



CHAPTER 2

Human Waste-to-fuel Briquettes as a Sanitation and Energy Solution for Refugee Camps and Informal Urban Settlements

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2.1 Introduction

2.1.1 Fuel and sanitation situation in the urbanizing town of Naivasha, Kenya

Urban communities in Kenya face the challenges of access to improved sanitation and affordable clean fuel that result in negative implications on health, dignity, food and nutrition security, and the environment. Improved sanitation includes flush, pour-flush toilets connected to a piped system, septic tanks, ventilated improved pit (VIP) latrines and pit latrines (Ministry of Health, Republic of Kenya 2016). For example, the sewerage coverage is estimated at only about 12% with a dismal 5% of the national wastewater being effectively treated (Gakubia et al. 2010). In poor urban settlements, less than 20% of the population has access to sanitation and 80% of facilities are shallow pit latrines that contribute to pollution of the environment (Ministry of Health, Republic of Kenya 2016). In rural areas 32% of the population has access to improved sanitation of which 72% has predominantly simple pit latrines providing varied degrees of safety, hygiene and privacy.

At the same time, over 80% of urban households in Kenya rely on charcoal and unfortunately most of it is unsustainably produced as 99% of charcoal producers use inefficient kilns (Mutimba and Barasa 2005). This is of great concern in the face of climate change where 6-9 kilograms (kg) of CO₂ eq. is emitted during the production cycle of 1 kg charcoal using inefficient systems (FAO 2017). With families spending up to 30% of their income on fuel, alternative solutions for both sanitation services and fuel are in high demand (Sanivation 2016). As with sanitation, there is a high charcoal demand in Naivasha estimated at over 3,000 tons month⁻¹ (Sanivation 2016). Households purchase charcoal from local retailers, who, in turn, buy from distributors. Charcoal prices fluctuate from as low as USD 0.30 kg⁻¹ to as high as USD 0.60 kg⁻¹ depending on the time of year and the current supply (Sanivation 2016). Because of these market dynamics, there is a need for a new fuel source that fits into the current cooking culture, primarily Kenyan cooking stoves, and that is consistent in price, quality and supply.

With a population of 180,000 expected to increase to 200,000+ by 2018, Naivasha lacks an efficient sanitation

infrastructure to support its growing population. Naivasha's employed population earns about USD 135 month⁻¹ primarily working at local flower farms and residing in poor and high-density settlements. Even though 89% of the population uses on-site sanitation, the local wastewater treatment plant is operational for only 25% of the time (Bohnert forthcoming), leaving most of the population exposed to disease from untreated waste.

2.1.2 Fuel and sanitation challenges in Kakuma Refugee Camp

Sub-Saharan Africa (SSA) generates and hosts the world's largest refugee population. Over 4 million refugees were hosted in the region by the end of 2015, equivalent to about a quarter of the total refugee population under the United Nations High Commission for Refugees (UNHCR) mandate and more than half (2.7 million) were hosted in the East and Horn of Africa region (UNHCR 2016). By then Kenya was ranked seventh in the world, hosting 553,900 refugees of which more than 60% was female and 70% children (UNHCR 2016). Kakuma Refugee Camp, the second largest camp in Kenya, is located in northwestern Kenya in Turkana County. It was opened in 1992 to host a population of 100,000 people, but by early 2018 the number was about 147,240 registered refugees and asylum-seekers, exceeding its capacity by far (UNHCR 2018). The impact of the Kakuma Refugee Camp has been excessive pressure on available resources and both internal and external space within the camp. There has also been notable conflict with the host community due to, among other factors, competition for resources including job opportunities and the role of aid that mainly supports refugees which induces envy by host communities (KISED 2017). The UNHCR in collaboration with local NGOs distributes firewood which is brought in from as far as 120 kilometers (km) away (UNHCR 2015). This is a major environmental concern in this arid and semi-arid land. However, the firewood offered to the refugees is scant and women, desperate to put food on the table for their families, exchange maize sufficient to feed the family for five days with firewood that could cook three days' worth of meals (Mendum and Njenga 2018). Another coping strategy is families skipping meals. About 97% of women, who disproportionately bear the burden of fuel collection, wander outside of the camp to collect firewood risking sexual violence and assault. (UNHCR 2015). Cooking with firewood poses severe health consequences with smoke-induced diseases causing 4.3 million deaths worldwide each year (Lim and Vos 2012).

Sanitation is a challenge as most of Kakuma's population relies on pit latrines as their sanitation solution. As these latrines fill, the waste stays in the ground posing a public health threat. In addition, new pit latrines must be dug every one to two years, putting great financial strain on refugees and the little remaining space there is in the camp. The

UNHCR and implementing partners provide the supplies for constructing the new pit latrines, costing approximately USD 100 latrine⁻¹ year⁻¹ in protracted settings like that of Kakuma Refugee Camp (UNHCR 2015). Refugees, however, either have to dig their own pit or pay for the digging service, a service which few can afford. The human waste-to-charcoal briquettes innovation, as discussed later, contributes to the development of affordable and sustainable cooking fuel while improving sanitation services, making refugee and urban informal settlements more habitable.

The human waste-to-charcoal briquettes innovation comprises:

- (i) Provision of sanitation service through the installation of urine-diverting dry toilets (UDDTs) in dwellings and
- (ii) The waste-to-fuel briquettes innovation.

The aim of the innovation is to improve sanitation and hygiene, enhance access to affordable cleaner energy, create employment for local communities and generate income for the local community and the Sanivation company. This case study illustrates gendered participation and benefits for men and women from adopting the human waste-to-charcoal briquettes innovation to exemplify women and youth empowerment in humanitarian situations and urban high density informal settlements.

2.2 Background on Sanivation's Human Waste-to-fuel Briquette Innovation

2.2.1 About Sanivation

Sanivation is a sanitation social enterprise established in 2014 and headquartered in Naivasha. The organization is committed to providing cost-effective waste-processing services and sustainable fuels in refugee camps and urbanizing communities. "Could I cook on this?" was a question posed to Sanivation's co-founder Emily Woods when she was using a solar concentrator as a means to render human waste safe for reuse. The question made Woods realize that by converting human waste into a biomass fuel, she could solve two problems: 1) the lack of incentives for safe disposal of human waste and 2) the lack of access to sustainable biomass fuels. She, and her co-founder Andrew Foote, proceeded to develop an aspirational, sustainable fuel product from one of the world's oldest renewable sources – human faeces referred to as 'human waste' in the associated charcoal briquette innovation.

To address the demand for sanitation services, Sanivation established and operates fuel factories in urban communities and refugee camps to produce and sell a more affordable and cleaner fuel than wood charcoal. At these factories, Sanivation uses two abundant waste streams to make the charcoal briquettes: fecal sludge and carbonized biomass

residues. Individually, each of these waste products has little value, but together, with the right processing, they can make an aspirational fuel valued at over USD 200 ton⁻¹.

Since its establishment in 2014, Sanivation has already launched two fuel factories, one in the rapidly urbanizing low-income neighborhoods in Naivasha, and the other in Kakuma Refugee Camp in northwestern Kenya. Through these operations, in total, Sanivation has so far treated and transformed 59 tons of waste, sold over 300 tons of charcoal briquettes and achieved a fuel production rate of 20 tons per month. Because of Sanivation’s market-based approach, it is able to create employment opportunities, with 74 staff of which 49 are men and 25 are women, in both Kakuma and Naivasha. Included is a paid team of 18 refugees. Sanivation’s female employees significantly contribute to the entire sanitation value chain – from installing toilets in people’s homes to waste treatment and briquette production to selling briquettes. As women and children are disproportionately affected by the unimproved sanitation conditions and traditional charcoal use, Sanivation focuses on and employs women to design and implement solutions that better meet their needs.

2.2.2 Gender roles in processing human waste-derived briquettes and the quality of the product

The charcoal briquette supply chain involves provisioning of UDDT human waste collection and treatment/processing, charcoal briquette production, packaging and sale (Figures 2.1-2.3, Figure 2.5).

FIGURE 2.1. THE THREE MAIN ASPECTS OF HUMAN FECAL-SLUDGE-TO-BRIQUETTES PROCESSING



Sanivation partners with local governments and households in informal settlements in Naivasha and refugee camps for implementation of human waste-to-fuel factories. The households provide Sanivation with human faeces through use of container-based UDDTs that separate fecal

material and urine (Figure 2.2a.) In Naivasha, currently, the faeces are collected from households located in Karagita and Mirera informal settlements that have subscribed to Sanivation’s sanitation service. While Sanivation’s clientele base is diverse, most clients are single mothers. In these households, Sanivation installs and services the UDDTs which are managed by women and the household pays about USD 2.00 per month. Twice weekly, trained Sanivation staff collect the waste and transport it to the fuel factory.

FIGURE 2.2. (A) A WOMAN DISPLAYS HER HOUSEHOLD’S UDDT IN KARAGITA AND (B) THE SANIVATION’S FUEL FACTORY IN NAIVASHA, KENYA.



Source: Sanivation.

A



Source: Sanivation.

B

For the work in Kakuma Refugee Camp, Sanivation received funding of USD 350,000 in 2016 from the Bill and Melinda Gates Foundation under a contract with the UNHCR. The aim was to capture energy value in human and other organic wastes contributing to improved fuel supply and sanitation. The funds were spent on the building of a fuel factory at Kakuma Refugee Camp. A similar model that was applied in Naivasha is used in the refugee camp in sourcing human waste where the UDDTs are provided to households in the camp and the waste is collected twice a week.

At each location, the fecal waste is transported to Sanivation’s centralized fuel factory. The faeces are treated, while the urine enters a soak pit. Within a day, the fecal material is treated, turning it into a safe binding agent for briquette use. Sanivation uses a patent-pending solar-thermal process to treat the faeces at the factory which are then used as binding agent (Figure 2.2b). Sanivation collaborated with the Centers

for Disease Control and Prevention (CDCP) in Atlanta, USA to test the effectiveness of the treatment system to ensure that the faeces are rendered safe for reuse.

The charcoal dust, which is considered waste as it cannot be used in its current form, on the other hand is sourced from charcoal traders. Sanivation management is pleased that various organizations such as the Food and Agriculture Organization of the United Nations (FAO) are working with communities to ensure sustainable charcoal production through improved tree management and use of improved kilns (FAO 2017). Charcoal dust or the carbonized biomass residue is crushed into a fine dust using a hammermill. The charcoal fines are then combined with treated human waste and compacted into ball-shaped briquettes, each piece weighing about 10 grams (g) (Figure 2.3). Young men are involved in the pressing and ringing while young women are involved in packaging.

FIGURE 2.3. (A) PROCESSING BRIQUETTES IN KAKUMA USING AN AGROMERATOR, (B) BRIQUETTES BEING DRIED IN KAKUMA, (C) PACKAGED AND BRANDED BRIQUETTES, (D) BRIQUETTE BURNING.



Source: Sanivation.

A



Source: Sanivation.

B



Source: Sanivation.

C



Source: Sanivation.

D

Sanitation processes faeces collected from 2,000 people per month and each factory has the capacity to produce 50 tons of charcoal briquettes monthly. The company, however, produces an average of 20 tons of briquettes per month which is 50% below the capacity due to the volume of faeces that is collected. As Sanitation scales up sourcing of raw materials, each factory's capacities will be met. This process contributes to providing collection and treatment of fecal sludge, thus offering poor households safe sanitation services, especially for women and children who otherwise risk assault when they have to visit pit latrines at night. It also treats human waste that would otherwise be dumped into the environment in the open or in pit latrines.

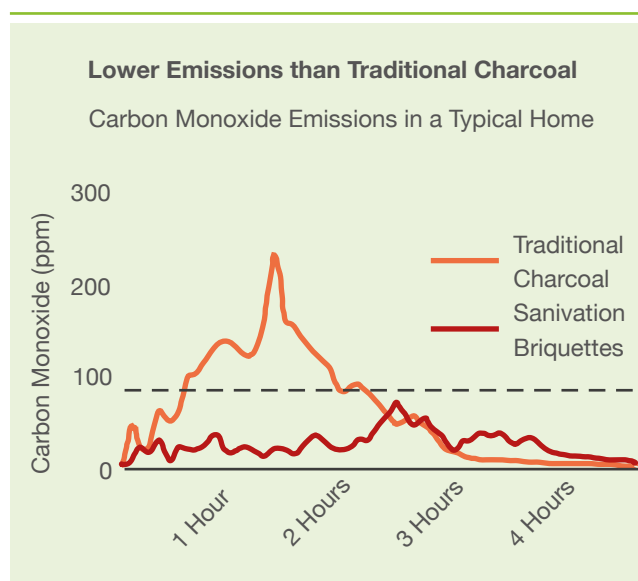
Before they were branded, the briquettes went through a quality assessment at the University of Nairobi for emissions, the Kenya Forestry Research Institute (KEFRI) for combustion properties and latterly the Massachusetts Institute of Technology (MIT). The combustion quality including energy expressed in terms of calorific value produced, ash content and volatile matter of the charcoal+human waste briquettes produced by Sanitation is better compared to that of the charcoal+soil briquettes produced by women's groups in Kibera slum, Nairobi, Kenya (Njenga et al. 2013; Table 2.1). The lower energy and higher ash content in charcoal+soil waste briquettes could be attributable to the non-combustible properties of the soil which was used as a binding agent by the women's groups. The calorific value of the briquettes compared well with that of firewood 14 kJ g^{-1} from various tree species (Fuwape 1993). Hence briquettes are a good source of cooking energy to complement or replace firewood which is the main source of cooking energy in the refugee camps in northwestern Kenya.

TABLE 2.1. QUALITY OF CHARCOAL+HUMAN WASTE BRIQUETTES COMPARED TO CHARCOAL+SOIL BRIQUETTES

	Charcoal+human waste briquettes*	Charcoal+soil briquettes#
Calorific value (kJ g^{-1})	15	13.5
Volatile matter (%)	14.1	18.7
Ash (content)	28.3	34.9

The charcoal+human waste briquettes burn with much lower indoor concentrations of carbon monoxide (CO) compared to traditional charcoal (Figure 2.4) which could be due to the lower carbon content, which is reduced by using human waste as a binder. Sanitation's briquette has been certified by the Kenyan National Environmental Management Authority (NEMA) and the Kenya Bureau of Standards (KBS). This briquette product is currently undergoing testing, in collaboration with the CDCP, to assess if there are any additional health risks with using the briquettes for cooking indoors; however, no data are available to date.

FIGURE 2.4. CO INDOOR CONCENTRATIONS FROM THE CHARCOAL-HUMAN WASTE BRIQUETTES COMPARED TO TRADITIONAL CHARCOAL.



To address health risks that might be associated with use of fecal sludge in briquette production, Sanitation collaborated with the CDCP to test the effectiveness of the treatment system. The results showed effective inactivation of pathogens, like *Escherichia coli* and *Ascaris suum*, in the faeces with the treatment system set at temperatures higher than 73°C for an hour.

2.3 Marketing of the Fuel Derived from Human Waste

Initially, Sanitation began selling the briquettes to small businesses, including restaurants and supermarkets, in order to refine the fuel and demonstrate uptake for a fuel derived from waste products. After selling 70 tons of fuel to small businesses, a superior product called *MaKaa ya Jamii* (Charcoal for the Family) which has been optimized for household use, was launched. Through a door-to-door sales strategy, Sanitation is reaching households in low-income neighborhoods throughout Naivasha. Customers prefer the fuel briquettes compared to traditional charcoal due to their longer burning period and less smoke generated, consequently contributing to savings in income and an improved kitchen environment with a potential positive impact on health and the environment.

In Kakuma Refugee Camp, Sanitation sells the charcoal briquettes to refugee households. As a result, the organization is developing a pull sales strategy – it has already seen customers coming from across the camp to request the briquettes. After nine months of operation in the camp, Sanitation has demonstrated that over a ten-year lifespan, a waste-to-value approach not only is more cost-effective but has the potential to reduce the cost of pit latrines by about 50% ($\text{USD } 42 \text{ household}^{-1} \text{ year}^{-1}$ compared to $\text{USD } 88 \text{ household}^{-1} \text{ year}^{-1}$). The Sanitation model demonstrates

that the refugees can pay for the product if it is available at an affordable price. The briquettes cost about a third, KES 15-20 (USD 0.15-0.20) kg^{-1} , compared to charcoal at KES 60 (USD 0.60) kg^{-1} , which enables the end-users to save on cooking energy cost. Refugees are not only searching for affordable firewood alternatives, they are paying for them. The briquettes help to reduce the cooking energy poverty experienced by refugees as they only receive about 10-20% of their fuel needs from the UNHCR. The other benefit of using Sanivation's briquettes is that they are saved from the drudgery of collecting firewood from the neighboring woodlands. The briquettes can be used with current cooking infrastructure and require minimum behavioral change.

The company sells the briquettes through door-to-door sales, an activity that is carried out by women who are hired by Sanivation or through retailers who own kiosks and are mainly young men (Figure 2.5). Along with charcoal, these

retailers sell other products like groceries and toiletries. Sanivation sells the briquettes for KES 20 kg^{-1} and the retailers resell at their own decided price (usually KES 25 kg^{-1}) compared to charcoal at KES 60 (USD 0.60) kg^{-1} . At the refugee camp, Sanivation sells the product to over 20 retail shops.

2.4 Impacts of the Human Waste-to-briquette Innovation and the Role of Women

Sanivation's innovative model using waste to generate a cleaner cooking fuel has the potential to achieve wide-reaching impacts on the environment, finances, livelihoods and health.

Environmental conservation: The briquette innovation contributes to reduction of the environmental and

FIGURE 2.5. A RETAILER SELLING SANIVATION'S FUEL IN KAKUMA REFUGEE CAMP.



Source: Sanivation.

health impacts associated with using traditional cooking fuels. Current biomass cooking energy production and consumption are unsustainable and inefficient resulting in loss of tree cover, forest degradation, climate change and illnesses associated with smoke in the kitchen (FAO 2017). In Kenya, over 80% of urban households rely on charcoal, yet most of it is unsustainably sourced although most of the wood used in charcoal production comes from private farms owned individually or by communities, mainly in drylands (Mutimba and Barasa 2005). The unsustainability in charcoal production and use is (1) due to felling of trees without replanting and (2) inefficient traditional earth kilns, employed by about 99% of charcoal producers in Kenya. These processes have low yields of about 10% of the original weight of the wood resulting in wood wastage and air pollution (Mutimba and Barasa 2005; Okello et al. 2001). Sanivation's contribution to mitigating environmental impacts are twofold. By displacing traditional charcoal, the briquettes save trees otherwise cut down for cooking fuel and also they lower carbon emissions from cooking, hence, combating deforestation, mitigating against climate change and reducing health risks associated with smoke in the kitchen.

Reduced household expenditure on cooking energy: In Naivasha, for example, households spend about 30% of their income on cooking fuel. At USD 0.20 kg⁻¹, Sanivation's briquettes can save families over 50% of income spent on charcoal. This is a significant reduction, freeing up finances for other expenses like school fees. As such, Sanivation launched a door-to-door sales strategy to reach as many households as possible with its affordable and sustainable fuel. Customers, especially women who are the predominant purchasers, see the briquettes as a cleaner and modern fuel of choice. They prefer them due to their longer burning time and less smoke generated compared to traditional charcoal, saving them time and money, as well as improving the kitchen environment. Additionally, the lower smoke and soot means customers use less water in washing pots, which is an additional value where water is a scarce resource. Anecdotally, fuel users have reported less coughing and chest pain when using the briquettes compared to firewood use. These benefits would be enhanced when combined with improved cooking stoves.

Source of employment for young men and women: The waste-to-energy factories employ 49 men and 25 women in both Kakuma and Naivasha. These include a paid team of 18 refugees, thereby giving refugees a source of income in the camp. Possibly, this also contributes towards security in the camp as jobless youth may resort to theft, drug abuse or recruitment to gangs that are a threat to national and international security while jobless women may be tempted to source income through prostitution.

Food and nutrition security: Briquettes are cheaper and hence less income is spent on cooking fuel, saving money that can be spent on buying food. Women in Kakuma exchange the little relief food they receive for firewood or sell the food to buy cooking fuel; given that the briquettes are cheaper this problem could be attenuated. Households also skip meals due to lack of fuel to cook, a challenge that cheaper fuels like briquettes could help to address.

Women and children's well-being: In Kakuma Refugee Camp, women travel long distances to collect firewood from the surrounding area. Through discussions with women at the refugee camp they expressed concern that this activity exposes them to risks of assault and rape cases have been noted. The refugee women thought that conflicts with the local community could be attributable to envy generated by the relief aid they receive and that locals consider refugees as contributing factors to environmental degradation. Affordable briquettes will reduce refugee women's workload, a risks of assault and will also improve relations with the host community as they will no longer be considered as instruments of environmental degradation. The portable toilets inside their dwellings allow women and children to relieve themselves at night reducing the health risks associated with holding urine for long periods of time, something they practice to avoid going out at night. They also reduce risks of attack and rape, especially for single women and children when nature calls.

Potential health benefits: Sanivation's briquettes have important health impacts. The briquettes burn cleaner as they have lower indoor concentration of CO than traditional charcoal. This improves the kitchen environment including air quality and thus reduces health risks associated with smoke which mainly affect women and children as they spend much time in the kitchen. Ensuring that human waste in a community is safely treated and reused improves safety and the health of the community, which in the long run will reduce diseases associated with poor sanitation.

2.5 Conclusions and Recommendations for Gender Inclusion

The Sanivation waste-to-energy initiative is a cost-effective, win-win innovation with multiple benefits related to energy, the environment, health, hygiene and sanitation. Through the provision of improved sanitation services such as household UDDS, Sanivation's model is able to improve hygiene and safety for women and children by preventing the need to go outside at night to use pit latrines. Provision of affordable, cleaner and safer cooking fuel near dwellings reduces women's workload and the need for women to travel long distances to collect firewood – a laborious activity that carries the risks of attack or rape. Time saved by women

can thus be used in other productive activities. Sanitation has employed a women-led sales approach, where the organization focuses on recruiting and hiring women to sell briquettes in the communities thus providing a source of income for them. Briquettes can be easily sold by young men who run retail shops in the refugee camp. The briquettes are a source of cleaner and cheaper cooking fuel which contributes to alleviating food and energy insecurity. Involvement of women in briquette technology in the refugee camp offers them an opportunity to be self-reliant as opposed to relying on relief aid, while equipping them with skills that can be used once they return home. Some limitations have been faced during the implementation of this innovation. Firstly, household income is challenged by installation of the UDDT. Considering the toilet subscription is 2% of the household's monthly income (USD 100), it is difficult for some families to justify the expense. Though they like the toilet, they often prefer using the free pit latrines instead because they cannot afford the extra expense. Secondly, the sales team is led by women and in Kakuma Refugee Camp the women are also expected by their families to take care of the family. As a result, when there is an outbreak in the camp, such as malaria, briquette sales decrease because women are at home taking care of their families. Concomitantly, in Naivasha a mainly female sales team sells briquettes to kiosks, restaurants, schools and households as well.

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