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A case study of the ethanol CleanCook stove intervention and potential scale-up in Ethiopia☆

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ABSTRACT

Background: Approximately 80% of Ethiopia's energy consumption is dominated by woody biomass fuel use, resulting in 91.2 million tons of firewood and 4.2 million tons of charcoal consumed annually. Ethiopia's dependency on non-sustainable energy, especially for cooking, has been a major concern for the nation for the past 30 years, contributing to deforestation, climate change, and adverse human health impacts.
Objectives: Our objective was to document the work of Gaia Association and the implementation of the ethanol CleanCook stove in the refugee camp and urban settings of Ethiopia. We then assessed the potential for the scale-up of ethanol as a household fuel.
Methods: We utilized the Reach, Effectiveness, Adoption, Implementation and Maintenance (RE-AIM) framework to evaluate the effectiveness and sustainability of the ethanol cookstove intervention. We obtained secondary data from a variety of sources to evaluate a.) The performance of the CleanCook ethanol stove; b.) Effectiveness of the ethanol cookstove implementation; and, c.) Barriers to scale-up and commercialization of ethanol use as a household fuel. In addition, we conducted primary analysis of qualitative surveys to evaluate the perceptions of the ethanol and adoption of the CleanCook stove.
Results: Our case study results provide critical insight into the 13-year implementation of the CleanCook ethanol stove in Ethiopia. Laboratory tests demonstrate that the CleanCook stove reduces harmful emissions compared to biomass stoves, and preliminary field tests show 24-hour average $PM_{2.5}$ levels of 200 μg/m^3. To-date 8731 CleanCook stoves were distributed to refugee households, while an additional 500 were sold at a subsided price to low-income urban households. CleanCook stove users report the continued use of multiple stoves.
Conclusions: The CleanCook ethanol stove has been implemented as an energy intervention for the vulnerable refugee population in Ethiopia for over 13 years. There has been limited success of a subsidized CleanCook stove among low-income households in Addis Ababa. This case study demonstrates the complexities of promoting a new fuel for household cooking, and the numerous obstacles and stagnations in implementation. Ethanol demonstrates some potential for scale-up and commercialization as a household fuel in Addis Ababa, but it may require simultaneous stabilization of ethanol supply, growth of a city-wide distribution infrastructure, and an affordably priced stove and fuel.

Introduction

Access to modern energy gerservices and technologies is a critical component of economic development and achievement of the Millennium Development Goals and Sustainable Development Goals 7 (Mehta, Gore, Prüss-üstün, Rehfuess, & Smith, 2006; World Health Organization, 2004; United Nations, 2017). It is estimated that approximately 3 billion people worldwide rely on solid biomass fuels for cooking and heating indoors, which results in adverse health effects (Bonjour et al., 2013; Forouzanfar et al., 2016). In Ethiopia, where 91% of all energy consumed is biomass (Tucho, Weesie, & Nonhebel, 2014), the dependency on non-sustainable energy and resulting deforestation has been a major concern for the past 30 years (Edwards & Langpap, 2005; Mulugeta & Tadesse, 2010). Use of biomass fuels among vulnerable refugee populations results in competition between refugees and their host community for resources, often sparking conflicts with the host community and violence against women (World Food Program, 2010; UNHCR, 2014). Advanced cooking technologies, including more efficient cookstoves and cleaner-burning fuels, are needed to improve health, reduce deforestation, and protect women and girls. Some alternative fuels to biomass include charcoal, kerosene, liquid petroleum

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gas (LPG), bioethanol, and electricity with each fuel having unique advantage and disadvantages for various populations.

Bio-ethanol for household energy is a clean-burning alcohol fuel produced with modern distillation technology. Ethanol is produced by the fermentation of sugars and can be produced from four main categories of crops; 1.) sugary crops such as sugarcane and sweet sorghum, 2.) grain crops such as maize and grain sorghum, 3.) roots and tubers such as beet and cassava, and 4.) fruits such as mango, cashew apple, banana and melons (Gaia Association, 2014b). In Ethiopia, where food security is an issue, ethanol production is based entirely on molasses, a byproduct of sugar production. The installation of ethanol distilleries has enabled sugar factories to use their process waste efficiently, make a saleable product, and reduce environmental impact of the waste. The ethanol produced at the sugar factories can be used as a cleaner, alternative household fuel to replace biomass fuel use.

The case study below outlines the work of Gaia Association, whose primary mandate is to provide sustainable cooking energy to refugee populations in Ethiopia. We utilize primary and secondary data sources to explore the impact of the CleanCook ethanol stove on both refugee and urban populations. We also examine the public policy impact of the refugee program and the potential for commercialization and use of ethanol in the urban setting, while evaluating the production, supply, distribution and market factors that could impact the success of ethanol as a scalable household fuel.

Background: national energy context

Ethiopia, a country of 1.1 million km^2, is home to over 100 million people, with 80% of the population living in rural areas (World Population Review, 2018). Approximately 93% of all energy consumed in Ethiopia is in the residential sector (Tucho et al., 2014). Electricity supply from the national grid generated by hydropower (Berhanu, Anuradha Jabasingh, & Kifile, 2017; Tucho et al., 2014) (Berhanu, Tucho), is accessed by only 27% of Ethiopia's population (92% of the urban population and 12% of rural population) (World Bank, 2018). Over 80% of Ethiopia's energy consumption is from woody biomass fuels (Gaia Association, 2014c), and it is estimated that 91.2 million tons of firewood and 4.2 million tons of charcoal are consumed annually (Geissler, Hagauer, Horst, Krause, & Sutcliffe, 2013).

A national survey identified firewood, charcoal, and electricity to be the major fuel types used across Ethiopia (Gaia Association, 2014c). Overall, firewood is the primary fuel used by rural households (96%) while 40% use charcoal. Firewood use in urban households is also high, at 70%, but the urban fuel market is dominated by charcoal, with over 90% of households using it for cooking (Gaia Association, 2014c). From 1996 to 2011 many urban households used kerosene for cooking, however since 2011 urban homes have steadily transitioned to charcoal, with the number of households reporting kerosene use dropping from 21.5% to 4.9% (Gaia Association, 2014a). Urban households are increasingly using electricity for cooking as prices of other improved fuels, namely kerosene, LPG, and charcoal, are continuously rising while that of electricity has remained constant.

Energy use in Ethiopian households for preparation of food can be broadly categorized into two categories, cooking and baking. Cooking includes primary cooking (meats, pulses, sauces, stews, etc., cooked in pots), boiling water, re-heating food, and preparation of coffee and tea. An important staple of the Ethiopian diet, injera, (similar to a large flatbread or pancake) is the main product of baking and is usually baked on a large blackened clay plate (*mitad*) that can be 54 to 60 cm in diameter. Injera is usually baked over an open fire with fuelwood or using an electric *mitad* (Gaia Association, 2014d). A clay plate containing electric resistance heating coils has been developed to cook injera using electricity. In Addis Ababa, only about 15% of households use an open fire for baking, while 50% use an electric mitad stove. In rural areas, biomass fuels are used almost exclusively for injera baking.

The choice of fuel and stove is highly dependent on the price and availability of the stove and the fuel and varies widely by urban and rural sectors. Stove stacking, the use of multiple stoves for cooking, is common across Ethiopia, due in part to price fluctuations of fuels, as well as unreliability of fuel supply. Since injera stoves serve a different purpose than pot-cooking stoves, the presence of an injera stove and a primary or pot cooking stove in the home results in there being more than one stove in the home.

Refugee populations and mandates for fuel

By the end of 2017, Ethiopia was home to over 883,000 refugees, making it the second largest host nation in Africa (UNHCR Ethiopia, 2017). The refugee population continues to grow as a result of ongoing conflicts in adjacent and nearby countries, with refugees coming mainly from South Sudan, Somalia, Eritrea, Sudan and Yemen. The provision of basic energy needs, especially for cooking, is usually not addressed for refugees, in part because of a gap between mandates for the host government and humanitarian organizations, with energy provision included in neither. Prior to Gaia Association's work to introduce new fuels into the refugee camps, the Ethiopian camps depended almost entirely on firewood gathered from the surrounding community. This resulted in pervasive depletion of woody biomass around the camps, tension between refugees and the local communities, and inadequate access by the refugees to cooking fuels.

The United Nations High Commissioner for Refugees (UNHCR) has acknowledged that the provision of domestic energy for cooking to refugee populations is one of the most critical challenges that requires partnerships with host governments, donors, humanitarian actors and, newly, commercial actors. In order to address the unmet energy needs, the UNHCR developed a strategic plan in 2014, the "Global Strategy for Safe Access to Fuel and Energy (SAFE)," with the goal of promoting "appropriate household fuel and energy technologies, to improve the protection and wellbeing of refugees" (UNHCR, 2014).

In Ethiopia, UNHCR operates the refugee care program in collaboration with various implementing partners, one of which is the Gaia Association. For example, in Ethiopia, the Norwegian Refugee Council is responsible for shelter and livelihood activities and the Lutheran World Federation is in charge of the water and sanitation program. The Gaia Association has become the leading supplier of cooking energy and various other energy services in the camps.

Methods, sources, and approach

Data for assessing implementation

Secondary data from gray literature, including programmatic reports from the implementing agency, as well as external unpublished studies and policy briefs, were used to evaluate the implementation of the CleanCook ethanol stove. Programmatic reports provided details on the number of households served for each year, number of liters of ethanol distributed, as well as other particulars related to programmatic developments such as trainings and stove maintenance. Additionally, these reports were used to evaluate the effectiveness of the CleanCook ethanol stove intervention and the program's ability to meet its defined goals.

We reviewed several peer-reviewed studies conducted with the CleanCook stove to evaluate the potential impact of the CleanCook stove to reduce emissions and impact population health. These studies included a water boiling test and laboratory emissions test of the CleanCook stove (MacCarty, Still, & Ogle, 2010) and performance and safety testing by Aprovecho Research Center (Still, MacCarty, Ogle, Bond, & Bryden, 2012). In addition, we reviewed a field study of CleanCook stove emissions by the University of California Berkeley (Pennise et al., 2009a). This study was conducted in a total of 33 households: 12 in Kebribeyah Refugee Camp, 12 in Bonga Refugee

Camp and 9 in Addis Ababa. Indoor air sampling for carbon monoxide and particulate matter (PM) was conducted for a 24-hour period. We also extrapolated results from a field study of exposure and health associations with the CleanCook stove in Madagascar (Practical Action Consulting, 2011).

Users' perceptions and factors influencing adoption were assessed from the initial pilot implementation in the refugee camps in 2005. This study explored user satisfaction of the CleanCook stove following implementation as well as fuel and time savings (Egziabher, Murren, & O'Brien, 2006). We also evaluated secondary data on the marketability and customer acceptance of the CleanCook stove in the urban commercial market from 2006 (Murren & Debebe, 2006).

To complement the secondary data, we conducted in-person interviews among 50 low-income households in Addis Ababa during July 2017. We randomly selected 50 members out of 500 members of the Former Women's Fuelwood Carrier Association (FWFCA) who owned a CleanCook to participate in the study. All surveys were conducted at the participants' home in the local language following informed consent.

Data for assessing commercialization

We evaluated the potential for commercialization for ethanol in Addis Ababa using data on items pertaining to the potential commercialization of ethanol as a household fuel from "The Holistic Feasibility Study of a National Scale-Up Program for Ethanol Cookstoves and Ethanol Micro Distilleries (EMDs) in Ethiopia" funded by DFID and the Strategic Climatic Institutions Program (SCIP). For this study, a variety of surveys, questionnaires, focus group discussions, and semi-structured interviews were conducted with key stakeholders including government institutions and ministries, service providers, and households (Gaia Association, 2014a; Gaia Association, 2014b; Gaia Association, 2014c; Gaia Association, 2014d).

Approach

We employed the RE-AIM framework as a platform to evaluate the success of the ethanol CleanCook stove by Gaia Association in two distinct implementation populations; 1.) a humanitarian population, and 2.) a low-income population in Addis Ababa. The RE-AIM assessment evaluated 5 distinct components of implementation; reach, effectiveness, adoption, implementation and maintenance (Glasgow, Vogt, & Boles, 1999). We then evaluated the potential for ethanol commercialization in Addis Ababa. Below, we present an overview of the implementing organization and the effectiveness of the CleanCook ethanol stove. We then focus on the implementation program specifics and household adoption of the CleanCook stove for the refugee camp population followed by the analysis of the low-income program. Finally, we outline plans for scale-up of the interventions and the potential for ethanol commercialization in Addis Ababa.

Overview of implementing organization

Project Gaia Inc. began work in Ethiopia by conducting CleanCook stove trials in three Jijiga-area refugee camps and Addis Ababa during 2005–2006 with a grant from the Shell Foundation (Egziabher et al., 2006). The original goal of the refugee program was to provide a clean and safe domestic energy option to refugee households. The program also aimed to relieve the burden of firewood collection, improve the health of women and children, and assist in environmental conservation. These pilot initiatives concluded in the development of the "Biofuels Development and Utilization Strategy" in 2007 that sought to encourage the supply of fuels from locally produced biofuels to enable an import substitution and improve Ethiopia's balance of trade (Tessama, Davis, Pv, & Lambe, 2013). Gaia Association was officially founded in 2006 following the pilot studies and was originally funded by Project Gaia Research Studies through a grant from Royal Dutch Shell and private donations in response to an invitation for ethanol cookstove trials by the Ethiopian Sugar Corporation.

Effectiveness of the CleanCook stove

CleanCook ethanol stove technology

The CleanCook ethanol stove was initially designed and developed in 2001 by Dometic Group and based on a stove developed by Origoverken AB. The stove was manufactured in Sweden and Slovakia. Current stove production is by CleanCook Sweden AB, founded in 2015, and manufactured in Durban, South Africa. The stove may be shipped fully assembled or in parts, to be assembled locally. There are two CleanCook stove, a single-burner model and double-burner model (Fig. 1). The ethanol stove contains a fuel canister with a capacity to hold 1.2 L of ethanol adsorbed onto the surface of a mineral fiber contained within the canister. When the stored ethanol burns, 1.2 L provides a burn time of 4–5 h at maximum heat and 7–8 h at low heat. The retention of ethanol fuel in the canister by adsorption prevents the fuel from spilling from the canister, and also makes it available for evaporation from the canister mouth or opening into a flue or combustion chamber. The canister is removed from the stove for filling and replaced in the stove for use (Fig. 1).

Laboratory test performance

The performance of the CleanCook stove was assessed at the Aprovecho Research Center in 2009 and 2010 with a 5-liter water boiling test (WBT) (Still et al., 2012). The CleanCook stove emitted 5.3 g of CO during a 45 min period of simmering 5 L of water, 14% of the CO of an open fire (Still et al., 2012). The CleanCook stove emitted 4.4 mg of fine particulate matter ($PM_{2.5}$) which is <1% of the $PM_{2.5}$ of an open fire, and is well below the bench-mark set by Aprovecho Research Center of 1500 mg used to complete the 5–1 WBT (MacCarty et al., 2010). In a comparison of 18 different stoves, the CleanCook stove was 3rd lowest

Fig. 1. Left; Double burner model of the CleanCook Stove; right; fuel canister being filled with ethanol.

in both emitted CO and $PM_{2.5}$ (only liquid petroleum gas [LPG] and solar stoves were lower) (Still et al., 2012). The water boiling test found that the CleanCook dramatically reduced emissions of particulate matter ($PM2_{2.5}$) and carbon monoxide (CO) compared to other stoves (MacCarty et al., 2010) (Table 1). It is estimated that the CleanCook stove uses approximately 22 kg of fuel per month (Still et al., 2012).

Several groups, including the Aprovecho Research Center, the United States Environmental Protection Agency (USEPA), and Kenya Industrial Research and Development Institute (KIRDI) have conducted laboratory testing of the CleanCook stove. The results of these laboratory tests state that the high-power thermal efficiency of the CleanCook stove is between 56% and 60% (Kenya Industrial Research and Development Institute, 2015; Jetter & Ebersviller, 2015; Still et al., 2012). In a study by Shen et al., a laboratory water boiling test showed the average high-power thermal efficiency of LPG fuels to be 56%, followed by ethanol fuel at 55% and kerosene at 41% (Shen et al., 2012).

Field evaluation

In 2009, UC Berkeley and the Center for Entrepreneurship in International Health and Development (CEIHD) conducted pilot testing of the CleanCook stove in Kebribeyah and Bonga Refugee Camps and Addis Ababa (Pennise et al., 2009b). The study evaluated concentrations of $PM_{2.5}$ and CO before and after the CleanCook stove intervention among 33 households. The study observed a significant 84% reduction in average kitchen $PM_{2.5}$ and a 76% reduction in CO for all households following the CleanCook stove intervention. In absolute numbers, 24 h average concentration levels of $PM_{2.5}$ decreased from about 1250 μg/m^3 to 200 μg/m^3 with the populations and CO levels were reduced from 38.9 ppm to 9.2 ppm following the intervention. The levels of $PM_{2.5}$ however did not reach the WHO 24-hour standard of 25 μg/m^3, or more lenient interim target of 75 μg/m^3 for a 24-hour period (WHO, 2014), possibly due to continued use of kerosene wick lanterns in homes or neighborhood contamination. Field tests of the CleanCook stove in Madagascar from 2008 to 2011 also provide evidence of the stove efficiency compared to a traditional 3-stone fire. Two study locations demonstrated carbon monoxide exposure reductions of 74% and 54% for the mother and 64% and 35% for the child. In addition, $PM_{2.5}$ reductions for the mother were 62% and 44%, while children saw a reduction in personal $PM_{2.5}$ exposure of 63% and 47% (Practical Action Consulting, 2011).

Measures of safety

In the tests conducted at Aprovecho, the CleanCook stove had a safety rating of 37 out of 40 (weighted rating of 98 out of 100) (Johnson & Bryden, 2015). The CleanCook ethanol stove scored a 4 out of 4 on 9 of 10 safety tests, and a 3.5 out of 4 on the test for flames exiting the fuel chamber (Johnson & Bryden, 2015).

During the pilot implementation of the CleanCook ethanol stove in the Jijiga refugee camps, discussed below, there were no accidents, injuries, or accidental fires reported among any of the households during the 540,000 h of stove use (120,000 L of ethanol distributed times 4.5 h of burn time per liter). Since the pilot testing, there have also been no reported accidents with the CleanCook ethanol stove. The excellent safety record is due to the design of the stove and fuel canister. The ethanol is poured into the fuel canister and once in the canister there is almost no risk of an accidental fire as ethanol will not spill or leak from the canister. Ethanol vapors, being of ambient temperature and near neutral buoyancy, will dissipate readily. This is in contrast to LPG vapors, which, when released from a pressurized cylinder, are extremely cold, with a vapor density heavier than air, and will follow the contour of the ground and collect in low spots where they can reach explosive concentrations, if ignited. (World LP Gas Association, 2008). The stove is not pressurized, and the fuel canister in the stove adsorbs alcohol fuel (Still et al., 2012). This prevents leaking, spilling, or exploding of fuel, reducing potential for accidents. If a CleanCook stove user were to overfill the ethanol canister when pouring from a 10-liter jerry-can, the extra fuel could leak out as a liquid and burn but it will not explode. Given the training on the stove use and fuel canister filling, there have been no reported incidents. There were however, 3 reported incidents in the refugee camps due to ethanol fuel not being used in the CleanCook stove. These fire accidents occurred when stove users attempted to light charcoal or firewood with ethanol. This is a common practice when families use kerosene and CleanCook stove users are now trained not to use ethanol in this manner.

Table 1
Performance gains of the ethanol CleanCook stove over other stoves (5-liter WBT; pot without lid)[a].

	Three stone fire	StoveTec Rocket	Charcoal Jiko	Wood/Charcoal Rocket Combo
Reduction in Particulate Matter	99.8%	99.5%	98.4%	91.0%
Reduction in Carbon Monoxide	93.4%	75.0%	95.1%	87.9%
Improved Efficiency	3 times	2 times	2.8 times	1.8 times

[a] Based on data from MacCarty et al. (2010).

CleanCook stove maintenance

To promote efficient and accident-free stove performance, Gaia Association provides on-going stove maintenance services in the refugee camps. The stove has very limited need for replacement. Repairs are most often needed on the pivot arm of the regulator plate that opens and closes the mouth of the fuel canister. This pivot arm can be maintained with basic hand tools, and other maintenance can be performed at any local metal workshop. Households may require a fuel canister replacement if damage from repeated food spilling has corroded the canister mouth or if dirty fuel has compromised the adsorptive capacity of the fiber in the canister. Canisters are made available as spare parts and can be easily replaced. They can also be cleaned and refurbished.

Refugee camp interventions

Pilot implementation

Gaia's work in the refugee camps began in Northern (Shimelba Camp) and Eastern Ethiopia (Jijiga Area Camps) in 2005 with a pilot program designed to assess the potential for ethanol as a cooking fuel in the humanitarian camps (Egziabher et al., 2006).

During the pilot project funded by the Shell Foundation, Gaia Association provided 150 CleanCook stoves to Eritrean refugee households in Shimelba Camp in 200, 150 stoves to Sudanese refugee households in Bonga Camp in 2006, and an additional 150 stoves to refugees in Kebribeyah camp, also in 2006.

In the Shimelba Camp, UNHCR and the Ethiopian Administration for Refugees and Returnees Affairs (ARRA) prioritized households that had elderly or disabled residents, female-headed households, or extremely large households. Ninety-nine of the 150 households were selected to complete a user survey on the CleanCook stove. Baseline surveys were conducted prior to the CleanCook stove intervention, and follow-up surveys were conducted bi-weekly for 3 months post-intervention. Of the 150 households, 50 were asked about stove efficiency, safety and performance compared to other stoves. Forty-three of 50 reported they enjoyed the speed of cooking with the stove, while 34 believed it was safer and 38 out of 50 described the stove as healthier (Egziabher et al., 2006). Twenty-six households reported using the CleanCook stove because it was free (Egziabher et al., 2006).

Among the Somali population in Kebribeyah Camp, the CleanCook stove was found to be suitable for all cooking needs; however, among the Eritrean population in Shimelba Camp, the CleanCook stove intervention did not displace the need for firewood for injera stoves.

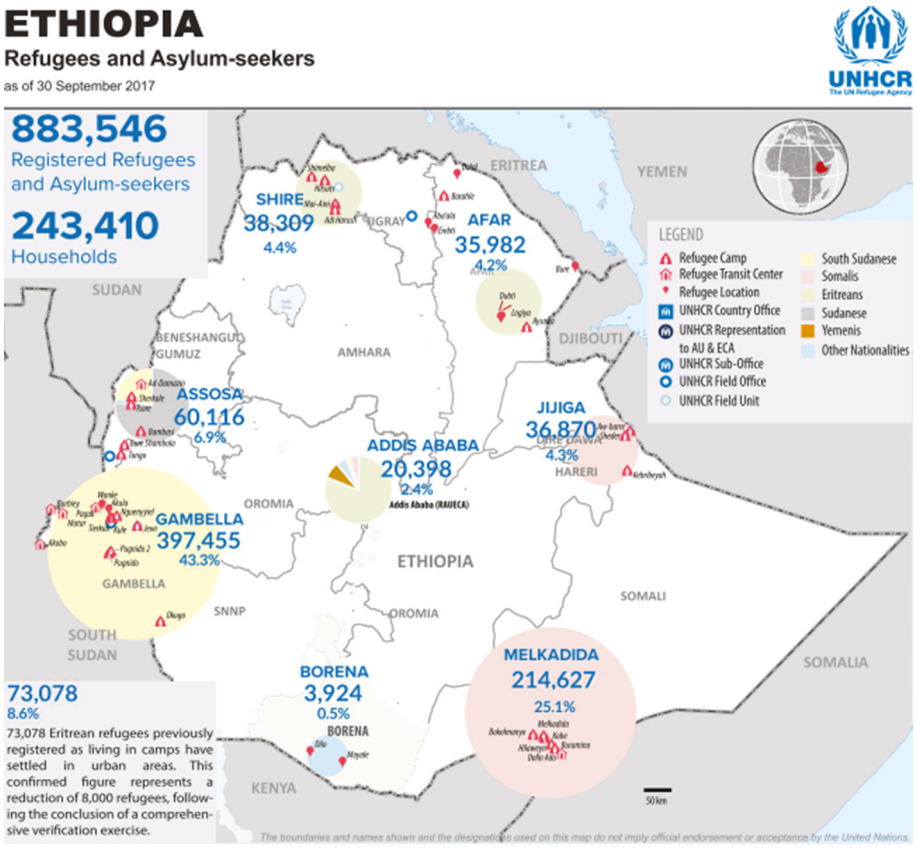

Fig. 2. Map of refugee camps and population in Ethiopia as of September 30, 2017 (UNHCR Ethiopia, 2017).

Additionally, among South Sudanese refugees in Bonga Refugee Camp, the CleanCook ethanol stove was not suitable for cooking porridge in large pots. Following the pilot studies, given the ability to displace all other stoves, Gaia and the UNHCR chose to focus implementation efforts on the Kebribeyah Camp and its two associated camps, Sheder and Awbare, in the Jijiga region. Stove and fuel stacking in the Somali

Table 2
Main implementation projects of Gaia Association.

Implementation Site	Location	Program Activities	Ethnic origins residents	Preferred staple foods	Efficacy of ethanol and other fuels
FWFCA Addis Ababa	Addis Ababa	• Supply fuel ethanol and ethanol stoves	Ethiopia	• Pot cooking: sauces and stew • Baking: Injera (up to 60 cm in diameter)	• Pot cooking: Ethanol CleanCook Stove. • Injera baking: Firewood
Shimelba Refugee Camp[a]	Tigray, Northern Ethiopia	• Supply ethanol stoves and electric Injera cookers in a group kitchen	Eritrea	• Pot cooking: sauces and stews • Baking: Injera (up to 60 cm in diameter)	• Pot cooking: Ethanol CleanCook Stove • Injera baking: Firewood
Kebribeyah, Sheder, Awbare Refugee Camps	Jijiga area, Somali Regional State (East)	• Supply fuel ethanol and ethanol stoves • Provide community training and follow ups monitoring • Maintain stoves • Install and maintain solar street lights • Monitoring and evaluation	Somalia	• Pot cooking: Rice, sauces, spaghetti, and stew • Baking: Small injera about 10 cm in diameter	Ethanol stove is used for all cooking, when sufficient fuel is available
Bonga Refugee Camp[b]	Western Ethiopia	• Pilot implementation and household survey	South Sudan	• Pot cooking; Corn porridge	• Pot cooking: Ethanol CleanCook Stove • Genfo porridge: Firewood
Tsore, Sherkole, Bambasi, Tongo and Gure Shembola Refugee Camps[c]	Assosa area, Western Ethiopia	• Supply fuel ethanol and ethanol • Stoves • Produce and distribute charcoal briquettes • Distribute • briquette stoves • Create income generating activities for refugees	South Sudan	• Pot cooking: Corn porridge	Ethanol stove is used for all cooking, when sufficient fuel is available

[a] Pilot implementation by Gaia Association. Current work is by Ethiopian Administration for Refugees and Returnees Affairs (ARRA).
[b] Pilot implementation.
[c] Currently part of a scale-up programming.

refugee camps is primarily due to ethanol interruptions. During ethanol fuel interruptions, as seen in Table 3, refugees may use supplemental kerosene for cooking, or utilize firewood or charcoal.

Gaia Association currently works in 9 different camps, employing several different energy interventions, of which the ethanol CleanCook stove is one. Its target population for energy services in the refugee camps is all 883,546 refugees in the country (Fig. 2). This was number of refugees in Ethiopia as of September 30, 2017 but this number is constantly changing as refugees move in and out of the country.

Ongoing implementation

Gaia Association currently operates household energy programs in 9 refugee camps, although the work in the Western refugee camps is only in the scale-up phase (Table 2). The CleanCook ethanol stove and fuel are provided to refugee families free of charge. Average family sizes in the Jijiga-area camps is 9 to 11 people, and families with 9 or more members receive 2 stoves. The procurement of ethanol for the refugee camps is completed for Gaia Association by UNHCR. Although UNHCR leadership at the headquarters level promotes improved cookstoves, local implementation of such programming is much more problematic. The consistency of the ethanol fuel supply and interruptions demonstrated in Table 3 were a result of procurement failures, insufficient funding, or insufficient supply. Logistical constraints often result in stagnation in the purchasing of ethanol for the refugees, resulting in fuel interruptions that hinder sustainability. When ethanol fuel is not available, UNHCR may still provide an alternative fuel, such as kerosene, for cooking when no local firewood is available for collection. A new Ethiopian policy allowing refugees to work and earn money in the formal sector has prompted a new initiative by Gaia Association. A pilot implementation of a market system for ethanol in the refugee camps will allow refugees to purchase cooking fuel with earned income, remittances from family members abroad, or from assistance received directly from the UNHCR in the form of cash or purchase vouchers (The UN Refugee Agency, 2018).

For all refugee programs, Gaia Association provides intensive stove and fuel training prior to all stove distributions in the refugee camps. The training covers operation, maintenance, safe fuel handling, and care of the stove to assure an extended stove lifetime. Each training session includes approximately 8–12 individuals and it takes about 15 min to learn to how to operate the CleanCook stove. Stove users are provided with a standard user manual in the local language that includes pictures to illustrate operation procedures and safety precautions. In addition, Gaia community workers (often refugees) conduct door-to-door refresher safety trainings with 40 households per week to reemphasize safety points and inspect the stoves for safety and functionality. Billboards have also been erected in the camps to promote the safe use of the CleanCook stoves.

Gaia employs both local village members and members of the refugee community and has a total of 46 employees in Addis Ababa and in the camps. The entire program consists of 3 Coordinators, 1 Stove Maintaining/Store Keeper, 1 Cashier, 2 Drivers, 12 Guards, 11 Bottlers and 6 Incentive Workers (refugee workers who are provided a small stipend by Gaia Association of 700 Birr a month). Under Ethiopian law, refugees cannot be formally employed; instead they are part of a team of Incentive Workers. In the refugee camps, all of the Community Workers, Distribution Supervisors and the Cashiers are women. Gaia Association has created >26 full time jobs in the refugee camps, of which 60% are held by women.

The total operational budget for the Jijiga refugee camps (Kebribeyah, Sheder, and Awbare) was close to $700,000 in 2015 and $500,000 in 2016 with administrative costs being 20% and 18% in 2015 and 2016 respectively. It is important to note that the staff were not fully utilized in either year due to ethanol interruptions. The payroll, benefits and health insurance costs of all employees of the Gaia Jijiga operation totaled approximately $64,000 annually. To break down the annual

Table 3
Gaia Association ethanol stove intervention in refugee camps: CleanCook ethanol stove distributions[a], fuel provision and interruptions.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Number of CleanCook Stoves Distributed	150	300	700	2300	52	0	0	112	0	N/A	4549	465	103	8731
Number of Kerosene Stoves Distributed	N/A	N/A	N/A	N/A	2000	0	454	2340	0	N/A	0	0	0	4794
Liters of Ethanol	N/A	300,000	189,000	466,600	262,055	N/A	598,782	250,000	270,000	N/A	316,989	690,002	488,835	3,832,263
Liters of Kerosene	N/A	N/A	N/A	N/A	N/A	487,838	562,555	465,559	37,000	N/A	54,000	75,345	155,000	1,746,297
Ethanol Interruption	No	No	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A
Reason for Interruption	N/A	N/A	N/A	Procurement difficulties	Insufficient production of ethanol	N/A	Insufficient production of ethanol	Insufficient production of ethanol	Procurement difficulties	N/A	Insufficient production of ethanol	Procurement difficulties	Procurement difficulties	N/A
Length of Ethanol Interruption	N/A	N/A	N/A	4 months (September–December)	8 months (May–December)	N/A	5 months	12 months	6 months (January–June)	N/A	4 months (January–April	N/A	6 months (March – August)	N/A

[a] Replacement of CleanCook stoves occurred for households that owned their stove for >10 years. Families with >9 members receive 2 stoves per family.

costs further, the cost for one refugee camp in Jijiga, the Kebribeyah Camp, is approximately $212,000 for program and $21,000 for administration. Program costs for one year include ethanol purchases and transportation ($197,000), stove costs ($11,000), and storage tank management together with fuel distribution ($4000). Administrative costs are $17,000 for salaries, $2000 for office rent, and $2000 for vehicle and other costs. Costs vary per year based on the amount of ethanol available for distribution and number of new refugees requiring the CleanCook stove.

Low-income urban intervention

The low-income urban household intervention program was commenced in 2005 with a partnership with a woman's cooperative, the Former Women Fuelwood Carriers' Association (FWFCA), with a membership of 4000 women. The FWFCA's purpose is to reduce the number of women who are dependent on gathering and selling fuelwood (mostly eucalyptus branches and leaves) for a living in Addis Ababa by creating alternative income generating activities for them (Mengesha & Tadele, 2006). Women fuelwood carriers are well known for carrying large burdens (weighing up to 70 kg) of fuel down from the mountains adjacent to Addis Ababa to sell in the market for use in cooking injera. To date, the FWFCA has provided 500 low-income households with the CleanCook stove. All women who have a CleanCook stove from the FWFCA purchased the stove at a subsided rate of Birr 300 (USD$12.85, based on the pre-devaluation rate of 23.5 Birr per USD). Fuel for the stove is provided by Finchaa Sugar Factory to the FWFCA cooperative and is then supplied by the FWFCA to all members at their office location at a retail rate of Birr 15 per liter (USD$0.65). The FWFCA retains a net profit of 1 Birr per liter.

Results from the in-person survey of 50 households in 2017 provide critical information on perceptions of the cookstove and stove stacking among these urban users. All 50 FWFCA members practiced stove stacking and reported using between 2 and 5 different stoves for cooking. In addition to the use of the ethanol CleanCook stove, almost all households reported use of a charcoal stove, while thirty-five houses used firewood stoves and 25 houses used electricity. Thirty of the 50 households used the ethanol stove as their primary stove, while 15 used a charcoal stove, and 5 used firewood as their primary fuel. Secondary fuel use was dominated by the use of charcoal (Table 4).

Several factors contributed to the stove stacking among the FWFCA urban population, including the practicality of the stoves for cooking local dishes, the cost of fuel, and overall speed and cleanliness of the stoves. In the 2017 survey, 39 of 50 women reported that multiple stoves were needed to prepare different foods. Households preferred to use the CleanCook stove and charcoal stoves for making wat (a meat or vegetarian stew or curry) or making coffee (Fig. 3). Thirty-six households reported using charcoal stoves for making coffee. Coffee ceremonies often occur multiple times a day in Ethiopia and charcoal users reported that maintaining ceremonial traditions was an important reason for using charcoal in making coffee (Fig. 3). Eighteen households also reported using the ethanol CleanCook stove to make coffee. The CleanCook stove was reported to be unsuitable for making the large Ethiopian injera, which is normally baked 2–3 times per week. Thirty-one households reported using firewood for baking injera, while 23 households used an electric mitad. In addition, households reported using multiple stoves during a single meal to cook the meal faster. Charcoal users reported an additional benefit of heating their home with charcoal.

FWFCA CleanCook stove users stated that they enjoyed the stove primarily because it was convenient and fast. Households using firewood and charcoal reported that the lower cost of fuel is a primary reason for its use (Fig. 3). Fuel interruptions also contributed to stove stacking. An additional 23.6% of the CleanCook stove users responded that they also used a kerosene stove because they ran out of ethanol and 26 households reported using charcoal stoves for heating their homes. Among the low-income participants, 86% of women surveyed believed that the ethanol fuel supply was consistent. This perception is likely to pertain only to women who receive their fuel from the FWFCA because women are obtaining fuel from a source which they control, where shortages are unlikely, compared to consumers in the city who purchase ethanol directly from distributors. In contrasting reports however, 36% of households stated that there were times when they did not have access to ethanol fuel due to its unavailability. In the in-person interviews with women from the FWFCA in 2017, 66.6% of the 50 women believed ethanol was “very safe” and 32.1% stated the stove was “safe”.

A few maintenance and fuel interruption issues were reported among the FWFCA members. About half of the 50 FWFCA households surveyed stated that they required a fuel canister replacement. Only 5 of the 50 households (10%) had stopped using the CleanCook stove for any period of time since they had received the stove in 2010. Two of the five who reported a temporary stoppage in stove usage stated that it was due to needing stove repairs while the other three indicated they had a lack of funds to buy fuel.

Table 4
Stove use among women in the Former Women Fuelwood Carriers' Association (FWFCA) who own a CleanCook Stove (N = 50).

	Ethanol	Firewood	Charcoal	Kerosene	Electricity
Stove Use					
Any stove use	50	35	49	3	25
Use as primary stove	30	5	15	0	0
Use as secondary stove	13	7	17	3	10
Reasons for Stove Use					
Baking Injera	0	31	0	0	23
Cooking wat (stew)	49	0	6	0	0
Making Coffee/Tea	18	0	36	3	0

Potential for scale-up

The scale-up of the CleanCook ethanol stove in humanitarian settings, in low-income urban settings, and in middle income commercial settings is affected primarily by the supply of ethanol. The potential for ethanol to be used as a commercial household fuel in Addis Ababa is also affected by its cost to consumers, due mostly to the impact of VAT on the retail price of the fuel.

Gaia Association believes that the commercialization of ethanol as a household fuel could reach all middle-income households in Addis Ababa, or about 75% of 600,000 households (total estimated for the city) by 2030. To date, in addition to the FWFCA stoves, about 3000 stoves have been sold by a business in Addis Ababa that targets middle income consumers. This is about 0.007% of the estimated achievable penetration rate in Addis Ababa (3000 stoves/450,000 households).

Ethanol production

Ethanol in Ethiopia is produced from molasses, a byproduct of sugar production,. Moreover, when a distillery is co-located with a sugar factory, it is able to use electricity and excess heat and steam from the sugar production for the distillation process (Fig. 4). While some molasses may be sold by the sugar factory for use as a cattle feed supplement, yet, this market is very limited. Export markets for molasses are uneconomical. As a result, most molasses produced in Ethiopia is dumped, either land applied or disposed of in waterways. Repeated land applications can cause the buildup of trace minerals in the soil to toxic levels, as in the case of fluoride pollution around the Wonji Sugar Factory (Kloos & Haimanot, 1999). Dumping of molasses in rivers produces elevated biological oxygen demand (BOD) and chemical oxygen demand (COD) levels that deprive the aquatic environment of oxygen, killing aquatic plant and animal life. The installation of ethanol distilleries at Ethiopian sugar factories are thus a benefit for the environment, while also providing an opportunity to monetize a waste product and produce

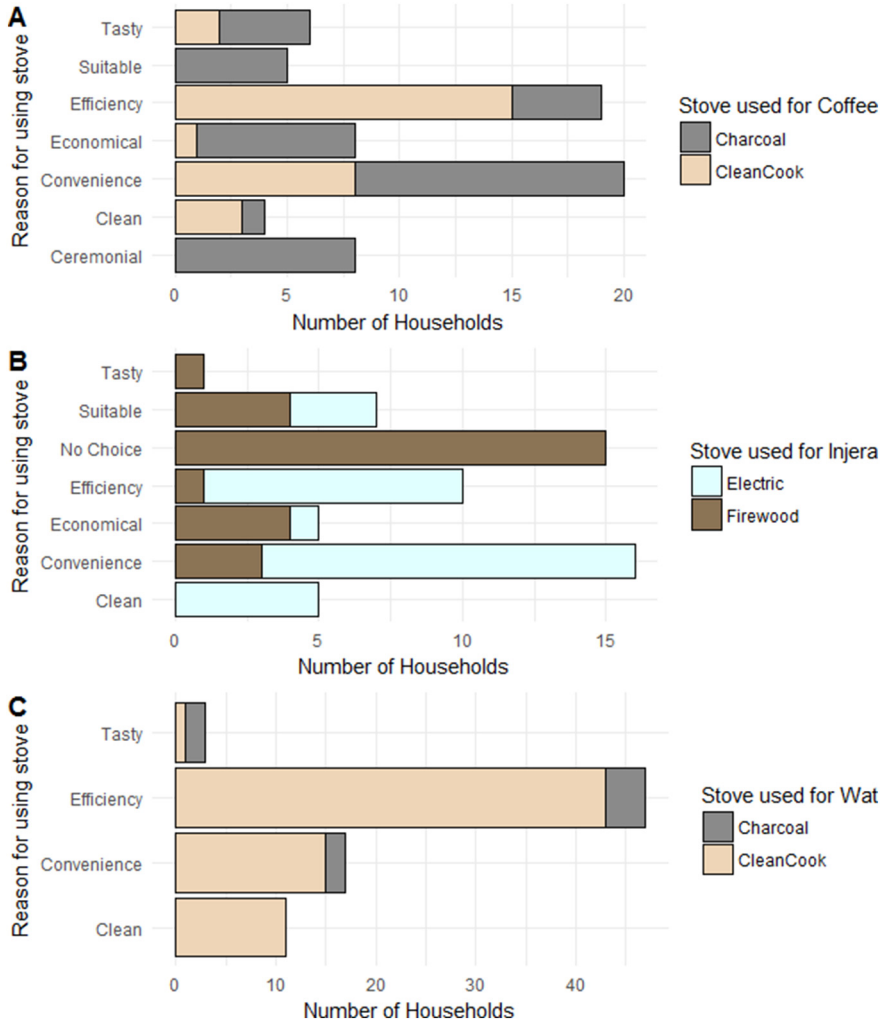

Fig. 3. Reported stove use and reasons for different cooking activities among 50 women using the CleanCook Stove in the Former Women Fuelwood Carriers Association (FWFCA): A). Coffee, B). Injera, C). Wat (stew).

a much needed revenue stream for the factory. While the addition of a distillery to a sugar factory represents a significant capital investment that requires finance and access to hard-to-obtain foreign exchange, nevertheless, the incremental cost of adding ethanol to sugar production is reduced by being able to obtain the heat and power from the sugar factory for the distillery.

Currently, two of the seven sugar factories in operation in Ethiopia, Finchaa Sugar Factory and Metehara Sugar Factory are equipped with distilleries for ethanol production (Table 5). These two factories have a combined annual production capacity of 32.5 million L, but rarely produce >26 million L annually. Four additional ethanol distilleries are under construction, which could also add an additional 84.3 million L of annual capacity.

Currently, the two sugar factories with ethanol distilleries produce sufficient ethanol for the refugee camps and limited commercial stove sales, in addition to the gasoline fuel blending program in Addis Ababa. However, production downtime due to old or poorly maintained equipment on occasion impact ethanol supply. Currently the refugee camp interventions use approximately 3 million L of ethanol per year, with an additional 10 million L potentially being available for commercial sales, provided there are no technical difficulties in production.

When ethanol is distilled at the sugar factories, it is stored in large-capacity tanks to await sale and shipment. For stove fuel, it is loaded into tanker trucks and, during this step, denatured with denatonium benzoate (Bitrex) or denatonium saccharide and colored with an industrial blue dye. The denaturing and coloring make the ethanol distinguishable for cooking and exceedingly unpalatable for drinking. The ethanol, thus denatured, is transported from the factories in tandem tanker trucks, which can carry up to 50,000 L (Fig. 4). Ethanol is then offloaded into storage tanks at fuel depots prior to distribution in Addis Ababa or in the refugee camps. Over the last 13 years, Gaia Association and the UNHCR have installed 500,000 L of bulk fuel storage in the three Jijiga refugee camps, Kebribeyah, Sheder and Awbare. The ethanol is dispensed from these distribution centers to the refugees. The ethanol fuel is filled into 10-liter jerry cans by the Gaia Association workers and distributed approximately once every 10 days. In the commercial market, ethanol is stored at a fuel depot on the outskirts of the city where it is filled into jerry cans and taken to a sales point. The commercial business operating in Addis Ababa has two 20,000-liter tanks while the FWFCA possess several smaller tanks. Ethanol is currently distributed in Addis Ababa in 5-and 10-liter jerry cans, with a plan in the future to also distribute ethanol in 1- and 2-liter returnable bottles. The FWFCA purchases ethanol directly from distilleries, not from the current commercial operator in Addis Ababa.

Gaia's work with the FWFCA has been slowed by the lack of ethanol distribution in the city, and the inability of the FWFCA to obtain working capital to expand its own distribution. The FWFCA has so far only distributed 500 stoves to its 4000 members. The association has been reluctant to sell the additional 500 stoves it has in stock to its members until their access to ethanol fuel is improved. Currently, FWFCA purchases fuel from Metehara Sugar Factory and transports it to the FWFCA headquarters in the Shiro Meda area of Addis Ababa,

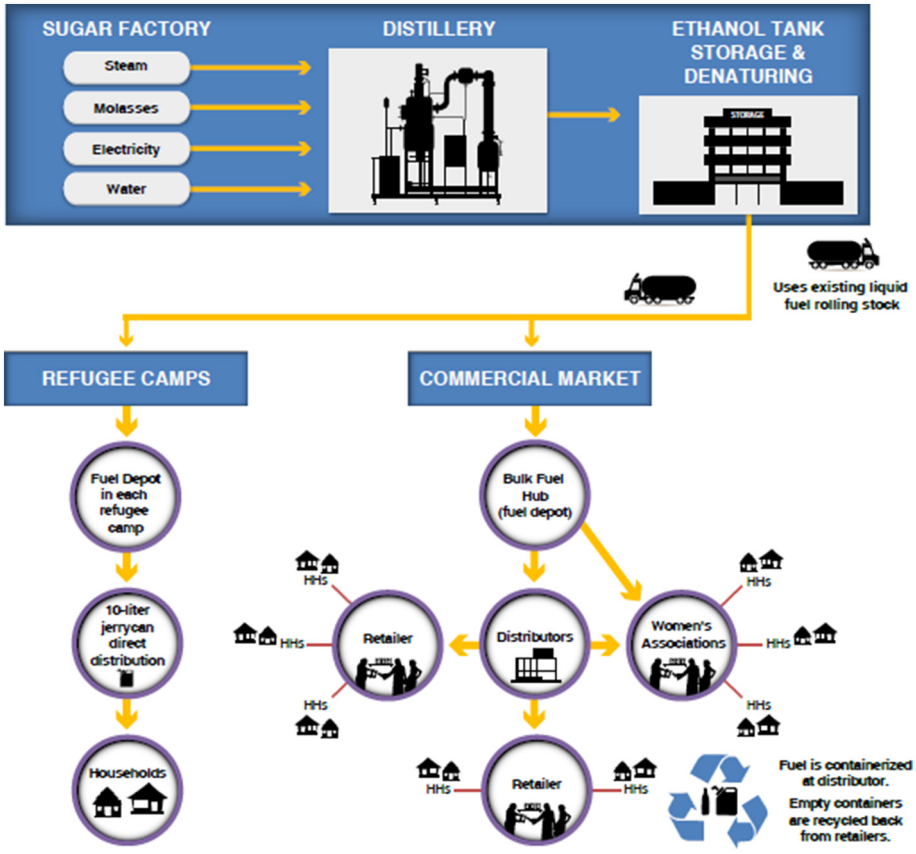

Fig. 4. Ethanol Supply Chain in Ethiopia.

where it is stored in a 10,000-liter storage tank, and from there distributed to members. The 500 stoves already distributed were sold to women living in the Shiro Meda chapter of the association, since they are easily able to access the fuel from the headquarters depot. The remaining stoves have not yet been distributed because the other members of the association live far from the FWFCA headquarters and do not have access to ethanol fuel. FWFCA has been working to remedy the supply situation. In 2012 the World Bank and the Nordic Climate Fund helped finance and build a micro-distillery for the FWFCA. The micro-distillery utilizes molasses waste from nearby Wonji Shoa Sugar Factory and when fully operational will produce 1000 to 1200 L of ethanol per day. Although the distillery is now producing ethanol, regular production and distribution have not begun because the micro-distillery is awaiting access to the electricity grid to supply the power needed to run the control system. The distillery has a backup diesel generator but this is only run on an occasional basis to produce ethanol, since the diesel fuel is expensive. The purpose of the micro-distillery is to enable the FWFCA to supplement its existing fuel sales with its own ethanol production, to supply not only its members but also the communities near the distillery site. The distillery is located in Gelan on the Addis Ababa Waste Management Authority campus on the southern edge of Addis Ababa city.

Ethanol commercialization in Addis Ababa

Two significant domestic markets for ethanol exist in Ethiopia, ethanol for fuel blending in gasoline and ethanol for cookstove fuel. Fuel blending, the addition of ethanol with gasoline for automobiles, has

Table 5
Sugar factories in Ethiopia.
Data from (Ethiopian Sugar Corporation, 2018).

Factory Location	Year Fully Operational	Cane Crushing Capacity (TCD)	Rated Capacity of Sugar Production (tons/year)	Ethanol Distillery Status	Ethanol Production current or planned (million L/year)	Financier
Finchaa	Sugar factory 1998; distillery 2003; expansion 2013	5000 increased to 120,000	110,000; increased to 270,000	Operational	20	Africa Development Bank and governments of Australia and Spain
Metehara	Sugar factory 1970; distillery 2010	5250	136,692	Operational	12.5	Ethiopian government
Wonji Shoa	2013	6250, will increase to 12,500	174,000, will increase to 220,700	Planned	12.8	Indian government
Tendaho	2014	13,000	300,000	Planned	31	Import-Export Bank of India (EXIM)
Arjo Dediessa	2015	8000	145,000 increased to 216,000	Not yet planned	–	–
Kessem	2015	6000; increased to 10,000	153,000 increased to 260,000	Planned	12.5, planned 30	Chinese Development Bank
Omo-Kuraz	2017	6500; increased to 12,000	250,000	Planned	28	Chinese Development Bank

Table 6
Price comparisons of ethanol fuel to alternatives in Addis Ababa.

	Birr July 2007	USD July 2007[a]	Birr Sept 2017	USD Sept 2017[b]	Birr Feb 2018	USD Feb 2018[c]
Fuelwood (per kg)	0.6	$0.07	3	$0.13	3	$0.11
Hardwood Charcoal (per kg in 40 kg sack)	1.87	$0.21	7.5	$0.32	7.5	$0.27
Charcoal (per kg in 1 kg bag)	1	$0.11	10	$0.42	10	$0.36
Kerosene (per liter)	4.15	$0.46	16.35	$0.70	16.35	$0.60
LPG (per kg)	4.61	$0.51	33	$1.42	33	$1.20
Ethanol, factory gate (per liter)	3.5	$0.39	9.37	$0.40	9.37	$0.34
Ethanol, retail Addis Ababa (with VAT) and retailer's margin (3.22 Birr) (per liter)			14	$0.60	14	$0.51

[a] Birr at 9.0/dollar in July 2007.
[b] Birr at 23.43/dollar in Sept. 2017.
[c] Birr at 27.5/dollar in Feb. 2018.

historically ranged upward to 6.5 million L annually, and household fuel has been about 3 million L annually. The interest in fuel blending by the government fluctuates as the price of crude oil changes. It is therefore difficult to know what percentage of the ethanol produced will be used in fuel blending from year to year. Fuel blending poses technical and infrastructural challenges, both in mixing with gasoline and in distribution and use in automobiles. As newer automobiles enter the market and older ones leave the market, gasoline-ethanol fuel blending becomes more of interest.

Several challenges exist when considering the potential for ethanol stove fuel commercialization in Addis Ababa. These include low awareness of ethanol as a cooking fuel and the price of the ethanol stove and ethanol fuel for users. According to a survey completed in 2014 under the Strategic Climate Institutions Programme (SCIP), awareness of ethanol fuel and ethanol cookstoves was low in Ethiopia, with only 13% of respondents at a national level (19% urban and 9% rural) reporting familiarity with ethanol for cooking (Gaia Association, 2014c). In addition to the low awareness of ethanol fuel is the high price of the CleanCook stove. The current price of the double-burner CleanCook stove is ETB 1900 (USD$81, prior to the Birr devaluation in September 2017). Like other consumer durable goods, the CleanCook stove is subject to importation taxes of 56%. Moreover, the cost of foreign exchange makes the importation of consumer goods expensive. The SCIP study in 2014 suggested that only 1% of survey respondents would be willing to pay more than ETB 1000 for the stove (Gaia Association, 2014c). Therefore, the absence of a locally manufactured stove, which presumably would be cheaper, represents a barrier.

Currently, the price of ethanol for end users is slightly higher than for other fuel options. Price comparisons are shown for the primary fuels used in Ethiopia in Table 6. Although there has been significant price inflation in Ethiopia over the last few years, with a devaluation of the Ethiopian Birr in September 2017, interestingly, the price of ethanol has remained stable unlike other household fuels, which have steadily increased in price.

In urban Addis Ababa, electricity is inexpensive and households therefore cook with electricity if it is available to the household (Table 6). A limitation to its use is that renters are not allowed to obtain a supply agreement, only dwelling owners are. Therefore, many in the city do not have access to electricity and must rely on other fuels for cooking. Electricity users themselves are limited by the supply of electricity as it is routinely rationed and is often interrupted with brownouts and blackouts. Both charcoal and fuelwood are sold in the city in the informal market. It is illegal to bring unlicensed charcoal into Addis Ababa for sale; however, this regulation is not enforced. Charcoal is sold in the informal economy with no VAT and is effectively unregulated. Charcoal can be purchased in 25 kg to 40 kg sacks or in 1 to 2 kg bags on the street. The price is cheaper at 7.5 Birr/kg when purchased by sack; however, most consumers purchase charcoal from local vendors close to their homes at a price of 10 Birr/kg. Street vendors sell chopped fuelwood to households that has been harvested from rural areas and trucked into the capital, often from distances of 200 km or more. There are no taxes imposed on these fuels, although licensed fuelwood sellers, like any business, must pay a business enterprise tax. Ethanol is the only household fuel that is sold on the commercial market with VAT charged (Table 7). However, the UNHCR and Gaia Association are able to buy ethanol for the refugee camps without VAT, at 9.37 birr ($0.34). Kerosene is exempt from some federal taxes as well as VAT and is sold at the same price as diesel fuel. If ethanol were exempt from VAT it would be similar in price to charcoal purchased at local street vendors and considerably cheaper than kerosene.

The Ethiopian government has several national policies and programs that address the development and promotion of improved cookstoves and specifically ethanol fuel and ethanol cookstoves. These include (1) the Ministry of Mines and Energy Bio-fuel Development and Utilization Strategy (2007) (Ministry of Mines and Energy, 2007), (2) the Growth and Transformation Plan, both GTP I and GTP II, produced by Ethiopia's National Planning Commission, with GTP II issued in 2016 (National Planning Committee, 2016), (3) the National Improved Cookstoves Program (NICSP), produced by the Ministry of Water and Energy (successor to the Ministry of Mines and Energy), (4) the Climate-Resilient Green Economy Strategy (2011), produced by the Environmental Protection Authority (Federal Democratic

Table 7
Daily cost of cooking (excluding injera baking) in Addis Ababa Feb. 2018[a].

Fuel type	Fuel Energy Content (per unit)	Efficiency of the stove[b]	Daily use equivalency[c]	Unit cost retail	VAT	Cost with VAT	Daily cost of fuel
Fuelwood (air dried)	15 MJ/kg[d]	20%	4.1 kg	$0.11/kg	No		$0.45
Charcoal	30 MJ/kg[d]	23%	1.77 kg	$0.27/kg	No		$0.48
Kerosene	43 MJ/kg[e]	40%	0.87 L	$0.60/L	No		$0.52
Ethanol	28 MJ/kg[e]	55%	1 L	$0.44/L	15%	$0.51	$0.51
LPG	45 MJ/kg[e]	56%	0.48 kg	$1.20/kg	No		$0.58
Electricity	N/A	55%	7 kWh[f]	$0.02 kWh	No		$0.14

[a] To compare cost of fuels, this table assumes no stove/fuel stacking but the exclusive use of one fuel.
[b] Based on data from MacCarty et al., 2010; Kerosene, ethanol, and LPG efficiencies are the average high-power thermal efficiencies reported in (Shen et al., 2017).
[c] Daily use equivalency of fuels is based on Energy Content of 1 Liter of Ethanol Fuel (28 MJ/kg) * Ethanol Stove Efficiency (55%) = 12.2 MJ (Ethanol Baseline). Calculation for daily use equivalency: Daily quantity of fuel consumed = 12.2 MJ (Ethanol Baseline) / fuel energy content/unit (kg or liter) * efficiency of the stove.
[d] (Hofstrand, 2008).
[e] (Argonne National Laboratory, 2010).
[f] (Gaia Association, 2014a).

Republic of Ethiopia, 2012), and (5) the Nationally Appropriate Mitigation Actions (NAMA), established by the Environmental Protection Authority in 2010. Together, these policies provide comprehensive guidance for the development and use of liquid biofuels in Ethiopia. Project Gaia was influential in helping to develop the 2007 Biofuels Development and Utilization Strategy. (See Appendix A for policy details).

The scale-up of the CleanCook stove and ethanol fuel in the urban markets continues to present challenges. The potential to scale-up and commercialize ethanol as a household fuel shows exciting potential, but investment in local manufacture of the CleanCook stove, or a stove of similar quality, and in the ethanol fuel distribution system need to happen early in the process.

Businesses in Ethiopia have many reasons for being risk adverse. Therefore, risks need to be mitigated. Supportive policy from the Ethiopian government, for example, the suspension of VAT on ethanol cooking fuel, could be extremely effective. Low awareness of ethanol as a household fuel and the limited number of CleanCook stoves in the market limit the uptake of ethanol fuel and thus the confidence of the government to invest in distilleries at the sugar factories. The lack of supply of FOREX and the cost to obtain FOREX make it difficult and expensive to import CleanCook stoves. On the other hand, investors are wary of importing CleanCook stoves if consumers do not have ready access to ethanol cooking fuel. This feedback loop is complex and will require additional attention to identify willing players and low risk pathways to enable the development of businesses. Project Gaia has a registered Cookstove Program of Activities with the UNFCCC and is currently completing registration with the Gold Standard Foundation. If carbon finance is brought to bear, this will help to mitigate risk for ethanol stove and fuel scale-up in Ethiopia, particularly if the carbon finance can assist in addressing the scarcity of FOREX and enable more stoves to enter the Ethiopian market as soon as possible to boost the demand for ethanol.

Study limitations

The results of the implementation projects by Gaia Association in the refugee camps and in low-income households in Addis Ababa are not representative of the efforts to reach the target population for commercialization and scale-up. The refugee population is unique in that the refugees do not pay for their stove or for fuel and often do not have alternative choices for cooking. (With the transition by UNHCR to more commercial approaches to delivering goods and services in the camps, this may change.) Similarly, the households in the FWFCA cooperative receive their CleanCook stoves at a subsidized rate, while they buy and sell their fuel commercially. The perceptions of these populations of the pros and cons of cooking with ethanol should be evaluated in this context. The FWFCA's reported use of stove stacking, however, is likely to pertain to other urban households that purchase and use ethanol stoves and fuel.

Conclusions

This case study describes the implementation of ethanol as a household cooking fuel in Ethiopia. The work of Gaia Association and its effort to promote the use of ethanol for cooking demonstrate the complex nature of introducing a new cooking fuel and the challenges of securing the necessary policy and investment required put in place the infrastructure necessary for commercialization. The inconsistent ethanol supply has slowed the move to commercialization and scale-up by creating uncertainty for both potential investors and consumers. However, market forces continue to make it possible for ethanol to be successfully commercialized for cooking, because of the increase in price and reduction in supply of other fuels, and the desire of consumers for better choices that what they have currently.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.esd.2018.06.009.

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