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Waste-to-Value Sanitation in Kakuma Refugee Camp

Analysis from the piloting of a business model involving container-based sanitation and a domestic energy reuse product

Contents

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Abbreviations and Acronyms

BCG	Boston Consulting Group
BMGF	Bill & Melinda Gates Foundation
CBS	Container-based sanitation
DCF	Discounted cash flow
FAO	Food and Agriculture Organization
GCR	Global Compact on Refugees
ha	Hectare
KES	Kenya Shilling
KFS	Kenya Forestry Service
kg	Kilogram
KIRDI	Kenya Industrial Research and Development Institute
LOKADO	Lotus Kenya Action for Development Organization
m^3	Cubic metres
MDG	Millennium Development Goal
NPV	Net present value
NRC	Norwegian Refugee Council
PM 2.5	Particulates with a diameter of 2.5 microns and below
ppm	Parts per million
UDDT	Urine Diversion Desiccating Toilet
UNHCR	United Nations High Commissioner for Refugees
WASH	Water, sanitation and hygiene
WTV	Waste-to-Value

1. Background

UNHCR obtained funds from the Bill & Melinda Gates Foundation (BMGF) to further research and develop sanitation solutions for areas with difficult ground conditions in protracted refugee camp situations in East Africa. The first step was a landscape analysis conducted by the Boston Consulting Group (BCG) in 2014 on sanitation solutions in protracted refugee camp settings. BCG concluded that whilst the basic pit latrine is usually the most cost effective option in the long run, waste-to-value (WTV) solutions can provide more cost effective alternatives in areas where the site is congested, or where there are difficult ground conditions (high groundwater table, flood prone, hard rocky ground, etc). The BCG study also found that WTV solutions might provide additional livelihood and protection benefits, but at that point WTV sanitation in refugee settings had been limited to small pilots. The next phase included a competitive call for cost-effective sanitation innovations for difficult ground conditions. Three solutions were selected and implemented as operational research projects, double vault urine diversion toilets (double vault UDDT) and vermi-filter toilets in Ethiopia, and container-based toilets to fuel briquettes in Kenya.

The operational research on container-based toilets to fuel briquettes had two phases. The first phase of the project, lasting until September 2017, confirmed the technical viability of the approach and user acceptance of both the container-based toilets and domestic fuel incorporating human waste. A validation workshop took place, and participants were impressed by the results. For incorporation as a standard solution in difficult ground conditions, participants wanted more information on the business model. Therefore, the second phase, ending in September 2019, set out to test the financial performance of the business model in Kakuma Refugee Camp. A total of 500 container-based toilets were installed and operated during the project. A timeline of key events is shown in Figure 2.

FIGURE 1: AERIAL VIEW OF KAKUMA TOWN AND REFUGEE CAMP IN 2018

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FIGURE 2: TIMELINE FOR KEY EVENTS OF THE PROJECT

1ST OCTOBER 2015	DECEMBER 2015	JANUARY 2016	22-3 FEBRUARY 2016
Start of project	Call for concept notes	Deadline for concept notes	Stakeholder workshop and selection of solutions
JUNE 2017	**MARCH 2017**	**NOVEMBER 2016**	**15 SEPTEMBER 2016**
First batch of 250 toilets installed and operational	Waste treatment / briquette production system installed	Toilet model developed	Contract signed between NRC and Sanivation
12 SEPTEMBER 2017	**30 SEPTEMBER 2017**	**9 NOVEMBER 2017**	**OCTOBER 2018**
Validation workshop for phase 1	End of project phase 1	Start of project phase 2	Second batch of 250 toilets installed
AUGUST 2019	**JUNE 2019**	**NOVEMBER 2018**	**OCTOBER 2018**
Decision taken by UNHCR to close project at end of phase 2	Briquette market survey by Sanivation	Briquette sales drop sharply to ~1.5 tons	Briquette sales peak at ~11 tons
SEPTEMBER 2019	**30 SEPTEMBER 2019**		
Toilets decommissioned and replaced with pit latrines	Project closed		

Both phases of the operational research for the container-based toilets to briquettes took place in Kakuma Refugee Camp. Kakuma Refugee Camp is located in Turkana County in the arid northwest of Kenya. The total camp population as at March 2019 was just under 150,000, comprising just under 30,000 households. The standard sanitation intervention there, as in most refugee camps, is a basic pit latrine. The pit latrines comprise an unlined pit up to 5m deep, a dome-shaped concrete slab, and a superstructure built from either wooden poles and corrugated metal sheet or, with a recently introduced self-build approach, mud bricks and a sheet metal roof. The pit is abandoned when full and another pit is dug within the compound. Households are instructed to reuse the concrete slabs and superstructure.

Of the 30,000 households in 2019, only 30 per cent (8,875 households) had access to a pit latrine. The proportion of households meeting the definition of Safely Managed Sanitation is less than 25 per cent as 1,658 latrines were full (less than 0.5m separation from the top of the accumulated waste to the base of the slab), and some latrines are prone to overflowing/flooding during regular heavy rains.

Kakuma Refugee Camp is subdivided into 4 areas, Kakuma 1, Kakuma 2, Kakuma 3, and Kakuma 4. In Kakuma 1, the space is limited and often there is insufficient space for the digging of new latrine pits to help increase coverage. Sanivation's container-based toilets are particularly advantageous for areas prone to flooding and where there is a lack of space to dig new pits and were therefore installed in such areas in Kakuma 1.

2. Sanivation system[1]

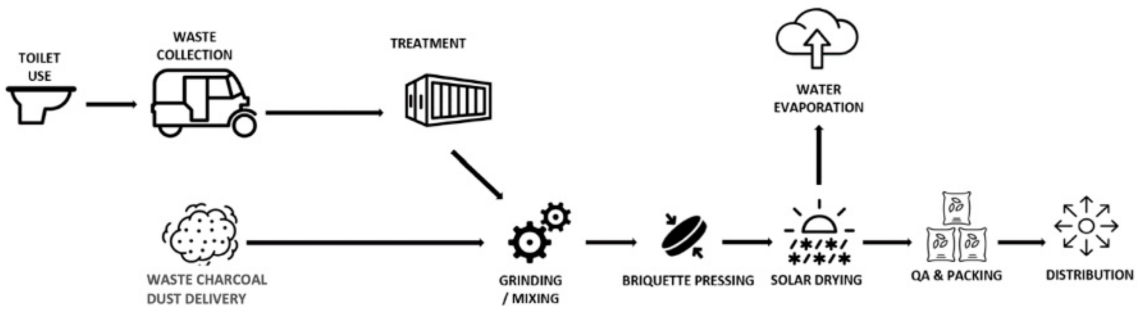
Sanivation is a social enterprise based in Kenya. Its mission is to increase access to safe and cost-effective sanitation services in urbanizing communities and refugee camps. The company piloted a sanitation system in Kakuma in 2014 that was based on its other operations in Naivasha, Kenya. Using the learning from this earlier pilot, Sanivation applied for, and was awarded, funding under the WTV project in 2016. The system, as described in Figure 3, consisted of 250 container-based-toilets with collection, treatment and conversion to charcoal briquettes. Sanivation was awarded further funding in 2017 to scale up operations to 500 toilets. Both phases were implemented in partnership with UNHCR and the Norwegian Refugee Council (NRC), which are responsible for Water, Sanitation and Hygiene (WASH) in Kakuma Refugee Camp.

2.1. Overview of the System

A schematic of Sanivation's system is illustrated in Figure 3.

FIGURE 3: OVERVIEW OF SANIVATION SYSTEM

Source: Sanivation



Sanivation designed an above-ground household toilet that contained faeces safely and could be regularly emptied. By being above the ground, the toilet avoided pit digging, mitigated the risks of the toilet overflowing into the environment and/or contaminating groundwater. The ability to regularly empty the toilet increased the lifespan of the toilet and decreased the need for space to build new ones, ultimately saving precious land space in a congested area. The need for continual biweekly emptying constituted a perceived vulnerability of the system, yet over the 3 years of the project Sanivation demonstrated reliable emptying and collection operations. Less than 1 per cent of scheduled collections were missed and missed collections were identified and promptly corrected. Flash floods were the main cause of the 1 per cent delays.

In Sanivation's treatment plant the collected faecal sludge was heated to temperatures above 65°C for a minimum of three hours – one of the most effective means to render faecal waste safe for reuse. The system had the capacity to safely treat 2 tons of faeces in a day. Once treated, faeces could be incorporated into charcoal briquettes by mixing it with charcoal dust and using a roller press to mould the mix into small pillow shaped briquettes compatible with refugee stoves. By carefully controlling the production process, Sanivation was able to produce a briquette that burnt 1.5 times longer, boiled 2.5 litres of water in 10 per cent less time and produced lower smoke emissions than traditional charcoal[2].

The toilet servicing, treatment, and briquette sales and distribution was operated by local refugees and host community members, under the part-time supervision of a national manager. During start-up phase, international staff members oversaw the rollout of the strategy and business model development, as well as the training of local refugees and host community. In the initial months, Sanivation staff members

1 A detailed description of Sanivation's entire system can be found in http://wash.unhcr.org/organisation/sanivation/

2 Tests were carried out independently by the University of Nairobi and the Kenya Industrial Research and Development Institute (August 2017).

were deployed on short assignments for the design and troubleshooting of the capital assets and transferring the technology to refugees to locally run the sanitation service. Details of the technical aspects of the implemented system can be found in the best practice guidelines by Sanivation and UNHCR[3].

In summary the system provides safely managed sanitation in difficult ground conditions as well as the production and sale of a sustainable fuel to replace locally collected firewood. In addition to benefits from reducing environmental contamination, lowering the risk of disease spread, and creating livelihood opportunities, the system has 1.7 tons of carbon dioxide offsets per household toilet per year as compared to status quo in Kakuma[4].

FIGURE 4: UPGRADED SANIVATION TOILET MODEL

Source: Sanivation

FIGURE 5: TREATMENT AND BRIQUETTE FACILITY DESIGNED IN A SHIPPING CONTAINER

Source: Sanivation

FIGURE 6: SANIVATION TOILET STILL USABLE AND SAFELY CONTAINING WASTE DURING FLOODING

Source: Sanivation

FIGURE 7: SHIPPING CONTAINER HOUSING THE TREATMENT PLANT

Source: Sanivation

3 UNHCR & Sanivation (2018) Sanivation and UNHCR Container-based toilets with solid fuel briquette as a reuse product: Best practice guidelines for refugee camps.

4 Based on research and analysis by University of Oregon Greenhouse Gas calculator

2.2. Operational Performance

2.2.1. SANITATION SERVICE

Users of the new container-based toilet system had a 95 per cent user acceptance rate and an independent evaluation found that 80 per cent of respondents preferred the Sanivation toilet to the pit latrine they used previously[5]. Sanivation monitored the amount of faeces collected from the toilets, which also indicated high usage. An average of 7 people used each toilet for defecation each day (average household size of the Sanivation toilets also happened to be 7 per household). Similar to pit latrines, children under 5 years of age were prone misusing the toilet, or not using it at all. Unlike pit latrines, however, the elderly and people with physical disabilities found the container-based toilet system particularly amenable. While there were some complaints of odours, overall users found Sanivation's toilet to be more hygienic than pit latrines, and less prone to insect nuisance.

Waste was collected by trained refugee employees who travelled to each household twice a week. The collected was consolidated in 60 litre plastic barrels and transferred via tuktuk to Sanivation's treatment site located just outside of Kakuma 1.

FIGURE 8: SERVICING THE TOILET

Source: Sanivation

FIGURE 9: TOILET SERVICING

Source: Sanivation

5 Antwi-Agyei, P. (November 2017) Evaluation of UNHCR Waste-to-Value Sanitation Project in Kakuma Refugee Camp, Kenya

2.2.2. WASTE TREATMENT AND PROCESSING

The waste treatment facility designed, installed, and operated by Sanivation had a capacity to treat two tons of faecal sludge daily, or approximately 1,000 people's sludge per day. The system was built inside of 40 ft shipping container for mobility and ease of installation. The treatment and waste processing utilized a heat-treatment technology, heating faecal sludge to >65°C for three hours to sterilize the waste. Then, the treated waste was mixed with charcoal dust, a waste product from the production of charcoal. This mixture of treated human waste and charcoal dust was then pressed and dried to produce sustainable charcoal fuel. The Sanivation site in Kakuma treated over 250 tons of human waste and produced over 150 tons of fuel briquettes over the 3 years of the project. The treatment plant was run daily by 10 refugee staff.

FIGURE 10: BRIQUETTE ROLLER PRESS

Source: Sanivation

2.2.3. BRIQUETTE USAGE AND DISTRIBUTION

User acceptance of the charcoal briquettes that incorporate treated human waste was found to be high. Prior to the commencement of briquette sales, Sanivation conducted a study with the two biggest refugee populations in Kakuma, South Sudanese and Somali, to understand perception and willingness to buy a faeces-based fuel. 40 refugees were given free samples and interviewed on their willingness to buy such a fuel. Two-thirds of interviewees expressed willingness to buy the briquettes at 20 KES/kg (similar to charcoal, which has an average price of KES 23/kg).

Refugees that were able to pay for fuel, purchased an average of 10kg per month through irregular small size purchases (some daily, some 3 times a week, some once a month). In order to capture these sales Sanivation visited targeted households every day through a network of sales representatives, to ensure that all targeted households had access to Sanivation's briquettes on any day they wanted to purchase.

Sanivation also conducted a brief market research study to better understand why customers purchased Sanivation briquettes[6]. When 20 refugee customers were asked why they purchased the briquettes rather than other fuels, 75 per cent cited briquettes being cheaper[7] than charcoal and 55 per cent mentioned that briquettes cook food faster. 20 refugee households in the briquette distribution catchment that were not purchasing briquettes were also interviewed. 50 per cent gave lack of money as the main reason for not purchasing briquettes. Some further explained how they had to survive with the free firewood provided or trade their food rations for charcoal from local sellers (5 bowls of food for 1 tin of charcoal). Trading rations for fuel is not an option for a private-sector fuel business.

6 Sanivation (2019) Briquettes Market Research Report

7 Briquettes were sold at KES 20/kg, versus an average of KES 23 for charcoal. Presumably the longer burn time of the briquettes is factored into the customers' assessment of the briquettes cost-effectiveness.

Through a direct-to-refugees distribution and sale model, Sanivation sold an average of 2 tons of briquettes per month throughout the project duration, while the project had a goal of targeted sales at 38 tons/month (peak sales were 11 tons/month). With the high user acceptance, but with challenges in distribution Sanivation tested and evaluated a number of channels for scaling briquette distribution. These included investing more in a distribution network for direct sales to refugee households, selling through retailers and selling to UNHCR (the main fuel supplier to Kakuma through its implementing partner LOKADO).

FIGURE 11: REFUGEE CLIENT WITH 1KG TIN OF BRIQUETTES

Source: Sanivation

FIGURE 12: BRIQUETTE DISTRIBUTOR

Source: Sanivation

FIGURE 13: BRIQUETTES BURNING IN A LOCAL STOVE

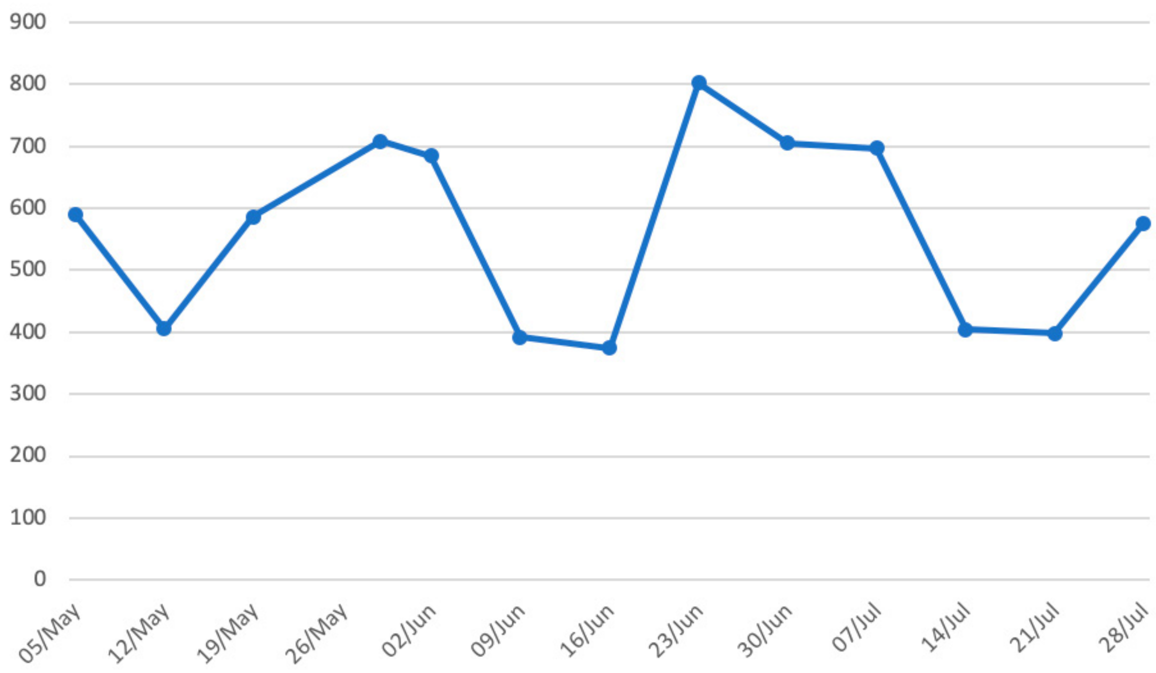
Source: Sanivation

2.2.3.1. Briquette Distribution directly to refugee households

One of the challenges of selling directly to refugee households was competing with the free firewood distribution. The monthly firewood distribution contributed to a regular drop of briquettes sales and morale of commission refugee sales staff. Figure 14 shows the actual sales from a single block over a three-month period. The table shows a monthly decrease in sales every time firewood is distributed in the block, and a gradual increase before it drops again with the next free distribution.

FIGURE 14: WEEKLY BRIQUETTE SALES IN BLOCK 11, MAY - JULY 2018

Source: Sanivation



With time and resources, Sanivation estimated the ability to scale distribution to the entire camp. It took approximately three months to market the briquettes in a new block (area of ~150 households) to achieve a 30 per cent sales close rate[8]. Sanivation estimates that building house-to-house distribution system for the entire camp (150,000 people) would take approximately two years to develop and require US$ 350,000 additional investment[9].

2.2.3.2. Briquette Distribution to restaurants

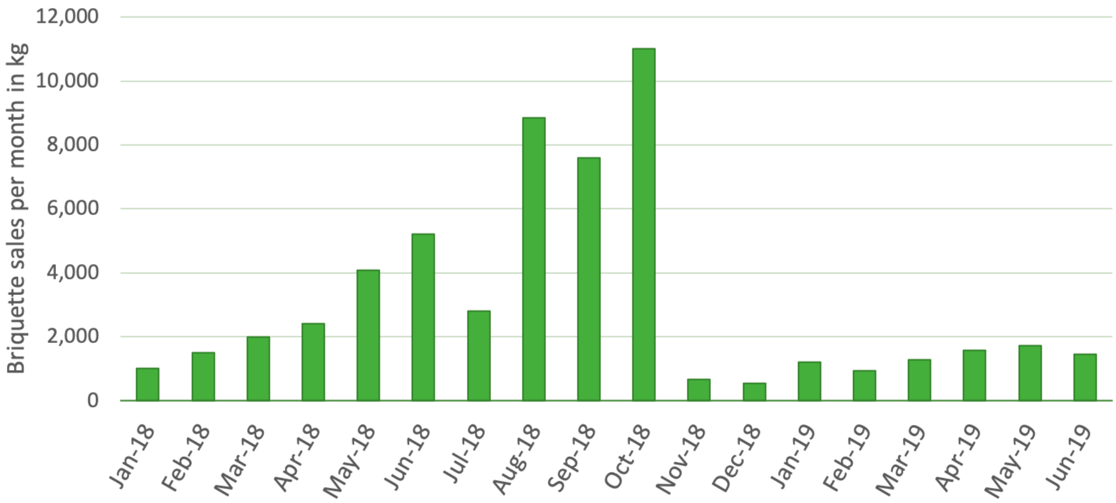
Sanivation pivoted to a new market in July 2018, selling to restaurants in nearby Kakuma Town, Lodwar Town (120 km away within Turkana County) and Kitale Town (420 km away). An early momentum saw bulk sales to restaurants quickly climb to around 10 tons in October, but the density of the market was still too dispersed. The costs for distribution to such distances made this model not feasible in competing with local charcoal. In 2019, with an unclear model to scale distribution at a low cost, distribution to restaurants and retailers was paused, and only local, cost feasible door to door sales in already marketed communities of the camp were continued. Figure 15 shows the total quantities of briquettes sold for the period of sales, combining both direct household sales and sales to restaurants.

8 Sales close rate: customer who purchased / customers that were offered the product

9 Sanivation (2019) Briquettes Market Research Report

FIGURE 15: MONTHLY SALES OF BRIQUETTES IN KG

Source: Sanivation



2.2.3.3. Briquette Distribution through UNHCR

Selling to UNHCR was the preferred option, even if they would be only able to commit 1 or 2 years at a time due to operational budgets procedures[10]. Sales to UNHCR would have low distribution costs due to its centralized distribution network. After extended discussions, however, UNHCR declined this arrangement. UNHCR purchasing of firewood from the host community is a viewed as a key element of peaceful coexistence and any partial replacement was predicted to cause tension.

2.3. Contractual Arrangements

Sanivation's project was implemented under contractual arrangements aligned to UNHCR's annual planning and budgeting cycle[11]. These arrangements were insufficiently flexible for services of a relatively complex nature being introduced under an operational research framework and introduced bureaucratic impediments whose removal was dependent upon the willingness and ability of multiple individuals to prioritize the project. Delays in funding flows were one consequence. This placed an additional burden on Sanivation on top of the technical and non-technical (e.g. land access) challenges that the company had to manage.

The Global Compact on Refugees (GCR), to which UNHCR is a signatory and primary stakeholder intends to provide a basis for predictable and equitable burden- and responsibility-sharing amongst UN members states and together with other stakeholders including the private sector. The GCR raises the need to enable private sector investment via policy measures and de-risking arrangements. UNHCR is moving from annual to bi-annual planning and budgeting as of 2019, which will provide some additional space and flexibility for innovative programming including private sector initiatives and service offerings, but further policy development would be required to create a truly enabling environment for private sector participation in refugee operations.

A high-level panel on humanitarian financing[12] called, in 2016, for a "grand bargain" in which donors would be more flexible, and aid organisations would reciprocate with greater transparency and cost-consciousness. In this spirit, BMGF and UNHCR provided a high degree of flexibility as to how the funds were utilised, and Sanivation provided complete transparency regards their expenses and revenues, facilitating the building of financial model for their business and its examination in the following section.

10 As of 2019, UNHCR's planning and budgeting is transitioning to 2-year cycles.

11 Specifically, under subcontract to UNHCR's WASH Implementing Partner for Kakuma, the Norwegian Refugee Council.

12 High-Level Panel on Humanitarian Financing Report to the Secretary-General (2016) Too important to fail—addressing the humanitarian financing gap.

3. Economic and Financial Analysis

3.1. Financial model

A key output of the BMGF-funded project was a detailed and field-tested financial model to evaluate the potential profitability or required subsidy. The financial model took the form of what would be termed an income statement in a set of financial accounts. The model excluded environmental, social, and other sustainability impacts, which may be able to generate additional revenue through project funding and carbon offsets. The model is based on actual quantities, prices, and costs occurring during the project (assuming a direct-to-refugee households sales and distribution approach), and potential revenues from briquettes assuming maximum possible sales. The data for the model was generated by an operation with a scale of 500 toilets serving, for the most part, one family each.

3.2. Cost structure

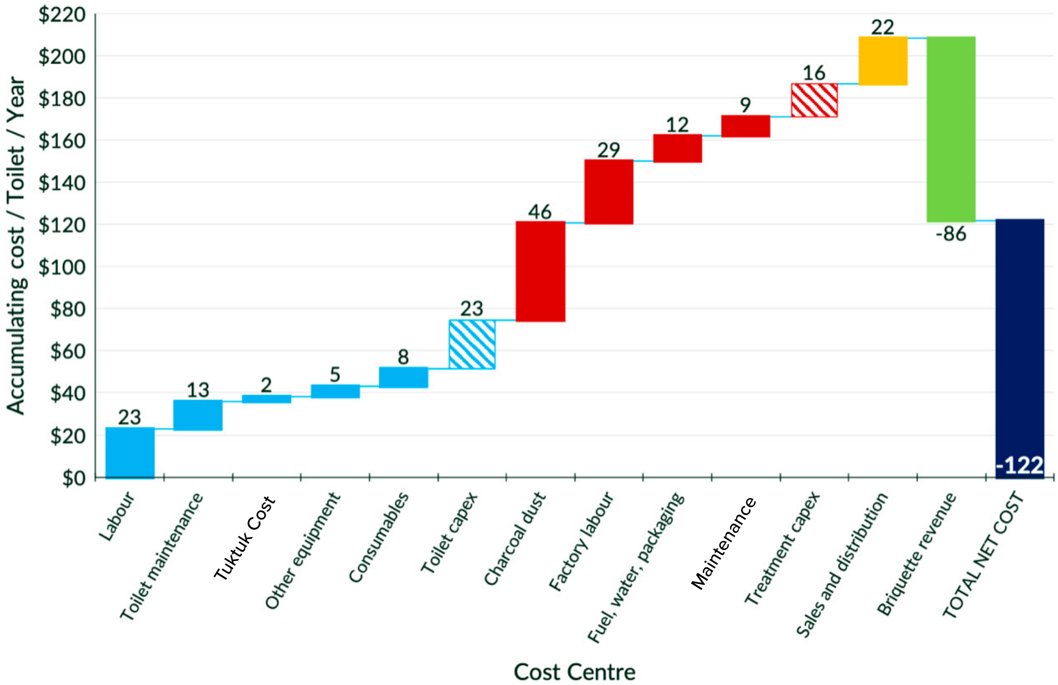
A cost structure for the operation is illustrated in Figure 16, with costs and revenues shown per household per year. The various cost and revenue centres are colour-coded according to logical groupings: toilets / servicing (light blue), treatment / briquette production (red), sales and distribution (gold), briquette revenue (green) and the revenue gap / subsidy required (dark blue). Capital expenditures within the toilets / servicing and treatment /briquette production groupings are indicated by diagonally banded fill. Costs are indicated by positive numbers, whilst revenues are shown as negative numbers. Figures for capex are based on straight line depreciation over 20 years with no terminal/disposal value.

The total cost of providing the toilet service and producing and selling briquettes was US$208/toilet/year. After potential briquette revenues, the net cost is US122[13.] If the entire stock of briquettes were purchased to replace firewood distributed by UNHCR to refugees, the net costs could be reduced to US$100, as sales and distribution costs would be removed. The cost analysis excludes any profit-taking, which would also need to be added in for a private sector implementation model.

13 Note: briquette revenue and the required subsidy add up to US$ 207, rather than US$ 208, due to a rounding error.

FIGURE 16: COST STRUCTURE FOR SANIVATION MODEL FOR 500 HOUSEHOLD TOILETS

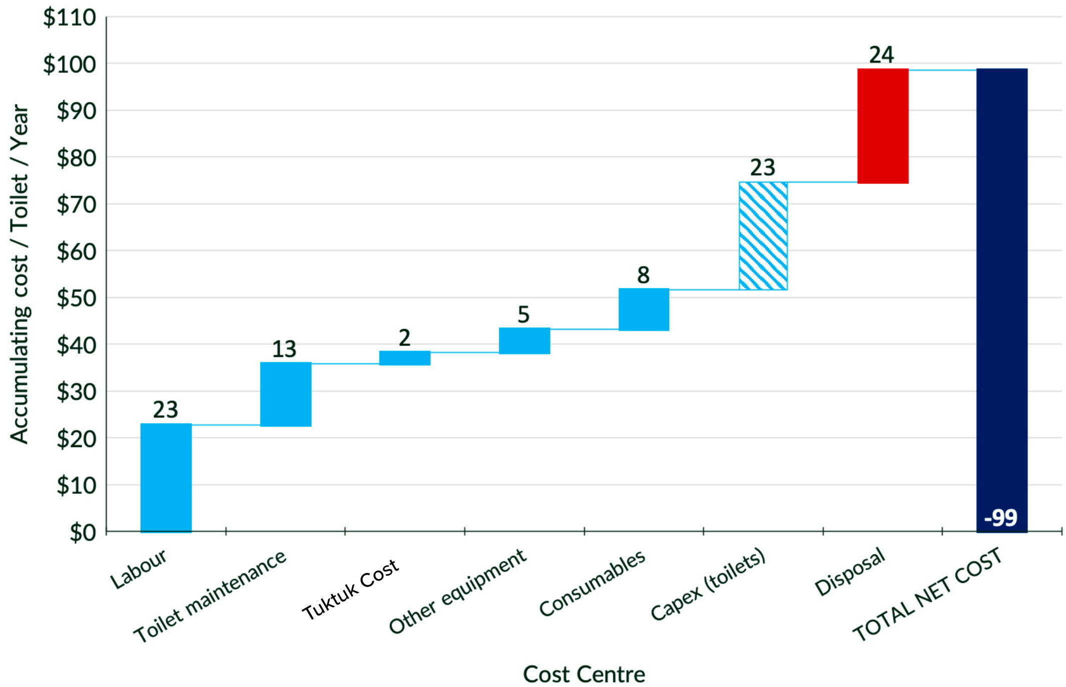
Source: Sanivation / UNHCR analysis



In the Kakuma context, the revenue of briquette sales did not cover the costs of waste treatment and briquette production. In this case, it is pertinent to look at the cost structure for a business model whereby waste processing is replaced by disposal to a sanitary landfill. As illustrated in Figure 17, the net cost in this case is similar around US$100/household/year, i.e. the same as for a business whereby all briquettes produced are sold via an offtake agreement to a single reliable buyer (with no sales and distribution costs).

FIGURE 17: COST FOR CONTAINER-BASED SANITATION AND DISPOSAL OF WASTE TO LANDFILL

Source: Sanivation / UNHCR analysis



3.3. Key cost drivers

The major cost centres to which economies of scale would be expected to apply are labour and the capex for the treatment plant. Labour represented 36 per cent of the total costs (US$ 52/toilet/year). As toilet servicing relies largely on manual labour, labour for the sanitation service (US$ 23/toilet/year) would not be expected to scale well. Factory labour for treatment and briquette production might scale better, particularly if the scale is increased by an order of magnitude (10x) or more. Treatment capex might also scale well under such a scenario. These two cost centres, however, constitute only 14 per cent and 10 per cent, respectively, of the total cost.

Conversely, cost centres that would not be expected to change at all at scale, consumables and household toilet capex constitute one-third of the total costs. Toilet capex under the current design is likely to remain constant, however a mass manufactured design may have room for cost reduction. Charcoal dust alone constitutes 22 per cent of the total costs. Scaling up could increase the unit cost by increasing demand but there may also be an opportunity to reduce the cost of charcoal and charcoal dust if charcoal production can utilise *Prosopis* – an aggressive woody invasive species that has proliferated around Kakuma – as is recommended to reduce natural resource degradation around Kakuma Refugee Camp[14]. The cost of charcoal dust was initially estimated at 0.05 US$/kg through an initial market assessment carried out with local Kakuma suppliers. Once the system became operational and Sanivation started procuring the dust from neighbouring towns to source the required quantities the costs accounted to 0.10 US$/kg due to transport and other fees. The price increase accounted for an overall system cost increase of 23 US$/toilet/year.

A solar concentrator (to heat and pasteurize the faecal sludge prior to incorporation into briquettes) was included in the initial waste treatment plant design to take advantage of the high temperatures in Kakuma refugee camp. While solar heating systems have been shown to work previously (e.g. in Sanivation's Naivasha operation), the solar concentrator system used in Kakuma was unable to reliably reach the required temperatures for safe waste treatment, resulting in recourse to a backup electrical heating system. This change led to an increase in fuel costs of approximately 5 US$/toilet/year. When implementing at a larger scale, an improved and more robust solar heating system could be introduced.

3.4. Non-Monetized Benefits

The non-monetized benefits afforded by Sanivation's solution differ from those provided by pit latrines and double vault urine diversion latrines. These benefits are difficult to value and therefore difficult to compare, and the project did not set out to make such a comparison. Nevertheless, below is a brief discussion on the health, livelihood and environmental benefits of the solution. Non-tangible benefits such as time-savings/convenience, reduced odours, and improvements in comfort are not considered as they are highly subjective and will vary with the values of different individuals and communities.

3.4.1. HEALTH BENEFITS

All three sanitation technologies referenced in the financial comparison are expected to bring significant improvements in health, but only Sanivation's system results in complete pathogen destruction. Double vault UDDT and pit latrine waste require additional treatment such as aerobic co-composting with other organic waste (agricultural crop residues or organic solid waste etc) for complete pathogen destruction. Otherwise, pit latrine or double vault UDDT waste must be disposed to landfill at sufficient depth and lateral isolation to prevent pathogens reaching the surface or any root crops. double vault UDDT waste is highly reduced in volume and pathogen content and therefore is safer to remove and transport than fresh sludge. The ash-like nature of the dried waste sometimes leads to complacency on the part of emptiers, who may haul it in open carts from which it is prone to spillage. Container-based sanitation involves the transport of fresh faecal sludge, and hence is not without risk, but in practice they are all but eliminated when professional container-based sanitation operators' tight safety proce-

14 FAO, World Bank, TerrAfrica (November 2018) Rapid Assessment of Natural Resources Degradation in Areas Impacted by the Refugee Influx in Kakuma Camp, Kenya. Technical Report

dures. The estimated benefit from achieving the sanitation Millennium Development Goals (MDGs) in Sub-Saharan Africa is US$ 6.0/person impacted/year[15] (inflated from 2006 to 2020). This is equivalent to US$ 30 per 5-person household per year. The value of differences between the three systems in the value of health protection (reduction in productive days lost due to illness and healthcare bills) will therefore be below this value, but it is beyond the scope of the project or this report to attempt to put a number on this.

Smoke emissions from Sanivation's briquettes are less than those of charcoal. Testing conducted by the Kenya Industrial Research and Development Institute (KIRDI) found that the briquettes produced 82 ppm carbon monoxide compared to 118 parts per million (ppm) for charcoal (30 per cent reduction), and 196 ppm PM 2.5 compared to 213 ppm for charcoal (8 per cent reduction). These lower emissions may help reduce the risk of respiratory illnesses.

3.4.2. LIVELIHOODS BENEFITS

As mentioned above, a significant proportion of the costs of Sanivation's system, US$ 52/toilet/year (36 per cent of total costs) goes to staff wages, thereby benefitting refugees and or host community members. If the faecal sludge is disposed to landfill rather than incorporated into briquettes, the combined figure for labour and charcoal dust purchase reduces to US$ 23/toilet/year (23 per cent of total). This compares to US$ 4/toilet/year for pit latrines and US$ 15/toilet/year for double vault UDDT. In total, over 25 refugees were incentive staff on the project and 8 members of the host community were employed. In addition to receiving an income, these staff received substantial training on health and safety, customer service, data collection and analysis, consumer sales.

The US$ 46/toilet/year paid for charcoal dust ends up in the pockets of the charcoal producers and transporters involved in the charcoal dust supply chain representing an additional income for the host community.

3.4.3. ENVIRONMENTAL BENEFITS

The environmental benefit of any alternative domestic energy product depends upon the mix of fuels that it will be substituting, and this mix will change over time due to varying availability (including due to environmental damage) and changes in policies and policy implementation.

Sanivation's briquettes were strongly linked with charcoal as a source of the primary raw material and as the fuel most obviously substituted for by the briquettes (they have similar appearance, burn properties and pricing). The briquettes can reduce charcoal consumption by around 10 per cent.[16] In Kenya, regeneration of the feedstock (trees) is generally not considered as part of the charcoal business[17] and in Kakuma, as in much of Kenya, the cost of obtaining the raw feedstock is not captured in the cost of charcoal in the marketplace. A report commissioned by the Kenya Forestry Service (KFS)[18] states that in Kajiado County (a semi-arid country with similar tree species to Turkana) where wood for charcoal production is purchased from wood owners, the price is equivalent to around US$ 28 per ton of charcoal produced from it. It is unlikely, however, that this price encompasses the complete cost of sustainable production and the report notes that it is likely a gross underestimate. A ton of charcoal requires

15 Hutton, G., Haller, L., Bartram, J. (2006) Economic and health effects of increasing coverage of low-cost household drinking water supply and sanitation interventions, Background document to the "Human Development Report 2006", United Nations Development Programme, World Health Organization, Geneva, Switzerland, Geneva 2007. NOTE: includes the estimated dollar value of treatment averted, non-medical health-seeking costs saved, work loss days prevented, and income loss averted by saving lives (summed and divided by the total impacted population).

16 Charcoal dust represents around 10 per cent of the total charcoal production. Based on controlled testing of equal weights of briquettes and charcoal, briquettes require 10 per cent less time to bring a litre of water to boiling point. Hence, we could conclude that the substitution is of 11 per cent but given that the figure for charcoal dust as a percentage of total charcoal is a rough estimate, we round the overall substitution figure to 10 per cent.

17 Bailis, R. (2009). Modelling climate change mitigation from alternative methods of charcoal production in Kenya. Biomass and Bioenergy, 33 (2009) 1491-1502.

18 Kenya Forestry Service / Ministry of Environment, Water and Natural Resources (2013) Analysis of the Charcoal Value Chain in Kenya.

around 7 tons of wood (7 – 11m^3, depending on moisture content).[19] As Savannah forest produces between 20 and 45 m^3 wood[20] and acacia species typically be harvested every 6 years[21]. In summary for every 1 ton of charcoal that Sanivation's briquettes replace, they are preventing in the order of 3 – 4 hectares of deforestation, or alternatively 1.7 hectares (6 years/ha x 9m^3 wood / 32.5 m^3/ha) of forest harvested sustainably.

As indigenous species (e.g. various *Acacia* spp.) are depleted around Kakuma Refugee Camp, increasing use is being made of *Prosopis*, an aggressive invasive woody species for firewood and even charcoal production. Having little cost (the time and effort required to collect and transport it), *Prosopis* and charcoal from *Prosopis*, has high potential as an environmentally sustainable alternative to charcoal from indigenous tree species. *Prosopis* is also therefore a low-cost competitor to other alternative fuels. The burn properties of *Prosopis*, however, are inferior and it produces a poorer quality charcoal than indigenous tree species. *Prosopis* and other firewood also requires harvesting and cases of gender-based violence have been recorded when women have been in search for firewood.

Container-based sanitation and waste reuse results in a significant reduction in total land area requirement for sanitation, with the saving increasing over time. While land is a significant challenge by UNHCR, the value of the land was not quantified in financial analysis.

19 Food and Agriculture Organization (1987) Simple technologies for charcoal making. FAO Forestry Paper 41.

20 *Ibid*.

21 Oduor, N. M., Ngugi, W. & wa Gathui T. (2012) Sustainable Tree Management for Charcoal Production. Acacia Species in Kenya. DFID

3.5. Financial Analysis

Cashflow and discounted cashflow analysis was conducted to determine the relative cost-effectiveness of investment in Sanivation's solution, generically referred to as container-based sanitation (CBS) with either briquettes or disposal, with that of double vault UDDTs and pit latrines. The analysis is based on the Kakuma context, i.e. Kakuma unit costs/prices and quantities, for materials and labour. Whilst in Kakuma the actual cost of pit latrines has been reduced by a refugee self-build approach, however, the financial analysis uses the cost when all materials and labour are paid for at Kakuma market rates and superstructures are built from wooden poles and corrugated metal sheet. The financial analysis focuses on financial flows and monetized costs and benefits. Non-financial environmental and social costs and benefits were ignored. Land costs were also ignored, as they are indirect and unknown (the land provided for refugee-related purposes is community or public/government-owned land). The cashflow models incorporated the following assumptions:

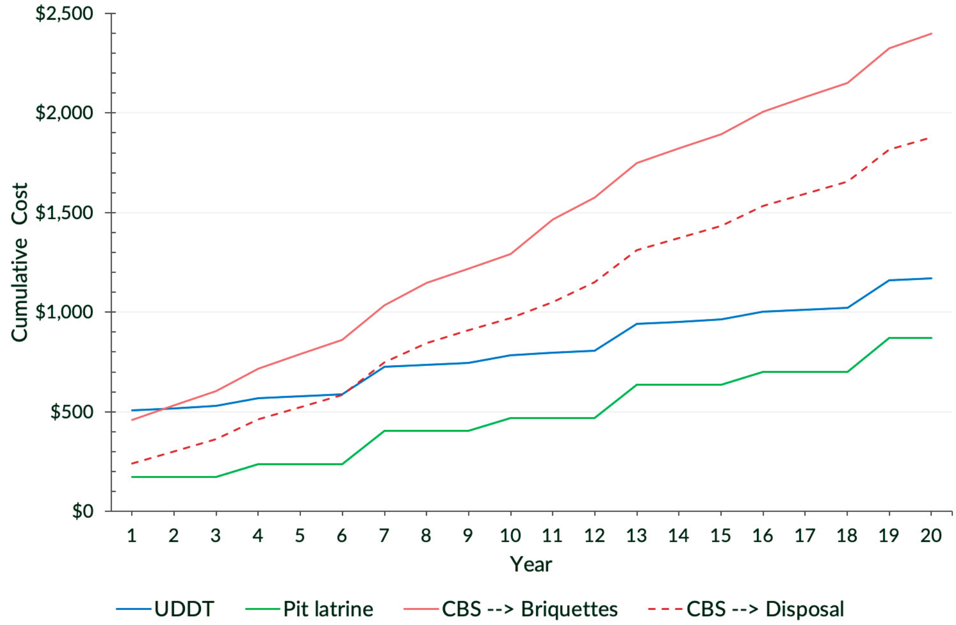
- **All compared solutions**
  - Toilet superstructures for all cases are built from wooden poles and corrugated metal sheeting and need to be replaced every 6 years.
  - An exchange rate of KES 100 to US$ 1 was used.
- **Pit latrine**
  - Pit latrines fill up in 3 years[22], at which point a new pit is dug and the slab and superstructure are moved (incurring expenses for pit digging and repairs to the superstructure).
  - Pit latrines have domed, wire-mesh reinforced slabs that have to be replaced every 6 years.
- **Double Vault Urine Diversion Desiccating Toilet (UDDT)**
  - Double vault UDDT vaults and container-based toilet pedestals and floors, being made of mor-tared masonry and concrete, have a lifespan of 20 years before replacement is required.
  - Double vault UDDTs have (relatively small) vaults that need to be emptied annually from year 3 (vaults take a year to fill and then are left for a year and emptied when the second vault is full).
  - Removed UDDT sludge is buried at a suitable landfill site near to the camp.
  - Double vault UDDTs require minor maintenance every 3 years.
- **Sanivation's model**
  - The waste treatment/briquette production plant is purchased at the start of year 1 and installed 3 months later, at which point operators are hired; briquette production and sales being 6 months into year 1.
  - Two units of each mechanical equipment for treatment and briquette production are purchased in year 1, and one unit of each in year 11. In this way, equipment that might break down are duplicated to ensure sufficient redundancy, and to increase their working life. At year 11, standby equipment should still have operational life left, whilst primary equipment will be at the end of its useful lifespan. A single mixing tank is purchased in year 1 and replaced in year 11. Set-up costs, incurred in year 1 only, comprise a 40-foot shipping container (transport container and housing for the equipment) and land set-up.
  - Small asset purchases, such as three-wheeled transport ('tuktuks') are depreciated over their lifetime and the depreciation amounts entered in the cashflow models.
  - Sales and distribution are 100 per cent from door to door sales

22 Pits are 5m deep and 80cm in diameter, and mean household size is approximately 5 people

A comparison of the 20-year (undiscounted) cash flows of the CBS/briquettes solution with pit latrines and double vault UDDTs is shown in Figure 18. The costs are normalized to the cost per toilet. This shows that the financial net cost of the CBS/briquettes solution is higher than the other two solutions across the entire timeline, except for year 1, when it is about the same as double vault UDDTs.

FIGURE 18: COMPARISON OF 20-YEAR CASH FLOWS

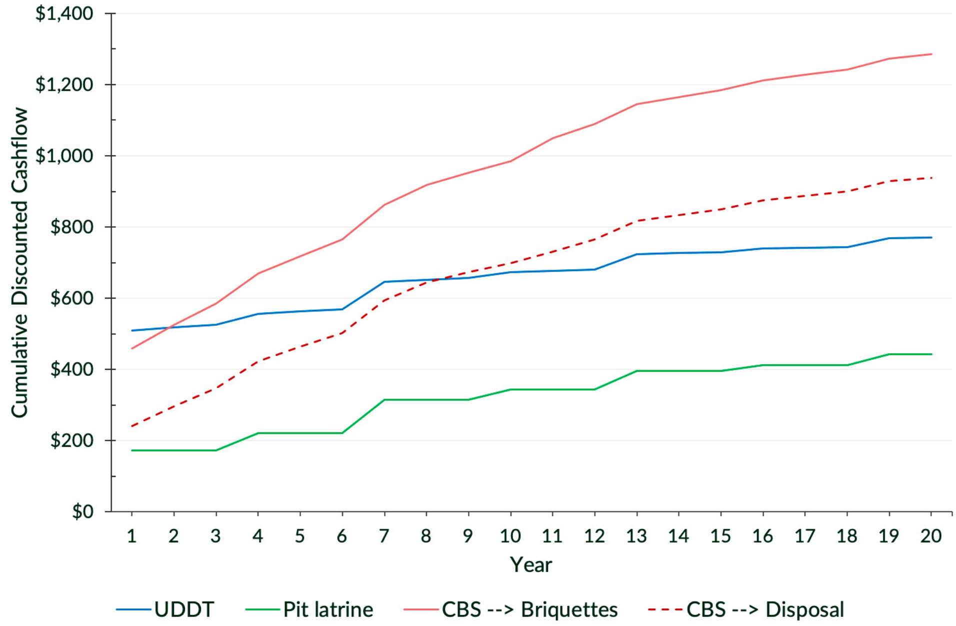
Source: Sanivation / UNHCR analysis



A 20-year discounted cash flow found that that net present value (NPV) of the costs of the CBS/briquette solution over 20 years was US$1,285 per toilet, compared to US$747 for the double vault UDDT and US$442 for the pit latrine. A discount rate of 10 per cent was used to reflect the increased risk and uncertainty of financial, economic and business conditions with time. Figure 19 shows the cumulative discounted cash flow (DCF) from year 1 to year 20.

FIGURE 19: COMPARISON OF 20-YEAR DISCOUNTED CASH FLOWS

Source: Sanivation / UNHCR analysis



A 20-year cash flow analysis for a CBS operation in which the waste is disposed to landfill after limited treatment (in drying beds) indicates that this strategy could be cost-competitive with double vault UDDTs (i.e. for environments with difficult ground conditions) for around 5 years or so, with the cumulative cost (present values) catching up with that of double vault UDDTs in year 6 (see Figure 18). Using discounted cash flows, CBS with disposal appears to have a lower cumulative cash flow (net cost) until year 8 (see Figure 19), having less capital investment. Up until somewhere between years 5 and 8, therefore, CBS appears to present a lower capital investment risk, which decision-makers would need to consider in their overall cost and risk analysis.

In short, CBS without waste transformation and reuse could be a competitive option for areas with difficult ground conditions in certain contexts. In scenarios outside of Kakuma, where market conditions may be more favourable for reuse, the CBS model could be more financially competitive. This is being demonstrated in Naivasha, Kenya, where 100 tons/month of faecal sludge produced by approximately 3,000 people is being treated and converted into a firewood substitute. Funds from sales to industrial clients create a positive margin to the cost of the entire system. In refugee camps that have access to lower cost biomass waste as well as the potential for large offtake agreements the model can have significant cost savings. Research by Sanivation in north-west Uganda (in the area around Rhino Refugee Camp) indicates the high availability of biomass (sawdust) and a potential industrial market.

3.6. Sensitivity analysis

As elaborated in section 3.3., the nature of the cost drivers makes it unlikely that the overall cost can be shifted sufficiently to bring the CBS/briquette business model to a point of being financially competitive with double vault UDDTs or pit latrines in Kakuma. For the sake of completeness, however, a basic sensitivity analysis was conducted by varying various costs by ±25 per cent and measuring the impact on the 20-year NPV (note that as the operating and net margins are negative, they do not provide a suitable performance measure for the sensitivity analysis). The NPV was found to be most sensitive to the briquette prices (±15 per cent for a ±25 per cent change in price) and charcoal dust price (±8 per cent for a ±25 per cent change in price). A ±25 per cent variation in the unit cost for toilet servicing labour or sales and distribution cost both resulted in ±4 per cent changes in the NPV, whilst for factory labour the NV variation is ±5 per cent. As these costs all scale in a more or less linear fashion, the variations in NPV are simply the result of the 25 per cent change multiplied by the relative contribution of the item to the overall costs.

A 25 per cent reduction in costs across the board would result in a CBS/briquettes business model becoming cost competitive with double vault UDDTs: the 20-year NPV matches that of double vault UDDTS, whilst the cumulative cash-flow is lower/better than that of double vault UDDTs until year 10, from which point they are about the same. A 67 per cent increase in revenue would have a similar impact (see Figure 20).

FIGURE 20: DISCOUNTED CASHFLOW WITH 25 PER CENT REDUCTION IN COSTS (LEFT) OR 67 PER CENT INCREASE IN REVENUE (RIGHT) FOR CBS/BRIQUETTES

Source: Sanivation / UNHCR analysis

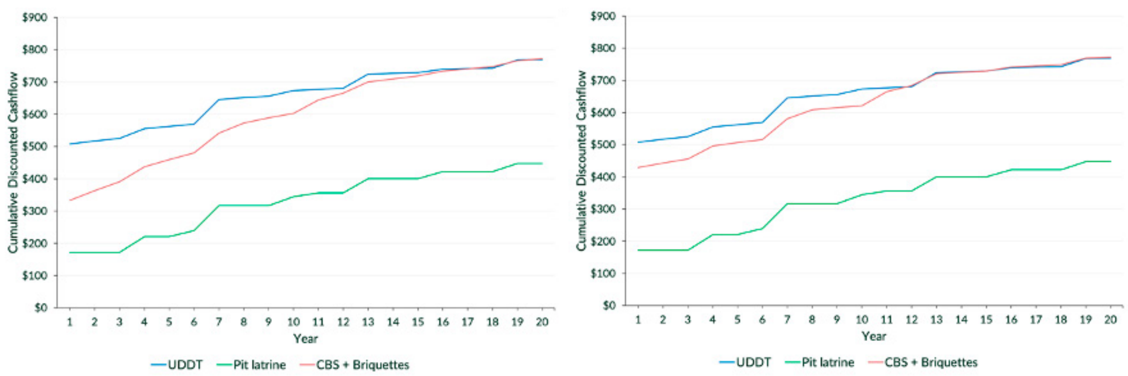


FIGURE 21: GENERAL VIEW OF KAKUMA REFUGEE CAMP

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4. Conclusion

Market-based solutions are increasingly seen as having an important role in filling gaps in public services provision and bring increased efficiency to humanitarian assistance. In response to a call for sanitation solutions for difficult ground conditions Sanivation introduced an innovative market-based solution in the form of sanitation with a waste-to-value component, implemented as operational research in Kakuma Refugee Camp in Kenya. One of the principle outputs for the project was a financial model of this solution. The model indicated that the service as implemented in Kakuma Refugee Camp was more expensive than the modelled pit latrine and double vault UDDT. However, the container-based toilets to briquette model brings additional environmental and livelihood benefits that may make it cost-competitive under the right market conditions.

Sanivation's solution brings additional environmental benefits, saves land space, creates livelihood opportunities and results in total inactivation of faecal pathogens. The value of these benefits is typically assessed in the qualitative or semi-quantitative assessments of the triple-bottom line approach[23]. To take account of these benefits in making programming decisions, UNHCR would need to be able to place a concrete value on these benefits – and realise them as a financial saving against its sectoral budget lines. Were the value of these benefits to exceed US$ 6.5 or US$ 9 per person per year, the container-based toilets to briquette model would be more cost effective than UDDTs and pit latrines,

23 For example, see Boston Consulting Group (2014, updated 2015) Improving Sanitation in Refugee Camps. Final Deliverable – Phase 1 Part 2.

respectively, if an offtake agreement were in place to eliminate sales and distribution costs. Alternatively, host government policy and regulation could bring the relevant externalities into market prices, for example, by requiring that all sanitation solutions are ensuring sludge is rendered safe for disposal or reuse and/or that charcoal and firewood are sustainably harvested.

As the funding environment for refugee operations continues to be challenging, engaging the private sector and harnessing market-based solutions is seen as an important strategy for bringing in additional resources and providing cost-effective services. The waste-to-value business model trialled in Kakuma illustrates the complexity involved in market-based solutions for sanitation in humanitarian settings. On top of the usual challenges of user acceptance, behaviour change and technical design that come when introducing new sanitation systems, the operation had to deal with the sales/distribution and marketing of briquettes, ensuring supply chains for two feedstocks (charcoal dust and faecal sludge) and technical challenges with the briquette fabrication process.

The host government, with the support of humanitarian and development actors have a role in providing de-risking arrangements for the private sector. The experience in Kakuma illustrates that this can sometimes be difficult due to local political dynamics. The domestic energy market in Kakuma is impacted by regular provision of free firewood and refugees have limited cash funds to make supplemental fuel purchases. Firewood is purchased from the local host community and substituting even a small proportion of the firewood for another product would have been strongly resisted. The increasing deployment of cash -based interventions and a move from annual to bi-annual planning within UNHCR could support market-based provision of goods and services in the future and the provision of more predictable subsidies, respectively, going forward. To truly support market-based initiatives, however, a more targeted approach to de-risking of will be required, ideally prior to commencement of the service.

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