CASE STUDY 4

Briquette production as reuse

Nakuru, Kenya

SNV

UTS Institute for Sustainable Futures

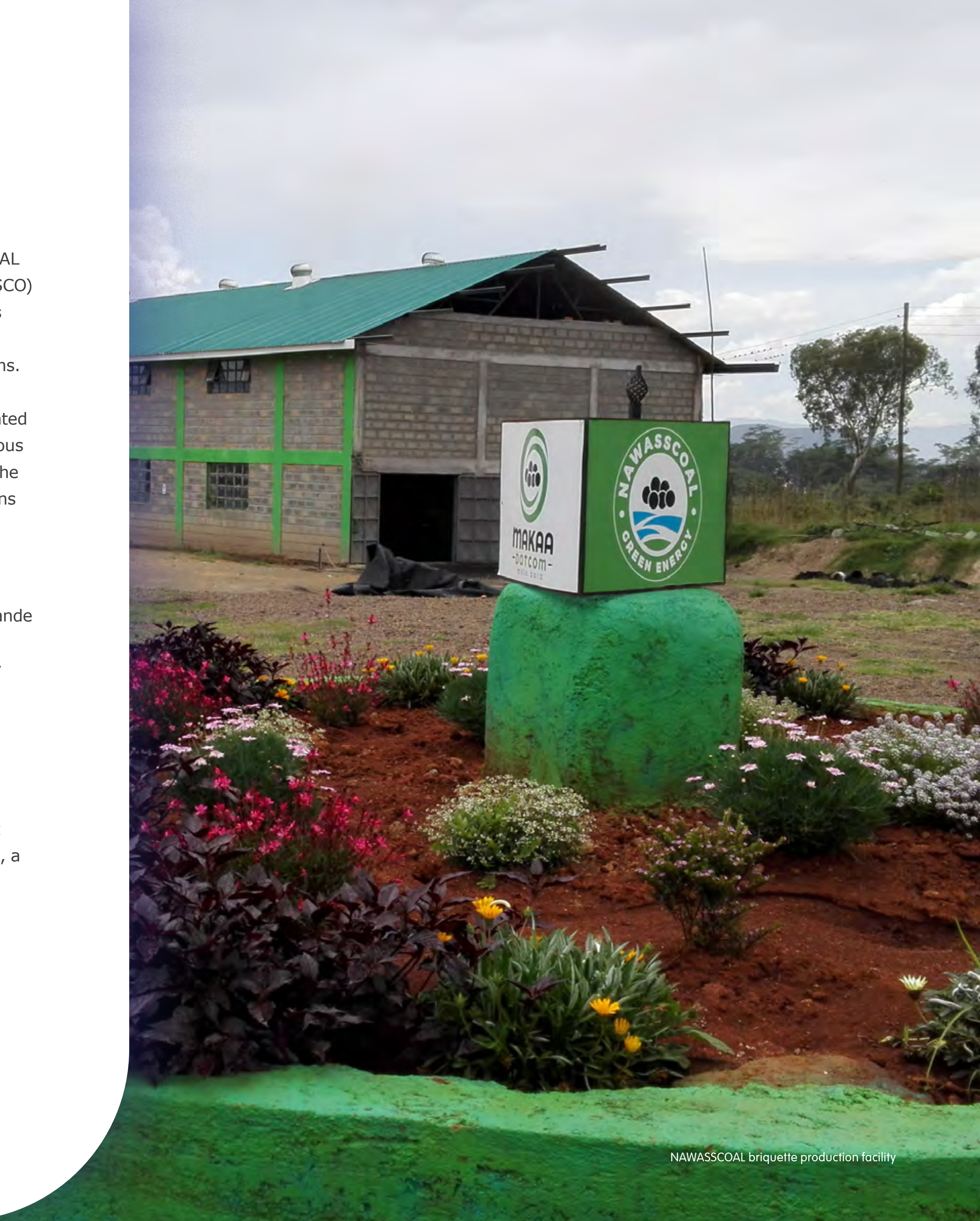
Background

Treatment selection and purpose

NAWASSCOAL produces and sells round-shaped carbonised briquettes made from treated sludge as an alternative fuel for domestic cooking and heating. NAWASSCOAL is a subsidiary of the Nakuru Water and Sanitation Services Company Ltd (NAWASSCO) and was established in 2018, after a pilot phase which began in 2013. NAWASSCO's conventional domestic water treatment plant was built in 1956 and rehabilitated in 2018 to enable compatibility and a well-functioning link to NAWASSCOAL's operations. Key considerations in selecting the NAWASSCOAL briquette production design included: (i) technological capability to process human waste into carbon concentrated material suitable for domestic briquette production; (ii) an ability to operate in various weather conditions, particularly during the rainy season; (iii) the need to fit within the available land area; and (iv) requirement to meet the environmental impact concerns of key stakeholders as the facility is located in a national park.

The briquette production facility was designed locally by a range of stakeholders under the Nakuru County Sanitation Programme (NCSP) (2013-2018). NAWASSCO implemented the NCSP with support of Vitens Evides International (VEI), SNV, Umande Trust, and the Nakuru County Government. The programme formed a steering committee with representatives of key departments in the NAWASSCO water utility as well as project partners and government representatives, who were involved through sub-committees in designing the facility and sourcing the technologies. Recommendations from the steering committee informed the final decision made by the programme and donor. The decision was also informed by the piloting of potential reuse products, e.g., different types of bio-fertilisers and biomass fuels through a partnership with Egerton University and other project partners. The pilot included product development and market studies, a feasibility and business model, a community pilot, and field trials.

> *The community trial with households in Nakuru's low-income areas confirmed people's willingness to use fuel produced from faecal sludge, as long as it would meet their cooking needs and [it was] affordable. The trials provided key insights for further product development and marketing, distribution, and sales strategies.*
>
> **WASH ADVISOR, SNV IN KENYA**



NAWASSCOAL briquette production facility

Agglomerator in operation using a rotating drum

Round-shaped carbonised briquettes in drying beds

Round-shaped carbonised briquettes used as an alternative fuel source

Description of the system

The NAWASSCO treatment plant is designed to receive any type of domestic wastewater, with the treated sludge used for the production of the briquettes by NAWASSCOAL. NAWASSCO receives greywater and blackwater through sewer lines and sludge from vacuum trucks or pit-emptying technologies. The NAWASSCO treatment plant receives an estimated 2,800 m^3/day of wastewater, which undergoes a screening process to remove sand and grit. This is followed by thickening in a primary clarifier to reduce the sludge moisture content, resulting in 1,020 m^3/day of sludge. The sludge is then pumped from the NAWASSCO treatment plant, through a newly built connection pipe, to NAWASSCOAL's briquette production site for further drying to 20% moisture content using open-air drying beds and a solar drier, or a combination of the two. This process results in approximately 200 m^3 or 140 t/day of sludge for processing into briquettes. The carbonisation technology used at the facility was designed to accommodate a wide range of biomass waste (any organic waste, including sawdust, rice husks, bagasse, and any type of human waste). Therefore, waste can be taken from the conventional treatment plant as well as directly from vacuum trucks.

The briquette production design has been optimised to ensure the required physical and combustion properties of the briquettes. Figure 1 (on next page) outlines the NAWASSCOAL production process, which includes a holding tank, open-air drying beds, a solar dryer, a carbonisation unit, hammer mills, a batch mixer, and a rotating drum or agglomerator. The briquettes are made of a combination of dried and carbonised sawdust (50%) and human waste/sludge (50%) by volume. The agglomerator works by tumbling the sludge and sawdust in a rotating drum, in the presence of a binding agent such as molasses, followed by drying of the briquettes on beds for up to four days. Testing showed that briquettes exhibited the positive attributes for moisture content (7.3%), volatile matter (34.5%), ash content (36.4%), and calorific value (22.001 MJ/kg), with molasses-bonded briquettes having a lower calorific value than faecal matter-bonded briquettes.[1]

[1] M.J. Mbuba, D.M. Nyaanga, P.A. Kabok and R. Eppinga, 'Effect of mix ratios and binders on physical and physical combustion characteristics of faecal matter – sawdust briquettes', *International Journal of Emerging Technology and Advanced Engineering*, vol. 7, issue 4, 2017.

Figure 1. Typical NAWASSCOAL briquette production process, including NAWASSCO treatment process (top of figure), drawn by SNV based on site visit

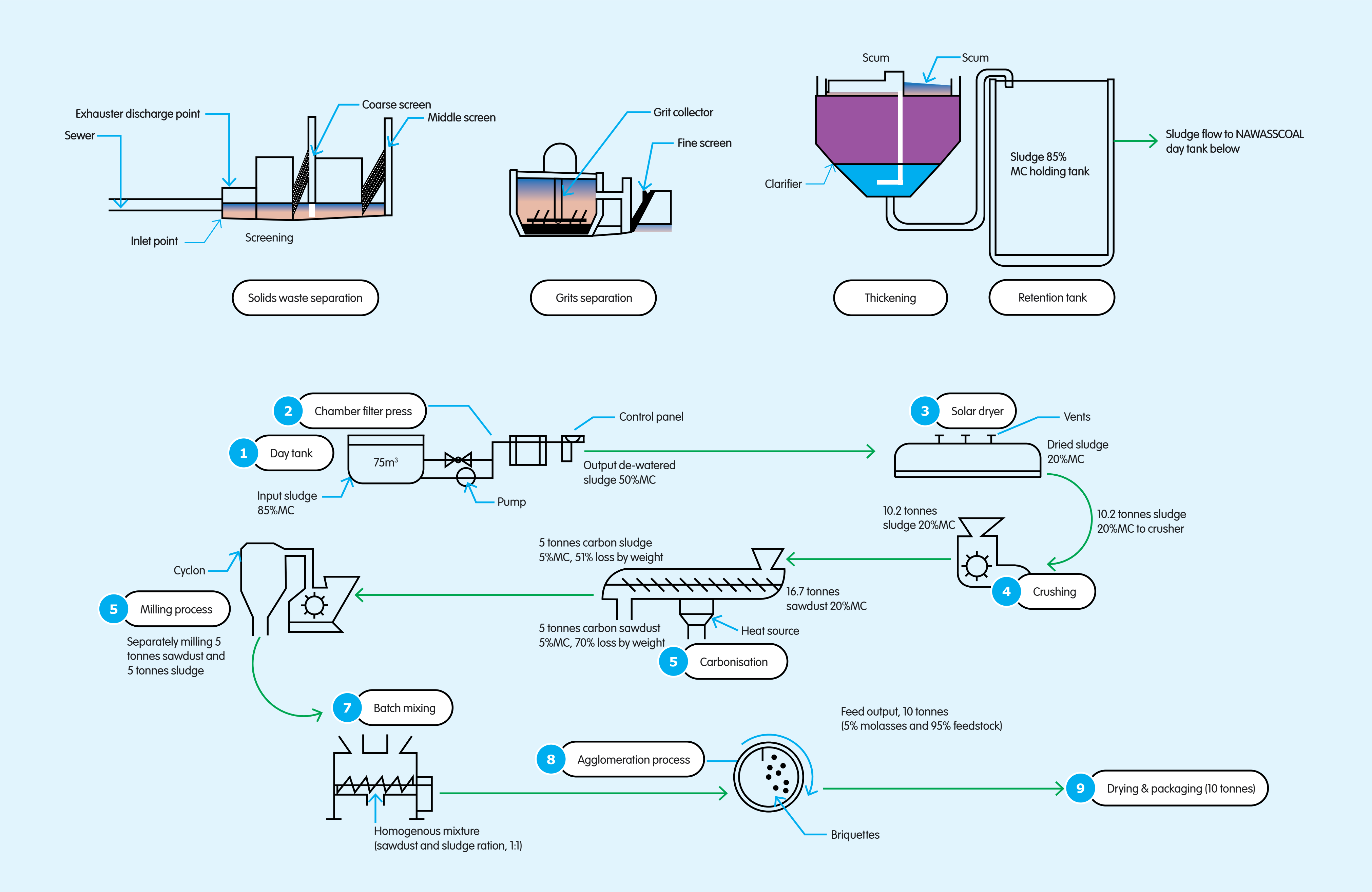


Table 1. Capacity and operating costs of the NAWASSCOAL treatment plan and briquette operations

	Conventional treatment plant	Briquette production for reuse
Design capacity	3,400 m³/day of wastewater	250 t/month
Operating capacity	2,800 m³/day of wastewater	10 t/month
Costs Capital expenditure (CAPEX) Operational expenditure (OPEX)	CAPEX = US$ 366,497 OPEX for NAWASSCOAL = US$ 14,020 (year one) OPEX for NAWASSCOAL = US$ 1,473 (year two) OPEX for NAWASSCOAL = US$ 18,172 (year three, estimated) OPEX for NAWASSCOAL = US$ 55,640 (year four, estimated) OPEX for NAWASSCOAL = US$ 206,458 (year five, estimated)[2]	

Regulatory environment and compliance

Treated effluent standards set by the Kenyan Natural Environment Management Authority (NEMA) are followed and met by NAWASSCO. Effluent standards for the conventional treatment plant are BOD (Biochemical Oxygen Demand) < 50mg/L and COD (Chemical Oxygen Demand) < 30mg/L.[3] The liquid part of the waste is further treated through a rock filter and grass ponds, up to the required standard by NEMA, then released into Lake Nakuru. Prior to construction, approval from all relevant parties, including the Kenya Wildlife Service and the Nakuru County Government, were required to ensure that environmental standards are met due to the facility's sensitive location in a national park. Concerns expressed by some stakeholders were overcome through a comprehensive consultative process.

> *The public participation process, which included neighbouring community and school representatives as well as Kenya Wildlife, NEMA, and the Chief's offices ensured that all stakeholders were informed and have since supported the initiative.*
>
> **GENERAL MANAGER, NAWASSCOAL**

Carboniser plant

Operation and maintenance: realities, challenges, and opportunities

Realities of running the treatment plant

Optimising production through technological considerations

Treatment technologies, which optimised production processes were chosen when designing the NAWASSCOAL facility. The carboniser was chosen to enable large-scale carbonisation of dried faecal sludge and other biomass materials. The solar dryer was introduced to accelerate drying and to be used in combination with the open-air drying beds. Using UV-treated solar lag materials, the temperatures in the solar dryer can reach 50° Celsius and drying is not affected by weather conditions like rain.

Staffing, OHS, and operator training

Key considerations for operating the facility include ensuring that sufficient staff are employed, Occupational Health and Safety (OHS) measures are followed, and training requirements are fulfilled. Currently, there are four skilled staff including a general manager, a marketing officer, a business officer, and a production supervisor, as well as three unskilled production assistants

[2] Every year, capacity of the facility is increased. This will require an increase in operational costs and capital expenditure. Operational cost increases will be covered by additional profits from briquette production.
[3] *Environmental management and co-ordination (water quality) regulations (2006)* Kenyan Natural Environment Management Authority, https://www.nema.go.ke/images/Docs/water/water_quality_regulations.pdf (accessed 1 December 2020).

working at the NAWASSCOAL facility. Typical activities performed by the production assistants include briquetting, milling, mixing, feeding the carboniser, shredding raw materials in preparation for carbonisation, drying of final products, drying sludge, packaging, and distribution/sales.
To ensure OHS the company works to eliminate contact with raw untreated sludge as much as possible. Where contact occurs, wearing of protective gear and equipment is required as well as following proper training in handling untreated sludge. Ensuring that machines are constructed following rules and regulations as outlined in the Kenyan Occupational Safety and Health Act (OSHA) 2007 is also key.

On-the-job training and manuals outlining key procedures help upskill staff. NAWASSCOAL has a health and safety manual, a finance manual, a corporate and governance manual, a production manual, a human resource manual, and a standard operation and maintenance procedures manual which outlines proper operation procedures. Operators have been trained on the job by those able to operate the machinery, including by local and international suppliers of machinery used at the facility for Operations and Maintenance (O&M) and safety training.

> *A comprehensive assessment of the safety requirements was conducted and recommendations like inoculation of staff, use of safety equipment and First Aid and Fire Safety Trainings were put in place. A health and safety manual was developed to guide day-to-day operations. Signage, marking on the floors, insulation of hot pipes, among other safety procedures, have since been implemented.*
>
> **GENERAL MANAGER NAWASSCOAL**

Meeting market demand through facility expansion and improvements

Expansion of the NAWASSCOAL facility and continuous improvements are required to meet the increasing market demand for briquettes. With a population of 500,000 in Nakuru Town, the market study from the design phase indicated that the need for briquettes is greater than can be satisfied by the current scale of operations. Taking local government plans to extend sewer and treatment facilities for the town in the years to come into consideration, an additional US$ 115,134 has been invested in the NAWASSCOAL facility, with the company currently seeking extra funding to continue expansion as per their business plan.

Solar dryer in the NAWASSCOAL facility

The overall lifespan of the facility is between 5 and 20 years due to the different technologies in operation. The lifespan of some locally produced machinery is up to five years, while for larger imported machinery, it is between 15 and 20 years. To ensure that the machinery fulfils its intended lifespan, continuous improvement and maintenance are conducted. Examples of improvements made include insulation of the carboniser, improved floor durability of the solar drier using high quality materials (including reinforced concrete with a top layer of waterproof cement and concrete pillars between the sludge and the metal), and drying racks constructed from metal instead of wood. Key maintenance activities include repair of the hammer mills and rotating drum, which are easily done locally by staff.

Challenges of operation and maintenance

Key considerations in choosing the most appropriate technology

A key learning by the briquetting facility operators was in the type of technologies to use and not to use if scaling up operations is a priority. To increase production speed, a professional briquetting machine would have been preferred over the agglomerator machines currently in operation, which in the Kenyan case would need to be imported. It was also found that the carboniser requires fairly significant preparation work before it can be installed, and the dryer element may not be required. Preparatory work included ensuring there were sufficient water tanks and cooling tanks, building a framework for conveyors, building channels for the floor, installing the pillar required for the carboniser to sit on, and installing electricity cables. The dryer element is not required when there is sufficient sunlight and solar drying can be relied on. This saves significant amounts of energy. Finally, more professional hammermills that deal well with carbonised materials are also advisable if the plant moves to large-scale operations, as are dewatering devices. Generally, the suitability of various machines depends on the scale envisaged and the budget available.

> *We maximise the use of the sun to dry the raw materials as well as the final products. By utilising the natural heat from the sun, the company saves on electricity cost.*
>
> **GENERAL MANAGER NAWASSCOAL**

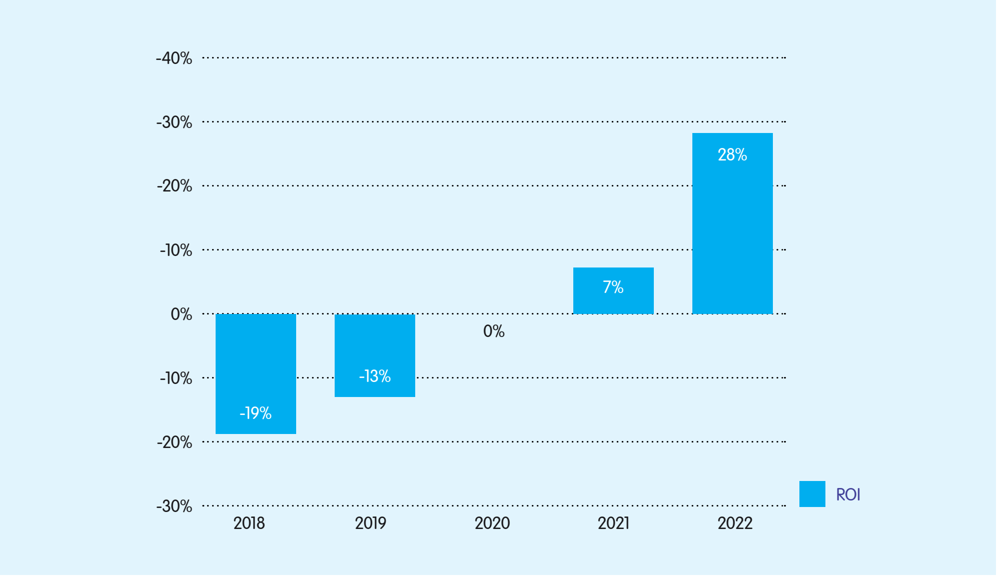
Absence of backup power supply

A key challenge faced by the NAWASSCOAL facility is the lack of a backup power supply. The facility relies on the electricity grid for power, which is one of the greatest costs, along with ongoing maintenance costs. Power outages can lead to delays in production of the briquettes. However, when there is no power, staff can work on other processes that do not rely on electricity. Even though the drying beds are covered, wet weather can also result in delays to drying of the sludge and the briquettes. NAWASSCOAL is currently proposing oven drying for the briquettes to prevent delays due to wet weather.

Ensuring financial sustainability

It was necessary for the company to break even within the first three years of operation to repay funds invested by NAWASSCO and to become financially sustainable. NAWASSCOAL inherited the capital investments made in the briquette facility through the NCSP EU co-funded programme and received loans from its mother company NAWASSCO (US$ 126,335) to cover operational expenditures for the first two years. This loan amount needs to be repaid at an interest rate of 5% once the company breaks even and begins making a profit, which is expected in the fourth year of operation, as shown in Figure 2. NAWASSCOAL plans to increase production capacity to 60 tonnes in the third year in order to cover operational costs and steadily increase production, allowing them to repay their loans and become financially sustainable.

Figure 2. NAWASSCOAL Return on Investment (ROI) prediction, based on conversation during site visit



Informed choice considerations	Briquette production as reuse in Nakuru, Kenya (NAWASSCOAL)
Operating & design capacity	Design capacity = 250t/month of briquettes Operating capacity = 10t/month of briquettes
Operating costs	CAPEX = US$ 366,497 OPEX for NAWASSCOAL = US$ 14,020 (year one) OPEX for NAWASSCOAL = US$ 1,473 (year two) OPEX for NAWASSCOAL = US$ 18,172 (year three, estimated) OPEX for NAWASSCOAL = US$ 55,640 (year four, estimated) OPEX for NAWASSCOAL = US$ 206,458 (year five, estimated)
Energy requirements	Grid electricity used for both single and three-phase machines using a 250KvA transformer, some natural processes including solar drying; per tonne of briquettes is US$ 20 for electricity
Input characteristics	Any type of sludge can be received by the NAWASSCO treatment plant (though not industrial sludge) or directly by the drying beds of NAWASSCOAL; to enable sludge to be used in the carboniser, moisture content needs to be less than 20% and particle size less than 5cm
Output characteristics	For the liquid effluent, BOD must be less than 50mg/L and COD less than 30mg/L, as per treated effluent standards set by NEMA; any pathogens in the solid part are completely eliminated during the carbonisation process
Reuse	Round-shaped carbonised briquettes (50% sludge/waste and 50% sawdust with molasses as a binder)
Land requirement	Land size for the facility is minimum of one acre; the current facility of NAWASSCOAL is built on 2.5 acres
Skills & human resources requirements	Seven staff in total: four skilled staff including a general manager, marketing officer, business officer, and production supervisor, as well as three unskilled production assistants; when scaled further, additional staff will be required
Technology/material (local) availability	Carbonisation unit was designed, piloted and imported from China; all other machines in operation were locally acquired and spare parts for all machines (including those from overseas) are locally available; over time some of this machinery was improved for safety and efficiency, in consultation with the fabricators

References

Environmental management and co-ordination (water quality) regulations (2006) Kenyan Natural Environment Management Authority, https://www.nema.go.ke/images/Docs/water/water_quality_regulations.pdf (accessed 1 December 2020).

Mbuba, M.J., Nyaanga, D.M., Kabok, P.A. and Eppinga, R., 'Effect of mix ratios and binders on physical and physical combustion characteristics of faecal matter – sawdust briquettes', *International Journal of Emerging Technology and Advanced Engineering*, vol. 7, issue 4, 2017.

This paper is a chapter in a publication of nine case studies presenting real-life faecal sludge and wastewater treatment practices. The stories were narrated by plant owners, operators, SNV staff, and partners in Indonesia, Bangladesh, Kenya, Zambia, Malaysia, India, South Africa, and Benin. The full publication was reviewed by Antoinette Kome and Rajeev Munankami, and available for download at: https://snv.org/cms/sites/default/files/explore/download/2021-treatment-technologies-in-practice-snvisf-uts-full-publication.pdf.

Citation: ISF-UTS and SNV, *Treatment technologies in practice: On-the-ground experiences of faecal sludge and wastewater treatment*, The Hague, SNV Netherlands Development Organisation, 2021.

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