%	0%	17%	11%

Table 3.9 Employment and sources of income for the households

Household Air Pollution

There is a close relationship between the location in which cooking occurs and the level of household air pollution (HAP). On average, a little over a third of the households had a separate kitchen in the main house while about 13% of them had their cooking places separate from the main house. Most households were aware of the impact of the cooking fuels they use on their health. All households interviewed in Kisakasaka felt that the fuel they use, firewood, affected their health. About 20% of the households believe that coughing and eye problems are related to cooking. Only 1% of them believe that back pain and cooking are related.

IV. Weekly Surveys Summary and Analysis

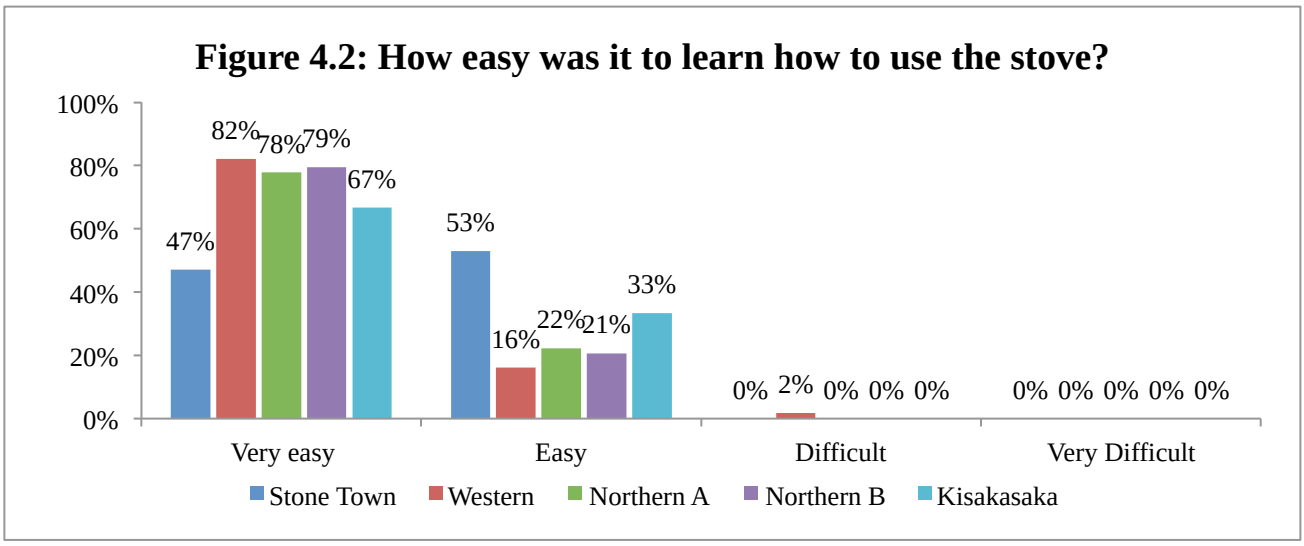
Figure 4.1: Woman cooking on the CLEANCOOK stove in Zanzibar

Once stoves were distributed in late January 2015, all 122 households were followed on a weekly basis. Six weekly surveys were administered to households including an initial survey, four weekly surveys, and a final survey. Forty households were also selected randomly to participate in a more intensive survey. The initial survey was administered following participants' first week of using the stove. This survey gauged households' initial impressions of the stove and fuel and tracked their weekly cooking habits. The final survey asked questions about the households' impressions of ethanol and the CLEANCOOK stove after using the stove for six weeks. The final survey also asked families if they saw any benefit in switching to the ethanol stove over their other stove alternatives and contained questions regarding the commercialization of the pilot project. Both the initial and final surveys contained the same set of questions as the weekly surveys. The weekly survey questions were used to track how much fuel was being purchased and used, what stoves and fuel people were using to cook, and who in the family was traveling to purchase or collect the fuel.

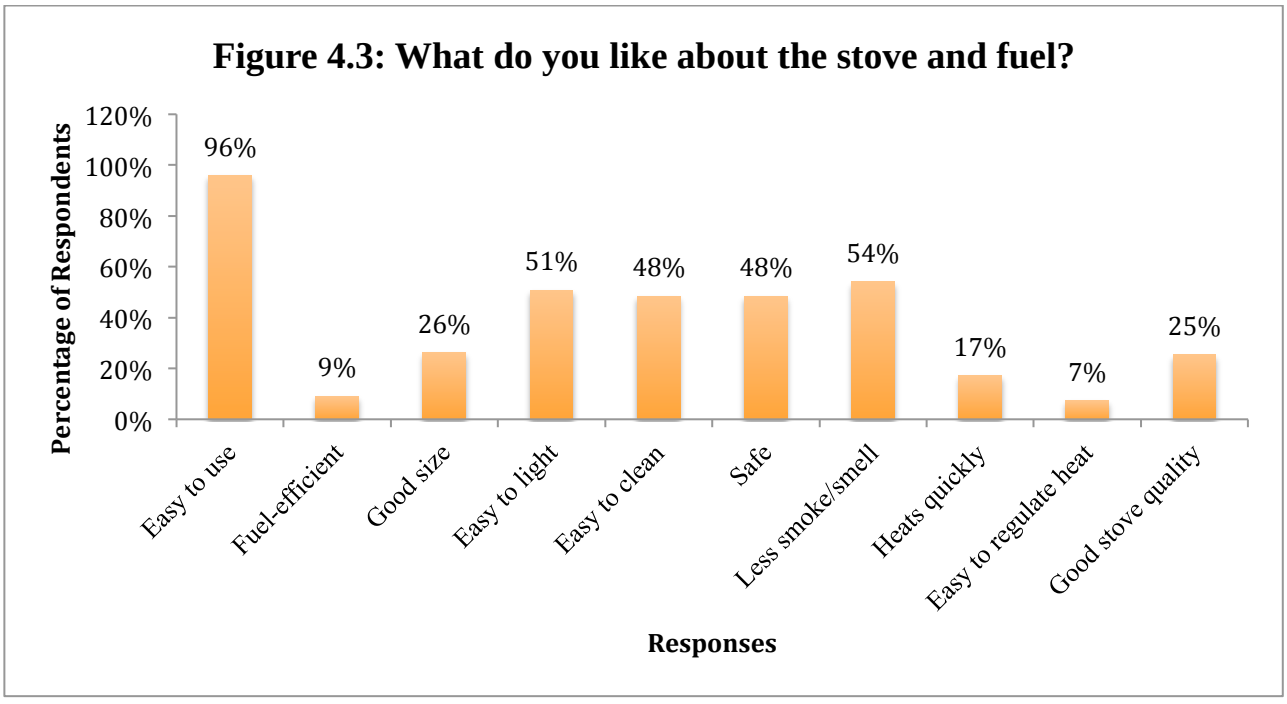
The intensive surveys were administered to 40 households over the final four weeks of the survey. Due to some confusion regarding the survey, only 110 surveys were completed out of the expected 160 surveys. The intensive survey looked at what people were cooking on a daily basis, how many people they were cooking for, and what fuel they were using at each meal. The survey also asked families to estimate how much they were spending on fuel each week.

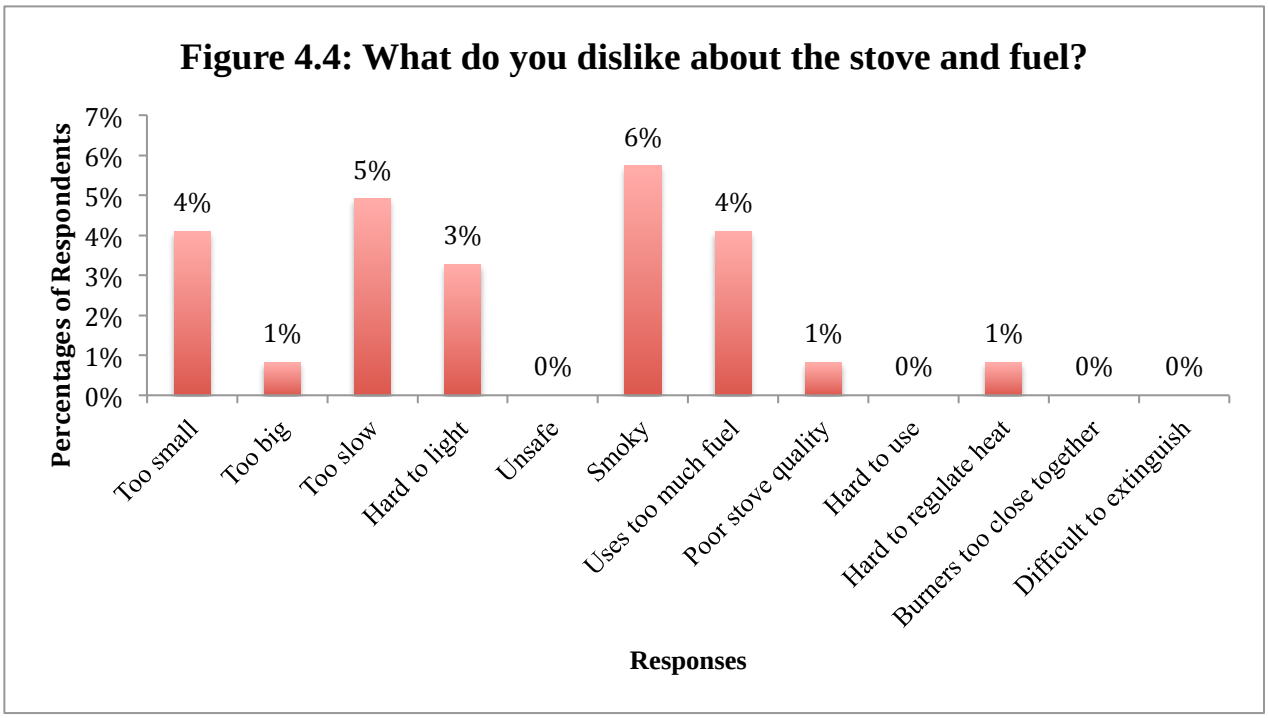
Initial Survey Summary and Analysis

The initial survey was administered to participating households following their first week using the stove. This survey was used to gather data regarding households' initial use and impression of the CLEANCOOK stove and ethanol fuel. Prior to receiving the stove, all households received two safety demonstrations and each household received a safety manual along with the stove. 100% of the households believed that these trainings were "easy" or "very easy" to understand and follow. 98% of the households found it "very easy" or "easy" to learn how to use the stove (Fig. 4.2).

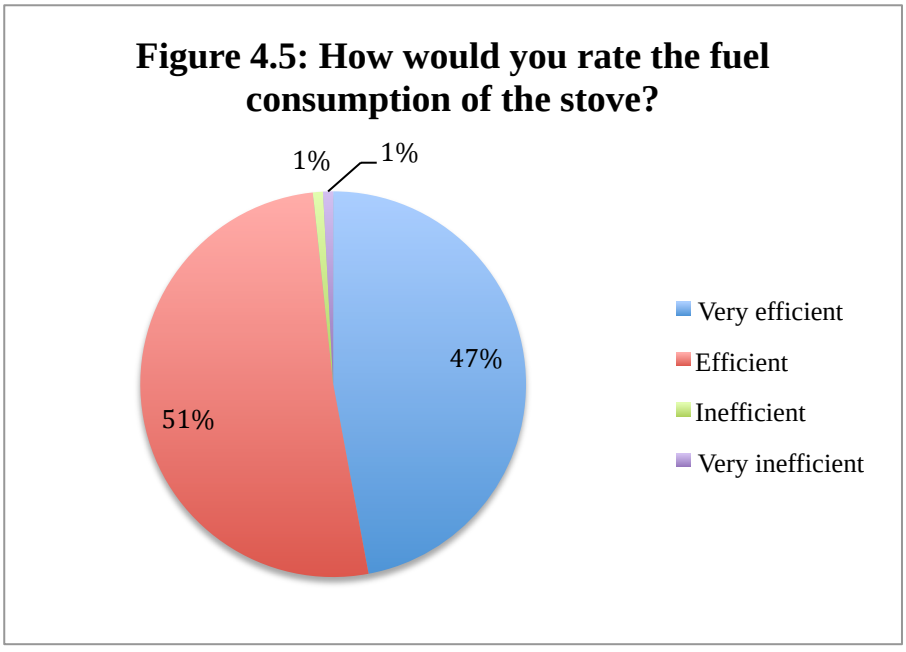


Once respondents learned to use the stove, 100% reported being satisfied with the stove. Participants were asked to list the various reasons they liked and were satisfied with the stove (Fig 4.3). The majority of participants (96%) said they liked the stove because it is easy to use. This was followed closely by: less smoke, easy to light, easy to clean, and safe. Participants were also asked to list what aspects of the fuel they disliked. The majority of households responded that they had no dislikes. However, 6% of respondents said that they found the fuel smoky (Fig 4.4). This can be attributed to the low quality of the fuel purchased from the Zanzibar Sugar Factory. Fuel with fusel oils in particular does not burn as well as clean ethanol in the CLEANCOOK stove. This issue could be easily remedied by purchasing better quality fuel. 96% of the interviewed households responded that ethanol was less smoky than their other fuels.



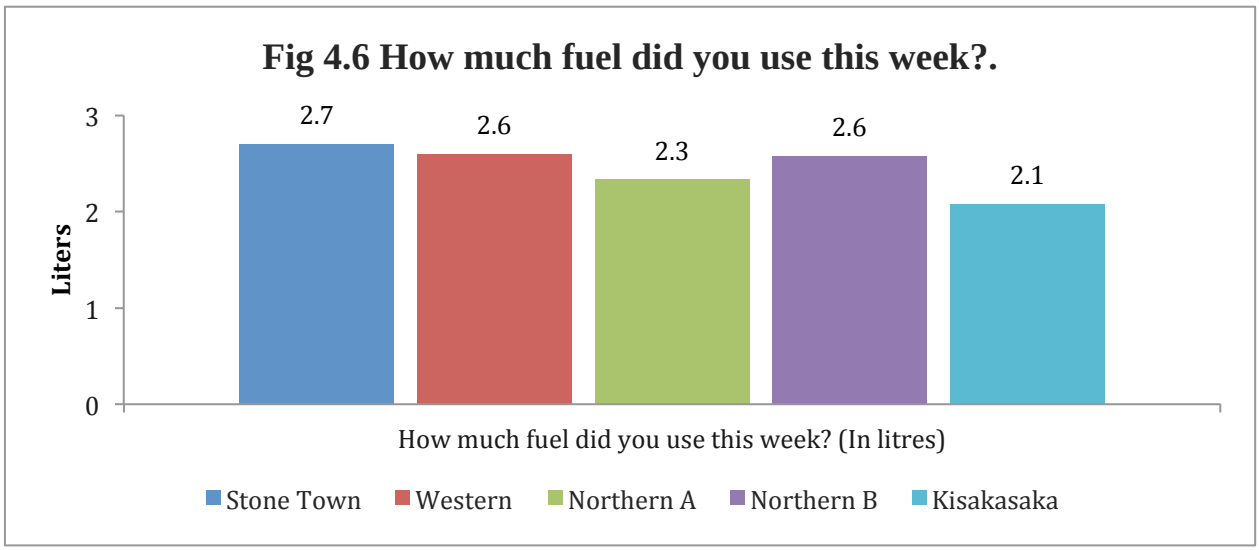


When asked whether it was easier or more difficult to cook on the CLEANCOOK stove versus their previous stoves, 99% of households responded that the CLEANCOOK stove was easier to use. 87% percent of households responded that they could use all of their pots on the stove, and 57% responded that they were able to do all of their cooking on the stove. The 43% that responded that they could not cook all their meals on the stove listed beans, stiff porridge, and rice for large numbers of people as examples of meals they could not cook. Several of these respondents explained it was because the fuel was consumed quickly for these longer cooking tasks. However, 98% of respondents said that the fuel consumption of the stove was either "very efficient" or "efficient" (Figure 4.5).



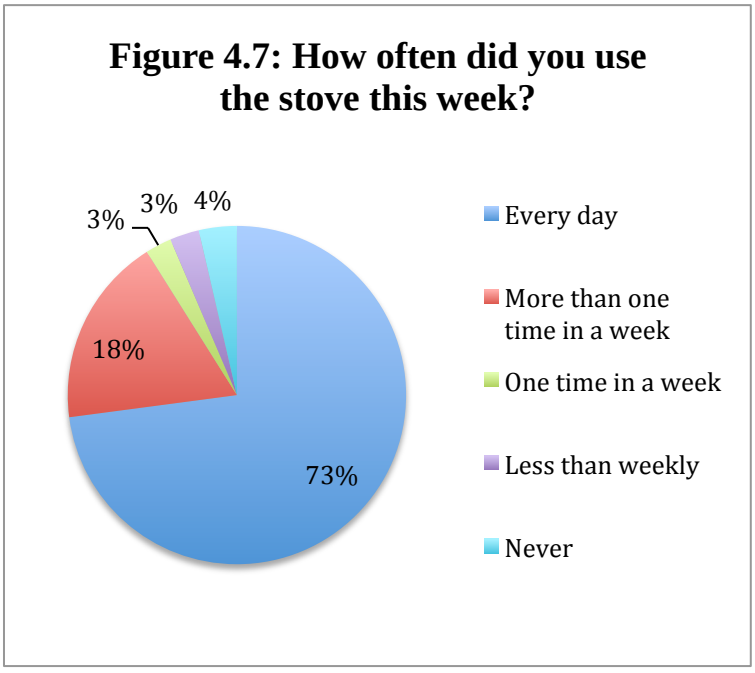
The safety of cookstoves is often an important consideration for families. 38% households felt that the ethanol stove was "very safe", while 62% felt that the stove was "safe". None of the respondents believed the stove to be unsafe or very unsafe.

Weekly Survey Summary and Analysis

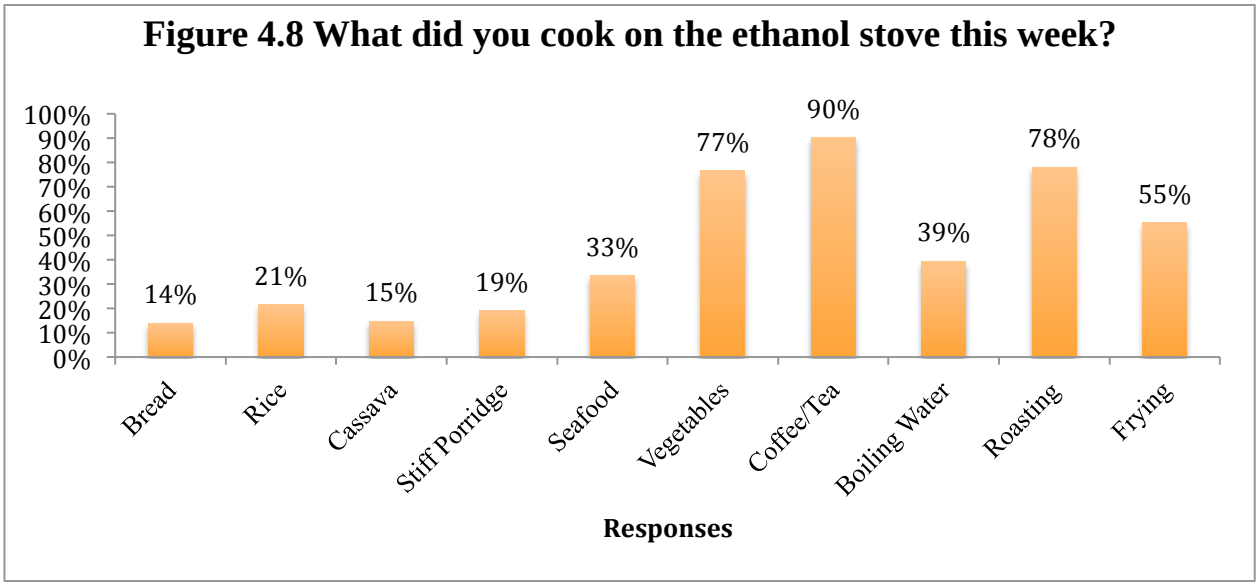


The weekly report questions were administered during all six weeks of the active surveying. The weekly survey questions were meant to gauge how often families were using the stove, what fuels and stoves they were using regularly, and if the usage of the stove was different based on district. On average for all six weeks, the study found that participants were purchasing between 2-3 liters a week (Figure 4.6). Participants in the more urban areas were purchasing slightly more ethanol per week than the participants in Northern A and Kisakasaka. However, families in rural areas, such as Kisakasaka, who reported collecting firewood for fuel in the baseline study, still regularly purchased ethanol. On average, families participating in the study used 2.6 liters of fuel per week. Based on responses from participants in the focus group discussions, the price of kerosene greatly affected the amount of fuel people were willing to purchase. At the time of the scoping study in early 2014, kerosene was 1,600 TSH per liter. At the start of the pilot study, kerosene was only 1,000 TSH per liter due to the overall decrease in global oil prices.

Throughout the study, 73% of families used the CLEANCOOK stove every day, and 18% of the participants used the stove more than once a week (Fig. 4.7). The most common types of cooking in which families used the ethanol stove were: making coffee and tea, roasting food, making vegetables, and frying food (Fig. 4.8). Families stated that they could cook everything on the stove, but chose not to because of fuel economy. 73% of families stated that the ethanol stove replaced one or more of their stoves over the six weeks. The charcoal stove was the most commonly replaced stove with 49% of participants switching to ethanol. 37% of respondents said that their wood stove was replaced, and 27% said their kerosene stove was



replaced. The primary reasons for this switch was: the cost of fuel, the speed of the ethanol stove, and the fact that there was less smoke when cooking with the ethanol stove. Of the participants who switched from the wood stove to the ethanol stove, 52% of respondents said it was because of fuel cost and 60% stated it was for health reasons. For families who switched from the charcoal stove to the ethanol stove, 78% of families said it was because of fuel cost. 91% of families who switched from the electric stove to



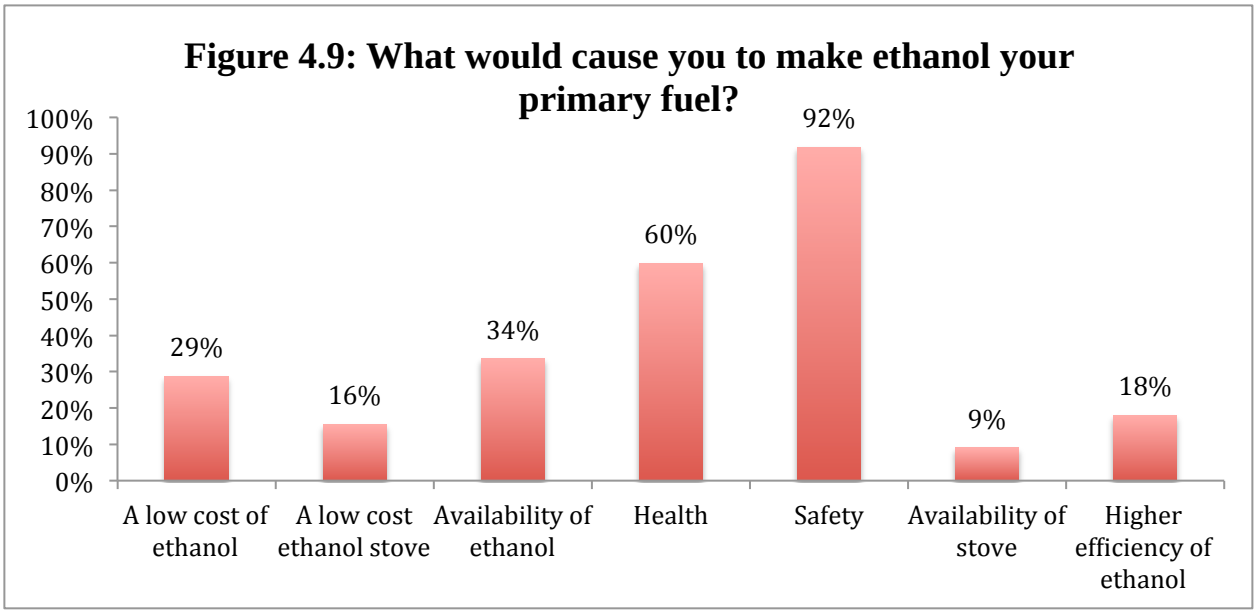
the ethanol stove said the change was because of fuel cost. Stove stacking is very common around the world. For the families who switched to ethanol from kerosene, 73% said it was because ethanol was less smoky, 60% said ethanol was faster, and 54% said the stove was easier to use. Families will use different stoves and fuels based on the meals they are cooking or changing costs of fuels. Even though the ethanol stove replaced stoves for families, 87% of families still continued to use stoves other than the CLEANCOOK stove throughout the study.

The male head of the household (45%) typically traveled to purchase the ethanol from the distribution centers. The wife of the household head traveled to distribution centers 29% of the time, and other female household heads traveled to the fuel depots 13% of the time. These numbers are in line with the responses for other fuels. Surveyors were asked to record their observations of the stove and fuel. The surveyors recorded that the stoves looked like they had been used during 99% of their visits. They also recorded that 80% of the stoves appeared to be kept in good condition and clean.

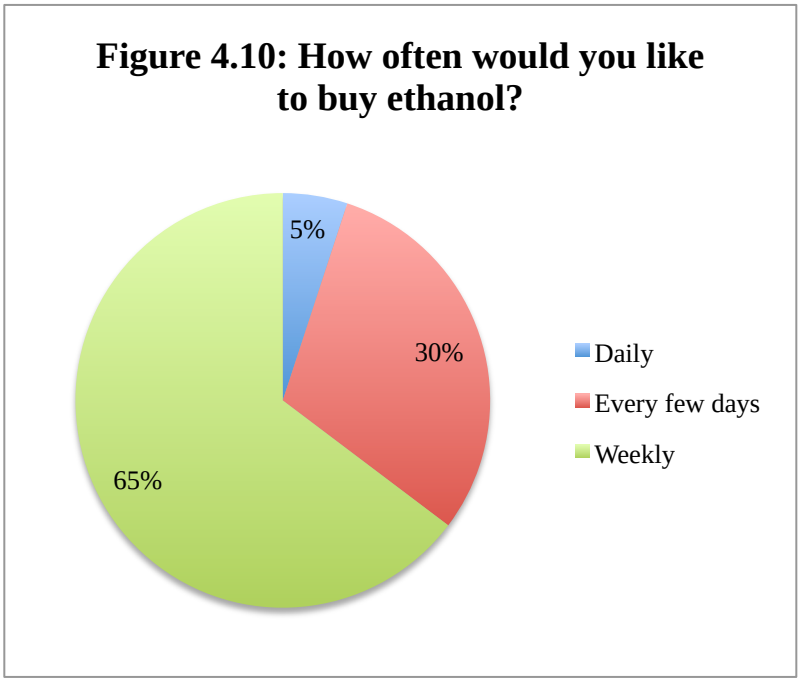
Final Survey Summary and Analysis

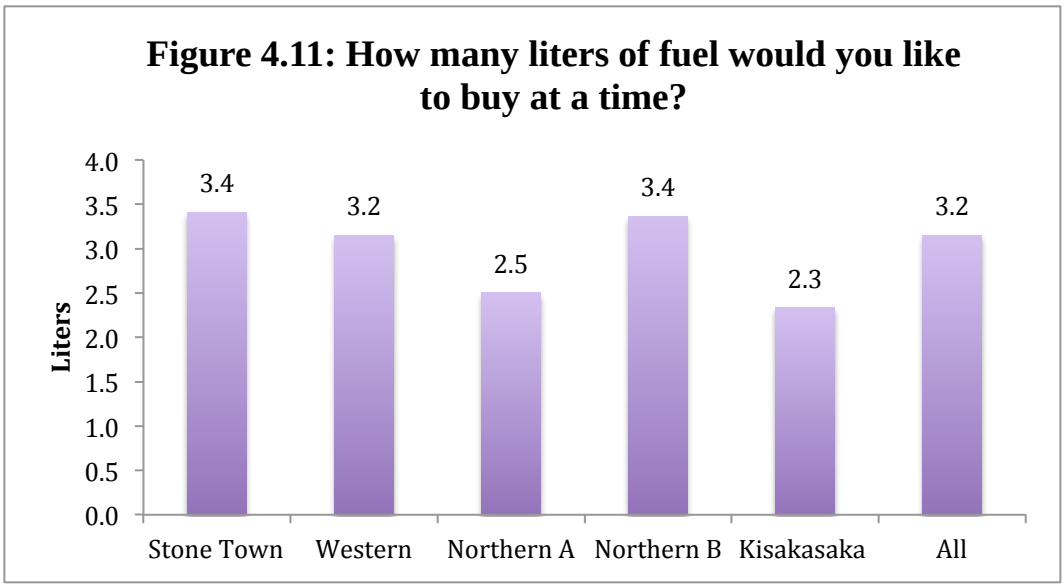
The final survey was administered during the sixth week of the study. Along with being asked the weekly questions, questions were asked about the benefits of using ethanol and how to commercialize the stove and fuel during a scale-up of the project.

Many families reported seeing a great benefit in using ethanol over other fuels. 95% of families believed that ethanol was preferable to other fuels. 94% of families believed that using the ethanol stove saved them time each day compared to other stoves. On average, families felt that the ethanol stove saved them 2.1 hours each day. When asked what would cause families to make ethanol their primary fuel, the majority of participants (92%) said that the safety of the fuel and 60% said the health benefits would cause them to primarily use ethanol fuel (Fig. 4.9).



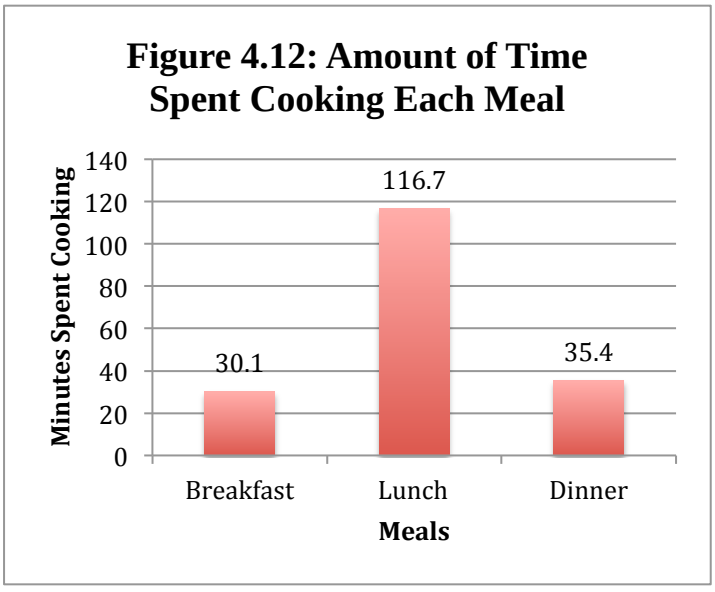
99% of participants said that they would buy ethanol fuel. The average cost that families wished to pay for a liter of fuel was 1,047.5 TSH. During the pilot study, ethanol was retailed in one, three, and five liter bottles to distribute the fuel. For a commercial scale-up, it is necessary to know how families prefer to purchase their fuel. Families stated that they would prefer to purchase fuel weekly (65%), every few days (30%), or daily (5%) (Fig. 4.10). Families also stated that they would prefer to purchase 3.2 liters of fuel at a time on average. This number differed slightly by district; with families from Stone Town and Northern B reporting 3.4 liters, and families in Kisakasaka reporting only 2.3 liters (Fig. 4.11). This is different than what was shared during a focus group discussion. During the discussion, families said they preferred to purchase fuel in one-liter bottles; however, they also stated that they wanted more distribution centers closer to their homes. The difference in these two responses may be because of how the fuel was distributed.



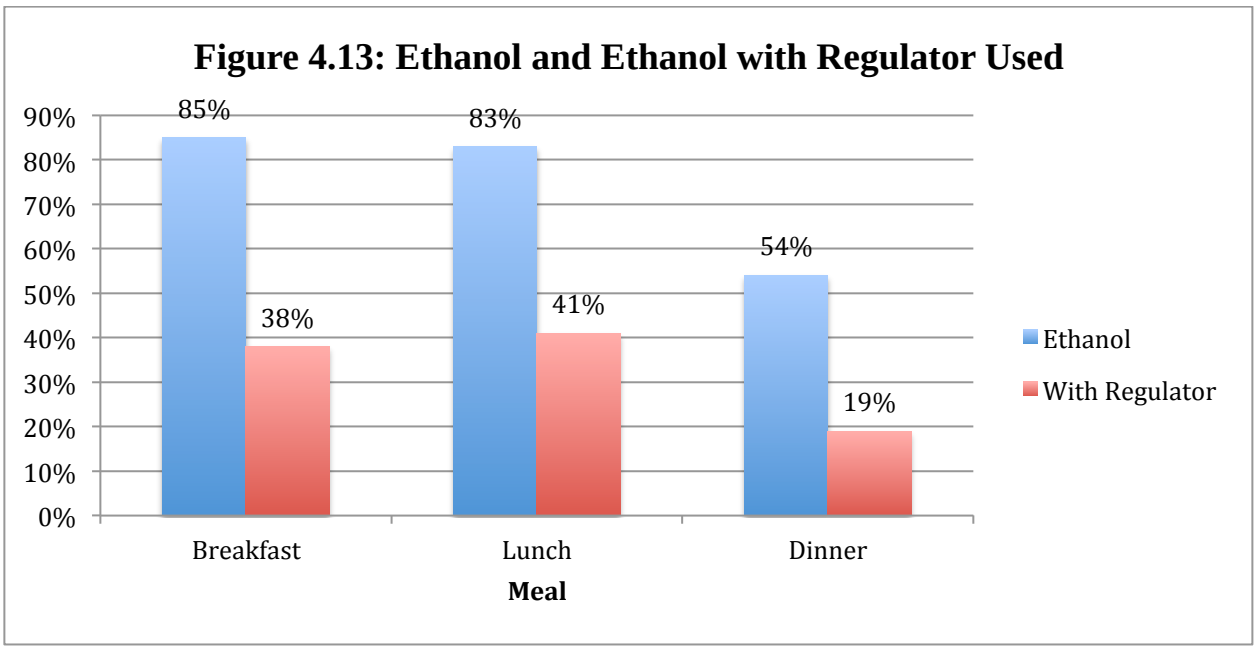


Intensive Survey Summary and Analysis

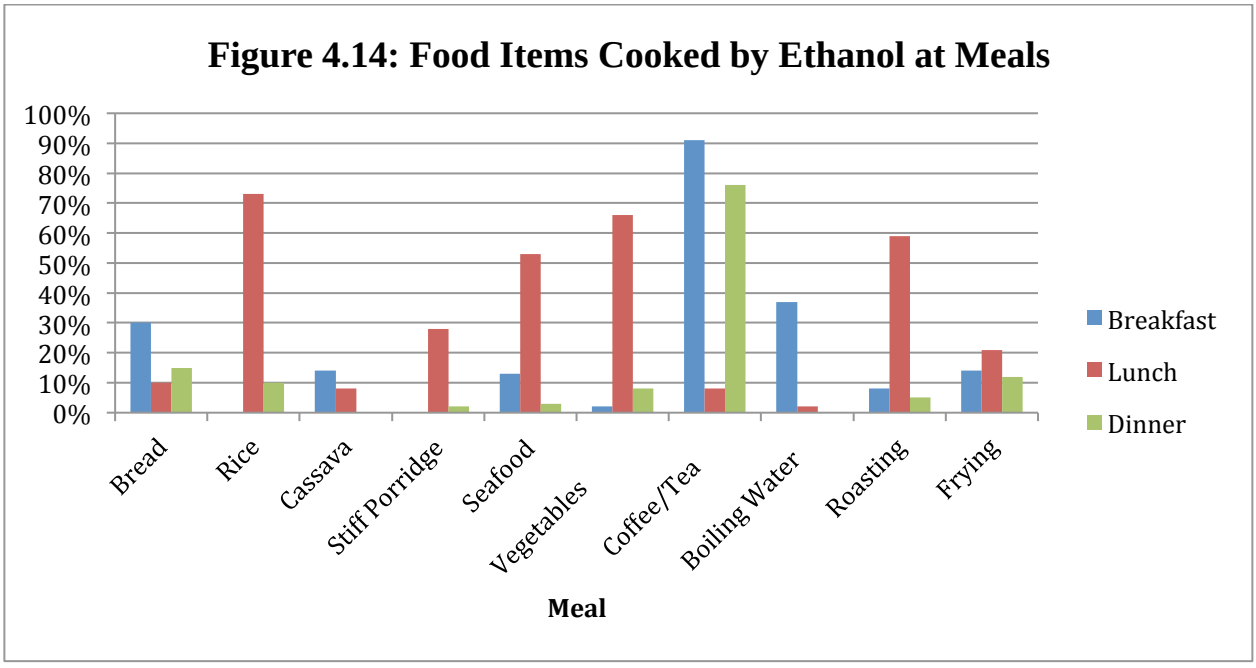
The intensive survey was administered to forty families during the last four weeks of the study. The survey was designed to assess what fuels families were using to cook each of their meals, how many people were at the meals, whether families were using the regulator on the ethanol stove, and how much fuel families purchased each week.



Lunch is the largest meal of the day in Zanzibar. On average, families in the pilot study spent 116.7 minutes per day cooking lunch for 7.5 people. Families spent 30.1 minutes per day cooking breakfast for 6.2 people, and the participating households reported spending 35.4 minutes each day cooking dinner for 5.2 people (Fig. 4.12). 85% of families used the ethanol stove at breakfast. 83% used the stove during lunch, and 54% of respondents used the stove at dinner. The regulator on the ethanol stove allows families to easily turn the stove on and off. It also allows families to conserve their fuel by using only the amount of power needed to cook each meal. Based on lab studies, the CLEANCOOK stove can burn on high power for four hours and burn on low power for up to nine hours with a full canister (1.2 liters of ethanol). Although families used ethanol regularly at each of their meals, the study found that the regulator was not used by many of the families at each of the meals. Only 38% of families used ethanol with the regulator at breakfast. At lunch, on average only 41% of the families used the regulator, and 19% of families used the regulator at dinner (Fig. 4.13). During the commercial scale-up, it will be important to highlight the fuel-saving benefits of the regulator to help families conserve fuel.

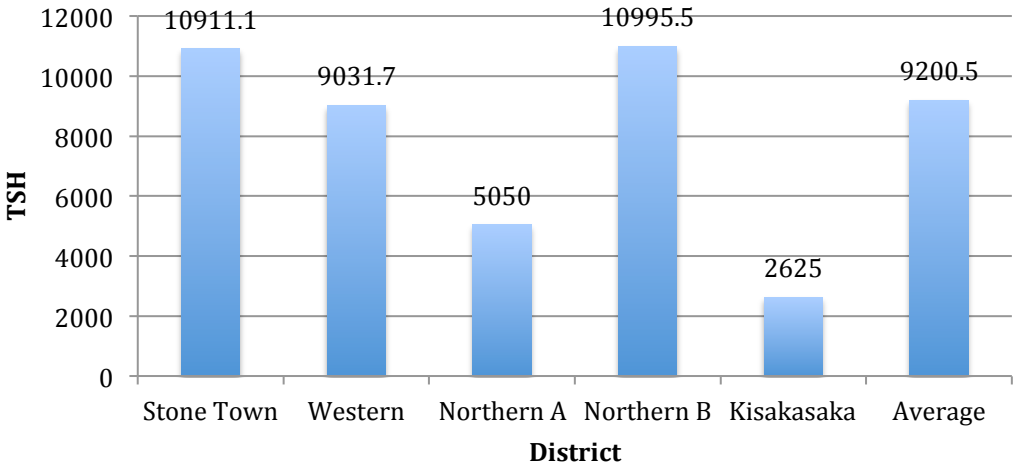


The intensive survey also tracked the food families cooked most often with the ethanol stove at each meal. During breakfast, the stove was used to make coffee and tea by 91% of families, followed by 37% of families boiling water, and 30% making bread. At lunch, the CLEANCOOK stove was used to make rice (73%), vegetables (66%), roasting (59%), and cooking seafood (53%). At dinner, families again made coffee and tea on the ethanol stove most frequently (76%). Families also cooked bread (15%), fried foods (12%), and rice (10%) (Fig. 4.14). In both the weekly surveys and in the focus group discussions, participants stated using the CLEANCOOK stove mostly for quicker cooking tasks. We can see this reflected in Figure 4.14 where staples such as stiff porridge was not frequently made on the ethanol stove. Families stated that they would adopt ethanol as their primary fuel and for longer cooking tasks if the price per liter was lowered.



This survey asked families to quantify their fuel purchases for the week. Families were asked to report how much they had spent on firewood, kerosene, charcoal, and ethanol during each of the four weeks. Based on these responses, the average weekly expenditure on cooking fuel in the Zanzibar pilot study was found to be 9,200.5 TSH. The average weekly expenditure differed significantly, as demonstrated in Fig. 4.15, based on the districts where families lived. Families in the Urban (Stone Town) and Northern B districts spent the most on fuel, spending 10,911.1 TSH and 10,995.5 TSH respectively. Families in Northern A and Kisakasaka spent 5,050 TSH and 2,625 TSH respectively. The families in Kisakasaka reported that they only spent money on ethanol; the rest of their fuel was collected. Although families in more rural areas, such as Kisakasaka, may not be able to afford to purchase fuel for all their meals, the pilot study demonstrated that there was some adoption of ethanol although it may be a new expense for the household. Based on the data from Figure 4.12, families spend around three hours per day cooking. Based on Project Gaia's past laboratory and field studies, the ethanol stove can run on a full canister on high power for up to four hours. Families in Stone Town and Northern B could switch over entirely to ethanol based on fuel cost alone. This demonstrates that an educational component will be necessary during the commercial scale-up to show the efficiency of ethanol fuel and the stove along with other benefits.

Figure 4.15: Weekly Fuel Expenditures



V. Household Air Pollution Monitoring

Household Air Pollution (HAP) monitoring aims to compare the concentration of Particulate Matter (PM) and Carbon Monoxide (CO) in the kitchens of randomly selected study households before and after a cookstove intervention. PM and CO monitoring is conducted for 24 hours in order to measure emissions from all cooking activities. The results are then easy to compare with the WHO-HAP guidelines for indoor emissions over a 24-hour period. Fourteen households were randomly selected and monitored during the "Before" study. Due to the delays in introducing the stoves, five households, which were part of the "Before" study, dropped out of the greater pilot study. This resulted in a lower number of households monitored for both the "Before" and "After" studies. Nevertheless, the nine households with a complete data for both "Before" and "After" intervention monitoring show enough significant results to demonstrate the impact of the CLEANCOOK stove intervention with respect to HAP.

Household Air Pollution Study Method

The study was conducted in a total of nine households randomly selected from the 122 households participating in the ethanol cookstove study. Sample households with enclosed or semi-enclosed kitchens were randomly selected from each study area in Zanzibar. The study monitored households' air quality for 24 hours both "Before" and "After" the households were introduced to cooking with ethanol-fueled CLEANCOOK stoves.

The following requirements were taken into consideration while placing the air quality monitoring equipment in household kitchens:

- 100 cm from the edge of the stove (combustion zone)
- 140 cm above the floor (cook's breathing space)
- 150 cm from any door or window that could be opened, where possible

The devices were placed for a 24-hour period in accordance with the above requirements. The carbon monoxide (CO) concentrations in the room were measured with the HOBO CO logger (model #H11-001, Onset Computer Corporation, Bourne, MA, USA), which was set to record a concentration reading every minute. Fine particulate matter was measured by the University of California, Berkeley Particle Monitor (UCB PM), which uses a photoelectric detector (Litton et al., 2004; Edwards et al., 2006). The UCB PM measured the PM2.5 concentration every minute (reported in units of milligrams per cubic meter of air, mg/m^3).

Figure 5.1: Charcoal stove from a household included in the HAP monitoring.

Post–Monitoring Questionnaire

A post-monitoring questionnaire was administered to the nine participating households at the end of both the "Before" and "After" intervention studies. The main cook of each household was asked a series of questions to determine what the household conditions were like throughout the monitoring period. These questions were designed to help interpret the HAP data collected during the 24-hour period. Questions

such as, what type of fuel was used, and for how long the participating family cooked, helped to explain why there may have been higher or lower levels of CO and PM recorded during the study.

Results: Household Air Pollution Concentrations

The following results are for the 24-hour concentration measurements of $PM_{2.5}$ and CO in the kitchens of Zanzibar. The nine households selected for the study used a metal charcoal stove as their primary stove and a kerosene stove as their secondary stove (Table 5.1). In the "After" study, the CLEANCOOK stove was introduced (Table 5.2).

In addition to the mean, minimum, and maximum PM concentrations recorded during each monitoring period, the UCB PM software calculated the highest, second highest, and third highest 15-minute average PM concentration. Each of these three metrics is a consecutive 15-minute period, and none of the three periods overlap. All values are displayed in Tables 5.1 and 5.2.

Table 5.1 Results of the 24-hour kitchen concentration measurements of $PM_{2.5}$ and CO in 9 households using charcoal and kerosene stoves "Before" intervention

HH ID	$PM_{2.5}$ Concentration (mg/m^3)							CO (PPM)	
	# Number of records	Mean	Min	Max	Highest 15-min Ave	2nd Highest 15-min Ave	3rd Highest 15-min Ave	HOBO Mean	HOBO Max
HH001	1441	0.06	0.05	0.57	0.22	0.20	0.18	7.9	176.5
HH002	1441	0.22	0.50	70.99	8.30	2.44	1.38	4.1	88.1
HH003	1441	0.52	0.05	123.41	17.00	9.02	7.36	9.1	219.7
HH004	1441	0.17	0.05	4.35	1.89	1.25	27.51	14.1	204.1
HH005	1441	0.29	0.05	4.85	4.39	4.14	4.10	8.9	252.9
HH006	1441	2.95	0.05	156.48	35.68	27.09	24.88	7.3	497.1
HH007	1441	0.68	0.05	23.52	11.87	7.74	5.48	11.1	497.1
HH008	1441	0.24	0.05	24.35	6.46	3.58	2.36	7.5	147.2
HH009	1441	0.06	0.05	2.97	0.54	0.39	0.19	8.2	78.4
	Average	0.58	0.05	45.72	9.59	6.21	8.16	8.70	240.12

Table 5.2 Results of the 24-hour kitchen concentration measurements of $PM_{2.5}$ and CO in the same 9 households using the CLEANCOOK stove and others "After" intervention

HH ID	$PM_{2.5}$ Concentration (mg/m^3)							CO (PPM)	
	# Number of records	Mean	Min	Max	Highest 15-min Ave	2nd Highest 15-min Ave	3rd Highest 15-min Ave	HOBO Mean	HOBO Max
HH001	1441	0.12	0.05	35.03	5.68	0.22	0.12	1.6	19.3
HH002	1441	0.12	0.50	1.89	0.90	0.67	0.51	1.1	24.2
HH003	1441	0.13	0.05	5.67	1.98	1.27	1.14	2.0	27.1
HH004	1441	0.075	0.05	1.49	0.74	0.68	0.66	2.7	29.1

HH005	1441	0.06	0.05	0.82	0.24	0.17	0.12	2.1	11.5
HH006	1441	0.08	0.05	4.03	0.91	0.80	0.21	2.4	16.4
HH007	1441	0.09	0.05	2.90	1.64	0.78	0.58	5.5	70.1
HH008	1441	0.06	0.05	2.33	0.34	0.10	0.09	0.8	6.6
HH009	1441	0.26	0.05	19.53	4.43	3.74	3.33	8.8	137.7
	Average	0.11	0.10	8.19	1.87	0.94	0.75	3.00	38.00

Table 5.3 below shows the means of the PM and CO data for the 9 households in the "Before" and "After" intervention monitoring, along with the standard deviations. The percent differences are also shown, comparing the "Before" and "After" averages (the "Before" values were used as the denominator)

Table 5.3 Average Kitchen Concentration and Percent Changes

	Before, Average	Before, Std Dev	After, Average	After, Std Dev	Percentage Difference (%)
PM: Average (mg/m3)	0.58	0.86	0.11	0.06	81.1
PM: Minimum (mg/m3)	0.05	0.14	0.05	0.15	0
PM: Maximum (mg/m3)	45.72	54.91	8.12	11.58	82.2
PM: Highest 15-min ave	9.59	10.58	1.87	1.91	80.5
PM: 2nd Highest 15-min ave	6.21	7.93	0.94	1.12	84.9
PM: 3rd Highest 15-min ave	8.16	9.92	0.75	1.03	90.8
CO: Mean, HOBO (ppm)	8.7	2.59	3	2.56	65.5
CO: Maximum, HOBO (ppm)	240.12	147.54	38	41.63	84.2

The average of the set of nine 24-hour average kitchen PM2.5 concentrations went down from 0.58 mg/m3 in the "Before" (charcoal & kerosene stove) phase to 0.11 mg/m3 in the "After" phase (CLEANCOOK stove and others). This is an 81.1% reduction. As shown by the smaller minimum value of PM concentration, 0.05 mg/m3 for both "Before" and "After" phases, the background condition of Zanzibar households had lower PM concentration during the monitoring. The average maximum PM2.5 concentrations dropped by 82.2% in the "After" sampling, relative to the "Before" phase. The highest, second highest, and third highest 15-minute average PM2.5 concentrations were also significantly lower "After" the introduction of the CLEANCOOK stove, by 80.5%, 84.9%, and

Figure 5.2: Project Manager Hillary Njau watches as Wubshet Tadele sets up HAP monitoring.

90.8%, respectively. Similarly, the average 24-hour kitchen CO concentrations measured by the HOBO CO logger, dropped from 8.7 ppm in the "Before" phase to 2.56 ppm in the "After" phase, a significant reduction of 65.5%. The average of the maximum CO concentrations was also significantly different: 240.12 ppm "Before" versus 41.63 ppm "After".

Post-Monitoring Questionnaire Results

The important findings of the post-monitoring questionnaires are described below. The surveys were administered to the main cook at the end of the monitoring sessions. All of the HAP study participants used a metal charcoal stove for cooking during the "Before" sampling phase, while three households used kerosene and LPG stoves as secondary stoves. Seven of the nine households used their other stoves with the CLEANCOOK stove during the "After" sampling phase. All households surveyed used an electric lamp for lighting on a daily basis in both the "Before" and "After" studies. The participants reported no cigarettes smoked and no emissions from other sources during the study. Lastly, the number of people cooked for in each household has showed a slight 0.11 increase on the average of the "After" phase (overall averages of 6.22 people "Before" and 6.33 people "After"). This is shown in Table 5.4 below.

Table 5.4. The number of people cooked for on the days of HAP sampling in the "Before" and "After" intervention studies

HH ID	Before, Number of people cooked for	After, Number of people cooked for
HH001	10	12
HH002	4	4
HH003	6	5
HH004	3	3
HH005	7	7
HH006	8	8
HH007	8	8
HH008	6	7
HH009	4	3
Average	6.22	6.33

Comparison of Kitchen Concentrations to International Standards

The World Health Organization (WHO) sets air pollution standards to offer guidance in reducing the health impact of air pollution (both indoor and outdoor) based on current scientific evidence. The WHO recently set new Air Quality Guidelines (AQG) for PM2.5 along with interim targets that are intended as incremental steps in a progressive reduction of air pollution in more polluted areas (WHO, 2014). The guideline for carbon monoxide was set in 2000 (WHO, 2000). The results of the HAP monitoring in the 9 households are compared to the WHO's AQG and interim target-1 (WHO, 2014) in Table 5.5 below. Note that the CO concentrations reported above in parts per million (ppm) were converted to mg/m^3 to match the unit used by WHO (by multiplying by the gram molecular weight of CO, 28, and dividing by the conversion factor of 24.45).

Table 5.5. Comparison of kitchen concentrations to WHO guidelines

	"Before" (modified traditional stove and charcoal stove) (24- hr avg.)	**"After" (CC stove and others) (24- hr avg.)**	**WHO interim target-1**	**WHO Air Quality Guideline**
PM2.5	575.4ug/m^3	109ug/m^3	35 ug/m^3 (24-hr mean)1	10ug/m^3 (24-hr ave) 1
CO	10 mg/m^3	3.5 mg/m^3	N/A	10 mg/m^3 (8-hr avg) 2

1 WHO, 2014.
2 WHO, 2000.

The average PM concentration in the kitchens was greatly reduced after the households began using the CLEANCOOK (CC) stove (from 575.4 to 109ug/m^3), a very significant improvement in household air quality. The households moved closer to the WHO interim target-1 of 35ug/m3 for PM2.5 (and the Air Quality Guideline of 10ug/m3) in the "After" compared to the "Before" high concentration. The "After" kitchen PM concentration in the sample households did not reach as close to the WHO interim target as expected since there were additional PM emissions from non-CLEANCOOK stoves such as charcoal and kerosene stoves that households continued to use. These PM levels could be lowered further if households switched to only the ethanol stove or other clean fuels such as LPG or electricity. The average CO kitchen concentration in the charcoal stove case was 10 mg/m^3, right on target with the WHO Air Quality Guidelines. This can be attributed to the households having kitchens with very good ventilation as was observed in most of the sample households. The CO concentration in the "After" case dropped to 3.5 mg/m^3 during use of the CC stove, significantly below the WHO guideline of 10 mg/m^3.

VI. Focus Group Discussions Summary and Analysis

Focus group discussions typically bring together 5-15 members of the pilot study to discuss their experience with the stoves. These discussions allow Project Gaia to ask qualitative questions about the users' experiences, follow up on discrepancies in survey data, and ask questions about the possible commercialization of the stoves. They also allow participants to bring up any questions to the implementers, voice their opinions, or make suggestions to the team. In addition to the weekly surveys, Project Gaia conducted two focus group discussions with participants. Participants were asked a series of questions regarding their general experience with the stove, the stove design, their experience using ethanol fuel, and pricing and marketing of the stove and fuel. Participants in these discussions were offered refreshments and a stipend for transportation to and from the session for their participation.

Key Summary from Discussions:

- Families were very pleased with the stove, said it could cook all of their meals, and had few requests for changes to be made to the stove body.
- Families preferred the ethanol stove to other stoves primarily because of the speed of cooking and cleanliness.
- Many households felt that the fuel was consumed quickly and only used ethanol for short cooking tasks.
- The cost of ethanol was frequently compared to the cost of kerosene, which decreased drastically during the course of the study due to a global decline in oil prices. Participants stated that if the cost of ethanol were lower, they would use ethanol for more of their cooking tasks.
- 1,000-1,300 TSH was listed as the ideal price per liter of fuel. Kerosene was 1,000 TSH per liter at the time of the study.
- Households believed that one liter of fuel burned between 3-4 hours. Three hours was the consensus in the second group, and four hours was the average in the first group.
- There are no cultural or religious concerns with alcohol fuel since it is dyed and denatured.
- Families preferred the two-burner stove to a single-burner alternative.
- Households have already recommended the CLEANCOOK stove to family and friends.

Focus Group Discussion – Mahonda

The first focus group discussion was held on March 12, 2015 with twelve pilot study participants from the Mahonda region.

Participants stated that the CLEANCOOK stove was very easy to use, light, regulate, and turn off. They felt that the stove was very safe, and their favorite features were the stove's appearance, strength, the fact that it was perceived to be easy to use and clean, and that there was no smoke. Participants said the stove was very clean and made it possible to cook in their living rooms. Households felt that the stove was of "excellent" quality and similar to the electric and LPG stoves they aspired to own. Participants recommended that one more burner be added to the double burner stove. They also noted that they would like different size burners on a single burner stove.

The participants stated that cooking with ethanol is an excellent alternative to other fuels because unlike charcoal and kerosene, ethanol is clean, fast, and easy to use. The participants felt that ethanol was comparable to electric and LPG, but preferred ethanol because it is cheaper. The participants did not like the "bad" smell of the ethanol when refilling the stove and felt that the stove consumed the fuel too quickly.[1]

The CLEANCOOK stove most easily replaced kerosene and LPG stoves. Participants said they preferred the ethanol stove to kerosene because the kerosene stove is difficult to light and use. Participants preferred ethanol fuel to LPG because it cost less. These participants said they most liked using the stove for quick cooking activities such as making tea, coffee, rice, vegetables, and boiling milk. They did not like to use the ethanol stove for energy-intensive cooking such as cooking meat and beans. For these cooking tasks, households continued to use charcoal and wood. Households felt that the CLEANCOOK stove was faster and cleaner than their other stoves. The participants also stated that the CLEANCOOK could accommodate all of their pots and cook any of their meals. The participants had a wide variety of opinions on the fuel economy of the stove. Some thought the stove had fair rate of fuel consumption, while others thought it consumed fuel too quickly. Based on these different opinions, some households preferred to do quick cooking tasks only and others to do all types of cooking on the stove. Most of the households were not sure about the burning-time for one liter of ethanol, stating that they have only a perception but not a measured time. However, some of the households indicated that one liter of ethanol burns for about 4 hours. Fuel preference depended on the weather according to the participants; the dry season gives them the option to use more varieties of fuel since good quality charcoal and wood are readily accessible.

Figure 6.1: Hillary Njau demonstrating the stove with a pilot participant in Kisakasaka.

Households took care to follow the safety instructions for their stoves and fuel. They refilled their canisters when they ran out of fuel, only used the bottles from the pilot study for the fuel, and kept them sealed and away from children.

[1] The smell referred to in the pilot study was due to a higher percentage of aldehydes in the ethanol fuel, which is common in lower-quality ethanol. At the time of the pilot study, this was the only fuel available from the Zanzibar Sugar Factory. There are many ways to increase the quality of fuel, thus reducing or eliminating the smell in the future.

Participants in this first group suggested a wide range of possible prices for commercial retail of the stove. 60,000 TSH was the minimum price, and 200,000 TSH was the maximum price stated. 80,000 TSH was the average recommended price for the stove. Participants stated that the price of the stove, along with its cleanliness, would be deciding factors in purchasing a stove. They recommended television advertisements and demonstrations as the most effective way to market the stove.

Households preferred to buy one liter of fuel at a time and favored accessing fuel from local shops within five minutes walking distance of their homes. They stated that local shops would enable them to purchase fuel in smaller quantities whenever they ran out. Households stated that a fair price for the ethanol would be 1,000 TSH per liter, which was also the price of kerosene at the time. Participants indicated that 1,200 TSH per liter would be the maximum they would consider to be a fair purchasing price.

The participants preferred a double-burner stove model. They recommended the Swahili names of Jikola Selama (Safe Stove) or Jikola Spiriti (Alcohol Stove) for the local market. Households were overall very pleased with the way the stove looks and do not want to see any changes to its appearance. They shared that they are already recommending the stove to friends, neighbors, and relatives.

Focus Group Discussion – Stone Town

The second focus group discussion was held March 14, 2015 with seven participants from Stone Town.

The participants in this session also felt that the CLEANCOOK stove was very easy and safe to use. Participants said that they preferred the ethanol stove for many reasons including: the shorter cooking times, its cleanliness, the handles that make the stove easy to clean and refill, and the ability to use water to clean the stove (unlike electric stoves), and the ability to turn the stove on and off easily at any time. The participants said that the time it took to prepare meals on the CLEANCOOK stove was considerably less than with other commonly used stoves. Households performed two to three cooking activities on the stove daily. Usually these were lighter cooking activities, such as making tea, frying, making soup, boiling milk, etc. This is because households believed that since the stove was faster, fuel was consumed more quickly. Thus, longer cooking tasks such as making beans or porridge led to higher fuel consumption. Households preferred to continue cooking rice on charcoal stoves because they felt the taste was better and because charcoal was cheaper on the market. Although all of the households were very pleased with the design of the stove, one participant stated that the pot supports were a bit slippery when being used to make stiff porridge in a pot without handles.

Participants indicated that the CLEANCOOK stove mainly replaced kerosene and charcoal stoves in their households because it was easier, faster, and cleaner. In some of the homes, electricity was replaced because the ethanol stove was faster and the fuel was perceived to be much cheaper. Participants felt that the stove was beautiful, and considered it a household decoration. They displayed the stove in their living rooms with other clean household furniture. They indicated a willingness to pay up to 200,000 TSH for the CLEANCOOK stove.

Households felt that ethanol was much safer than other fuels, particularly kerosene and LPG. They did not regularly use the regulator except to turn the stove off and on. These households agreed that with one liter of fuel, the stove burned for about three hours. The households refilled

their stoves about once or twice a week whenever the fuel ran out since there is no indicator for how much fuel is left in the canister. Households stated that during the rainy season, ethanol and kerosene would be their preferred fuels because the biomass fuels become wet and hard to use.[2]

During this session, households were asked to anonymously write down the amount they spend weekly on cooking fuels. Responses ranged from 12,000 TSH on the low end to 30,000 TSH on the high end. This group felt that it was important to have several different sized fuel bottles available to purchase. Their bottle preference differed depending on how much cash they had on hand. Participants thought that 1,000 TSH was a reasonable price for a liter of ethanol, and they are not willing to pay more than 1,300 TSH. Households were willing to walk only ten minutes for a round trip to purchase fuel. They recommended continuing distribution through local shops around Stone Town, which would be close to their homes and other participants.

This group recommended the Swahili names for the CLEANCOOK stove to be Jikolo Haraka (Quick Stove) and Jikolo Okolamuda + Tunza Mazingirr (Save Time + Clean Environment Stove). They did not have any requests for changes to be made to the stove and said that they preferred the double-burner stoves.

[2] This focus group discussion was conducted during the dry season in March, however Project Gaia can confirm a rising demand for ethanol and an increase in the amount of ethanol fuel purchased during the rainy season at the time of compiling this report (May – June).

VII. Government Involvement and Steering Committee

Steering Committee Meetings

In order to include the local government of Zanzibar in the pilot project and plans for scale-up, UNIDO arranged for the formation of a Steering Committee with members from several of the ministries, including: the Department of the Environment in the First Vice President's Office, the Ministry of Energy, the Ministry of Trade and Industries, the Ministry of Empowerment, Youth, Women and Children, and Zanzibar Bureau of Standards. Three meetings were held with the Steering Committee thus far, taking place on January 30, 2015, March 13, 2015, and April 29, 2015. These meetings were held to encourage government support and develop policies that would be beneficial to the project and eventual scale-up. The UNIDO Project Manager, Hillary Njau, led the three meetings.

The first meeting, held January 30, 2015 at the Zanzibar Sugar Factory, was arranged to introduce members to the pilot project concept and progress. Stoves had already been distributed to the majority of participating households and distribution would be completed on January 31 in Stone Town. Weekly surveys began on January 26, 2015. Mr. Njau asked the committee members to support the project and act as ambassadors for the pilot to their respective ministries. Committee members assured Mr. Njau of their full support for the project.

The second meeting was held on March 13, 2015 at the Emerson on Hurumzi Hotel with Wubshet Tadele of Project Gaia. Mr. Njau provided a status update on the pilot project. The pilot surveyors updated members on their role in the pilot study, challenges they were facing, and the changes they saw in household behavior and environment. Members were informed of the household air pollution monitoring underway in the pilot study and were invited to a stakeholder meeting at Bwani Hospital. Members reiterated their support for the pilot and scale-up.

The third meeting was held on April 29, 2015 at the Ministry of Empowerment, Youth, Women and Children to discuss the closeout of the pilot study, plans to continue the fuel supply to households, and commercial scale-up. The Committee discussed ideas about how to continue the fuel supply, particularly during the month of Ramadan. It was decided that distributors would take a commission payment of 200 TSH per liter of ethanol sold as opposed to the original system where they were paid 10,000 TSH per week for selling fuel from their stores. The Committee recommended that all the ethanol at the Zanzibar Sugar Factory be procured and sold until the project can be fully scaled-up.

The Steering Committee will continue to be consulted and updated as Project Gaia and partners work to scale-up the project to commercialization.

Project Gaia Government Meetings

During the scoping study and throughout the pilot study, Project Gaia representatives have met regularly with government officials, stakeholders, and UNIDO representatives to further the project. Project Gaia has met with the Ministry of Finance, the Zanzibar Planning Commission, the Ministry of Energy, the Bureau of Standards, and the Zanzibar Sugar Factory. Project Gaia has also submitted tax and subsidy recommendations to the Zanzibar Planning Commission and the Ministry of Finance.

VIII. Summary of Key Pilot Findings

- 95% of participating families believed that ethanol fuel and the CLEANCOOK stove was preferable to other stoves. 73% of families used the stove every day during the study.
- Families preferred the ethanol stove to other stoves primarily because of the speed of cooking, safety, health benefits, and cleanliness.
- 94% of families believed that using the ethanol stove saved them time. On average, families reported saving 2.1 hours a day by using the ethanol stove during the pilot study.
- In rural areas, such as Kisakasaka, where 100% of families included in the study collect firewood, participants were still willing to purchase ethanol fuel.
- Families spent about three hours cooking each day. On average, families in the pilot study spent 9,200.5 TSH on cooking fuel each week.
- Families were very pleased with the stove, said it could cook all of their meals, and had few requests for changes to be made to the stove body.
- Many households felt that the fuel was consumed quickly and only used ethanol for short cooking tasks.
- The cost of ethanol was frequently compared to the cost of kerosene, which went down drastically during the course of the study. Participants stated that if the cost of ethanol were lower, they would switch over more of their cooking tasks to the CLEANCOOK stove.
- Families wished to buy fuel weekly 2-3 liters at a time, or they requested more distribution centers and the ability to purchase small amounts.
- 1,000-1,300 TSH was named as the ideal price per liter of fuel. Kerosene was 1,000 TSH per liter at the time of the study.
- Households believed one liter of fuel burned between 3-4 hours.
- Households have already recommended the CLEANCOOK stove to family and friends.
- The average particulate matter concentration in the kitchens was greatly reduced after the households began using the CLEANCOOK stove (from 575.4 to 109ug/m^3), a very significant improvement in household air quality.
- The CO concentration in households dropped to 3.5mg/m^3 during use of the CLEANCOOK stove, significantly below the WHO guideline of 10mg/m^3.
- There is considerable government support for the ethanol stove project in Zanzibar.
- Project Gaia recommends a commercial scale up based on the above findings.

IX. Recommendations for Continuing Fuel Supply and Commercialization

Based on the pilot study results, Project Gaia recommends continuing the fuel supply for pilot households and creating a plan for a commercial scale-up targeting early 2016 for the initial launch. Project Gaia and its for-profit affiliate, Source Fuel, are working with local partners to develop a sustainable fuel and stove business. Project Gaia will provide a carbon credit program through the Gold Standard in order to help provide the stoves to families at a reduced cost.

Continuing the Fuel Supply

Setting the groundwork for the commercialization of stoves and fuel will take time. While the foundations are being laid, Project Gaia will work to continue the fuel supply to the pilot study families who invested in stoves. To close out the study, PG recommends giving the stoves to the participants for the original 15,000 TSH. This will encourage more participants to continue using the stoves and provide a market for commercialization in 2016. Data from the continued supply will also help inform the commercial scale-up. For example, although the study officially ended in March, fuel has continued going to distribution depots. With the heavy rains in May, consumer demand for ethanol was higher than in the dry season during the study.

Project Gaia will purchase the remaining fuel stock from the Zanzibar Sugar Factory and make it available to the pilot participants at the five distribution centers. To continue the fuel supply, Project Gaia will use the money from the sale of ethanol and the down payments on the stoves to purchase this fuel. This amount will not cover more than 2,000 liters of fuel; thus, Project Gaia will contribute the funds necessary to purchase the remaining fuel, employ a local project manager to oversee fuel distribution, pay for the labor to fill the bottles, and pay for transportation of fuel to the depots. Project Gaia will also subsidize each liter by 200 TSH. The distributors will sell ethanol for 1,600 TSH per liter and will be allowed to keep 200 TSH per liter sold. The distributors will have to pay for the fuel upfront, and Project Gaia will no longer provide the distributors with payments to sell the fuel. This will reduce costs. Since the Zanzibar Sugar Factory only has between 1,000 – 4,000 liters of ethanol in stock, there will be a short interruption in the fuel supply until commercialization starts. Project Gaia and its affiliate, Source Fuel, are working to create a commercial business with local partners for Q1 of 2016. Providing the stoves to families at a cost far below market value will encourage goodwill towards the project until a reliable fuel supply can be created.

Commercialization

Project Gaia recommends the commercialization of ethanol stoves and fuel in Zanzibar for economic, environmental, and social benefits. Commercialization will allow the stoves and fuel to be self-sustaining, to expand to the more rural regions of Zanzibar quickly, and to create business opportunities for local people in the distribution of fuel and stoves. Not only would ethanol fuel create opportunities for local enterprise, but its adoption would also reduce the island's reliance on imported fuels, such as charcoal, kerosene, and LPG. Project Gaia is working with its for-profit affiliate, Source Fuel, to create partnerships with local businesses to provide ethanol and stoves at an affordable price for the end-user. Project Gaia will stay involved with the scale-up in order to monitor the quality and safety of the operation and also to provide a carbon-financing program. This program will help to provide the stoves to families at a lower cost. CLEANCOOK has now created stoves that can be shipped in pieces so that the stoves may be manufactured in country.

Distribution

According to the data we gathered through the scoping study and pilot study, ethanol has the potential to be very competitive on the fuel market. However, its ability to become competitive relies heavily on the supply chain model that would be put into place for the fuel distribution. For the pilot study, we tested a supply chain system that utilized one, three, and five liter bottles. Feedback and price-analysis confirm that this model is not beneficial to the end-user and cannot be profitable without large government subsidies due to the high cost of new bottles and labels. Additionally, such a large volume of bottles in circulation will contribute greatly to the amount of waste produced in Zanzibar. For these reasons, we recommend a supply chain that would utilize specialized retail centers, drum transportation, and a jerry can distribution model that would allow the end-user to purchase only the amount of fuel desired. The jerry cans and drums would be recycled throughout the supply chain to reduce waste and cost of fuel.

Zanzibar Sugar Factory and Ethanol Supply

During March 2015, Project Gaia representatives Daniel Seals and Harry Stokes traveled to Zanzibar for meetings with local stakeholders, including the Zanzibar Sugar Factory executives. While the Zanzibar Sugar Factory is willing to sell their remaining stores of ethanol to continue the fuel supply in 2015, they are unwilling to produce fuel for a commercial scale-up until the market has reached 10,000 households. They are also unwilling to sell the fuel below 0.90 USD (1,629 TSH). Project Gaia recommends importing fuel from neighboring East African countries, Brazil, or India. Importation will provide several benefits to local consumers. Imported fuel will be higher quality, causing the stoves to produce less soot. Kenyan, Brazilian, and Indian ethanol producers have highly competitive prices; imported fuel will cost less for the end-user. Finally, the imported fuel will help spur the local market for ethanol. Once a market is demonstrated, local ethanol producers may be inclined to increase production and sell fuel for a more competitive price.

Government Regulations and Standards

During Project Gaia's trip in March 2015, Daniel Seals and Harry Stokes met with government officials, stakeholders, and the project Steering Committee. Project Gaia and UNIDO shared the details of the pilot's progress in these meetings and spoke with officials about a possible commercial scale-up. There is government support for a scale-up; officials are also interested in receiving guidance on standards and regulations for ethanol fuel and stoves. After 20 years of implementing projects, Project Gaia has experience in creating systems that are both efficient and safe. Project Gaia is creating a list of recommendations for government regulations and standards regarding the quality of stoves, quality of fuel, storage of fuel, labeling of fuel, and other safety concerns. Through Project Gaia's and UNIDO's work with the government, import taxes on the ethanol stoves have now been removed.