Setting the stage for the circular economy

Waste resource recovery opportunities in Naivasha, Kenya

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Cover photo: Vegetable waste waiting to be fed into a biogas digester, Gorge Farm Energy Park, Naivasha, Kenya © Daniel Ddiba / SEI

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Contents

Background and acknowledgements

In 2017, Stockholm Environment Institute (SEI) and Sanivation launched a project to explore the opportunities and benefits that a circular economy approach to sanitation and waste management could bring for Naivasha Sub-county in Kenya. This collaboration is within the UrbanCircle (Urban Waste into Circular Economy Benefits) project and the SEI Initiative on Sustainable Sanitation.

This report is a deliverable within that collaboration, and it provides an account of the various organic waste streams in Naivasha, their quantities and physical and chemical characteristics, the ongoing resource-recovery initiatives in the sub-county and the key stakeholders involved in sanitation, waste management and resource recovery. This account will be a basis for co-developing future scenarios that elaborate the full potential of resource recovery from organic waste streams in Naivasha with the participation of SEI, Sanivation and other local stakeholders. Since this report provides an overview of the infrastructure set-up for the sanitation and waste management chain in Naivasha and the actors connected to it, it can act as a handy reference to other stakeholders working in the sanitation, waste management and resource recovery sector in Naivasha and the rest of Kenya.

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1. Introduction

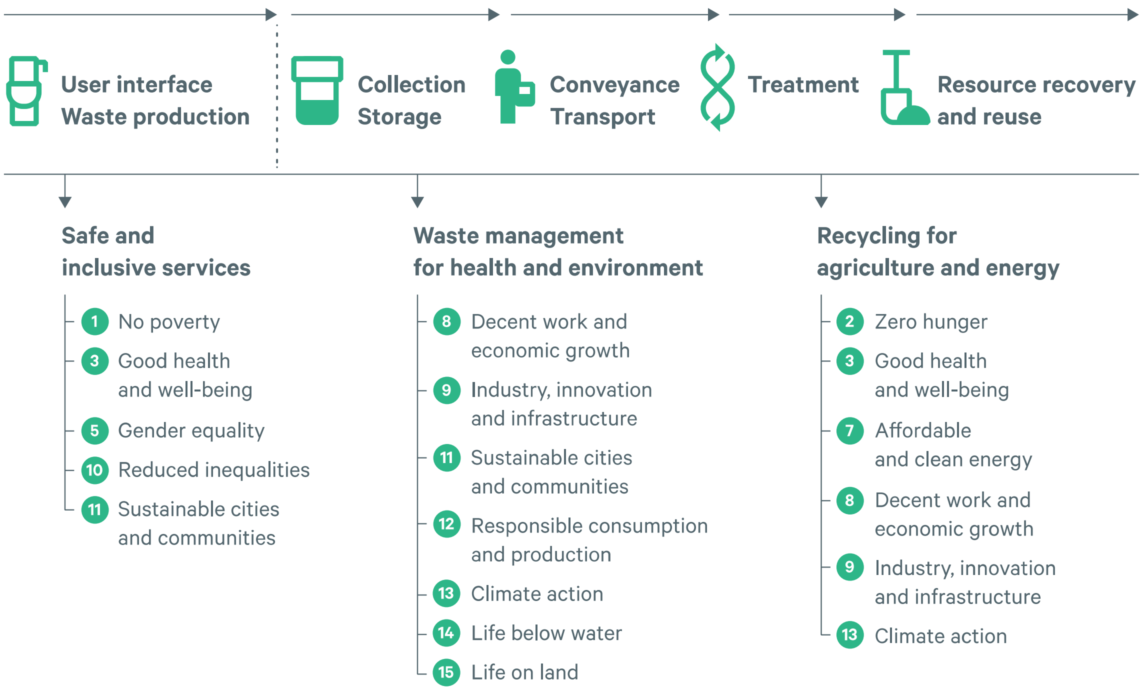
1.1 Background

The world's urban population is expected to reach 5 billion in 2030 and 6.4 billion in 2050 (Angel et al. 2011). The majority of this population will be concentrated in cities in Africa and Asia. This will lead to increased demand for food, water and energy among other resources, along with increased generation of waste. Sustainable natural resource management in and around cities will be essential to cope with these challenges.

Improved natural resource management in urban areas can have many direct and indirect benefits that substantially contribute to human well-being. Inadequate waste management, such as poorly functioning sanitation systems (e.g. wastewater and excreta management) and uncontrolled dumping of solid waste are common around the world, causing pollution, degradation of ecosystems, adverse health impacts and eventually depletion of natural resources. This inadequate management results in lost socio-economic and environmental potential from waste streams, which might include the safe reuse of valuable nutrients and organic matter that could boost food production, renewable energy generation and new business opportunities (Andersson et al. 2016).

Indeed, applying circular economy principles to the management of organic waste streams is increasingly seen as part of the solution to the challenges of growing waste generation, amid rising demand for resources in growing cities (Ellen MacArthur Foundation 2017). For organic waste streams, harnessing the opportunities for resource recovery can contribute significantly not only to improved health, livelihoods and water, food and energy security, but also climate change mitigation, reduced eutrophication in aquatic ecosystems, and reduced dependency on fertilizer imports (Andersson et al. 2016). Furthermore, moving beyond collection and containment of organic waste and incorporating resource recovery provides opportunities to contribute to multiple Sustainable Development Goals (SDGs), as shown in Figure 1.

Figure 1. Contributions to multiple SDGs of applying circular economy approaches for organic waste streams along the sanitation service value chain



SEI's UrbanCircle project (Urban waste into Circular Economy benefits) is focused on integrating waste management and resource recovery into circular urban economies.[1] UrbanCircle is developing a way to visualize and highlight synergies between different waste and resource flows, particularly water, waste, food and energy.

This report presents an inventory of organic waste resources, ongoing resource recovery initiatives, and stakeholders involved in sanitation, waste management and resource recovery in Naivasha, Kenya – one of the UrbanCircle case study urban centres, along with Chía, Colombia, and Stockholm, Sweden. This is a first step towards creating scenarios and roadmaps for a circular economy based on organic waste resources in Naivasha, which are intended to point the way for the country of Kenya and other cities in sub-Saharan Africa.

Section 2 provides some working definitions of terms used in the project and describes how the inventory was compiled. Section 3 looks at which stakeholders are involved along the sanitation and waste management service chain in Naivasha, including resource recovery and/or disposal of waste. Section 4 identifies the sources, the quantities and qualities of the various organic waste resources, along with existing resource recovery initiatives in the city. Section 5 looks at current and potential markets for resource-recovery products while Section 6 offers some conclusions.

The findings are based on a literature review, stakeholder identification, scoping interviews and a stakeholder workshop held in Naivasha in May 2018.

1.2 Naivasha

Naivasha is one of the 11 sub-counties of Nakuru County, located about 90 km north-west of Nairobi. The sub-county occupies 1685 km^2, which is 22% of the total area of Nakuru County (County Government of Nakuru 2018), and includes Lake Naivasha (see the map in the appendix).

Naivasha is home to a mix of people from different ethnic groups and socio-economic backgrounds. Most of Naivasha's population has migrated from different parts of Kenya or even other countries, mainly for business and work, especially in the tourism and agricultural sectors. The population of Naivasha is estimated to have grown from around 145 000 in 1999 to 225 000 in 2009, and is expected to reach approximately 670 000 in 2040 (Mott MacDonald 201 7). Naivasha's population size is comparable to other notable African cities like Gaborone, Botswana; Porto-Novo, Benin; Windhoek, Namibia; and Takoradi, Ghana. Kenya has several other towns of around this size.[2]

Naivasha is fast-growing in economic terms, due mainly to thriving agriculture and tourism sectors, which are key income generators for the county and for Kenya. The main agricultural activity is floriculture, and Naivasha is home to the largest number of flower farms in Kenya. Naivasha's climate, the availability of water from Lake Naivasha and proximity to Nairobi's airports for export are particularly favourable for floriculture. The Kenyan flower industry, a large part of it concentrated around the Lake Naivasha area, employs about 2.1 million people directly and indirectly, according to the Kenya Flower Council.[3]

Naivasha Sub-county is also an important geothermal energy production site, especially the areas around Olkaria and the volcanic Mount Longonot. The electricity produced is fed into the national grid. Currently, the Olkaria block has an installed capacity of over 400 MW (County Government of Nakuru 2018). There are proposals by the national government to develop an industrial park in Naivasha Sub-county, which will take advantage of the standard gauge railway (SGR) dry port that will be set up in Naivasha along with the abundant geothermal energy (County Government of Nakuru 2018).

1 UrbanCircle is a 3-year project funded by Formas, A Swedish Research Council for Sustainable Development. See www.sei.org/urbancircle for more information.
2 See https://worldpopulationreview.com/continents/cities/africa.
3 See http://kenyaflowercouncil.org/?page_id=92.

1.3 Resource and waste management challenges

Kenya aspires to develop a more sustainable and circular economy, according to the country's Vision 2030 (Government of Kenya 2007) and the draft waste management policy (Ministry of Environment and Forestry 2019).

Furthermore, Kenya's urban population is expected to grow from 14.7 million in 2020 to 21.8 million by the year 2030 and to 42.6 million by 2050 (UN DESA 2015). According to the World Health Organization (WHO) and UNICEF (2017), 65% of urban residents in Kenya lack access to basic sanitation services and 17% lack access to safe drinking water. Inventories of excreta flows that have been conducted in the towns and cities of Kakuma, Nakuru, Kisumu, Nairobi and Mavoko indicate that between 59% and 79% of all excreta ends up untreated and disposed in the environment (Dewhurst 2018; Furlong 2015; Furlong 2015; Kappauf and Heyer 2018a; Kappauf and Heyer 2018b). In Naivasha, this figure is at 78% (Bohnert 2017).

The rate of solid waste generation in Kenya's urban areas ranges from 0.31 to 0.75 kg/person/day and less than half of the waste generated is collected (Soezer 2016). Of the solid waste that is collected, only 8% is recycled and the rest ends up at dump sites and landfills (Kaza et al. 2018). Over 60% of the solid waste generated in Kenya's cities and towns is organic (NEMA 2014) and this share is likely to grow significantly due to the country's expanding agro-industrial sector, including dairy and meat production, floriculture and horticulture, and traditional export crops like coffee and tea.

Naivasha presents an interesting case study to examine how circular economy principles to the management of organic waste streams can contribute to meeting the emerging challenges of urban growth in Kenya and other parts of sub-Saharan Africa.

Workers collect up carboard for recycling at the Naivasha dumpsite. © CONSTANZE WINDBERG

2. Methods and data sources

2.1 Definitions

The following definitions are used in the report and the UrbanCircle project.

Circular economy

According to Kirchherr et al. (2017), "a circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production, distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations." The circular economy is thus framed as an alternative to a traditional 'linear' economy (produce – use – dispose) in the cycles of both technical and organic materials (Ellen MacArthur Foundation 2017, p.17). The aim is that in a circular economy, nothing is regarded as waste; products and materials are used for as long as possible to extract the maximum value; and at the end of their life cycle, the resources are recovered to regenerate new products and/or energy.

Bioeconomy

Bioeconomy can be defined as the "knowledge-based production and utilization of biological resources, biological processes and principles to sustainably provide goods and services across all economic sectors" (Dubois and Gomez San Juan 2016). "Biological resources" refers to biomass, which includes both primary agricultural raw materials and agricultural waste or residues. The latter are covered within the scope of this report.

Organic waste resources

There are multiple definitions of what is regarded as "waste". In this report, we use the term "organic waste resources" as described by Klitkou and Iversen (2016), since they attempt to mitigate the negative connotations around "waste" while also acknowledging the valuable resources embedded in it. By "organic waste resources", we refer to a combination of organic waste streams that easily decompose and which may hold significant moisture content such as faecal sludge, wastewater, sewage sludge, food and market waste, slaughterhouse waste, agricultural waste, processing waste from the manufacturing of food products, etc.

Wastewater

Wastewater is used water from any combination of domestic, industrial, commercial or agricultural activities, surface run-off/stormwater, and any sewer inflow/infiltration (Tilley et al. 2008). Wastewater from domestic sources includes excreta, flush water, anal cleansing materials and water from kitchen, laundry and bathing activities. As an alternative to "wastewater", the term "blackwater" is used when referring to only a mixture of urine, faeces, flush water and anal cleansing materials, while "greywater" is used when referring to only a mixture of "water generated from washing food, clothes and dishware, as well as from bathing, but not from toilets" (Tilley et al. 2014).

Sewage sludge

Sludge is a mixture of solids and liquids, containing mostly excreta and water, in combination with sand, grit, metals, trash and/or various chemical compounds. "Sewage sludge", which is sometimes referred to as "wastewater sludge", is sludge that originates from sewer-based wastewater collection and (semi-) centralized treatment processes (Tilley et al. 2014).

Faecal sludge

Faecal sludge comes from on-site sanitation technologies and has not been transported through a sewer. It is raw or partially digested, a slurry or semisolid, and results from the collection, storage or treatment of combinations of excreta or blackwater, with or without greywater. Examples of on-site technologies include pit latrines, unsewered public ablution blocks, septic tanks, aqua privies and dry toilets. Faecal sludge from septic tanks can also be referred to as "septage".

Stakeholder

A stakeholder is a "an individual, group, or organization, who may affect, be affected by, or perceive themselves to be affected by a decision, activity, or outcome of a project" (Project Management Institute 2013).

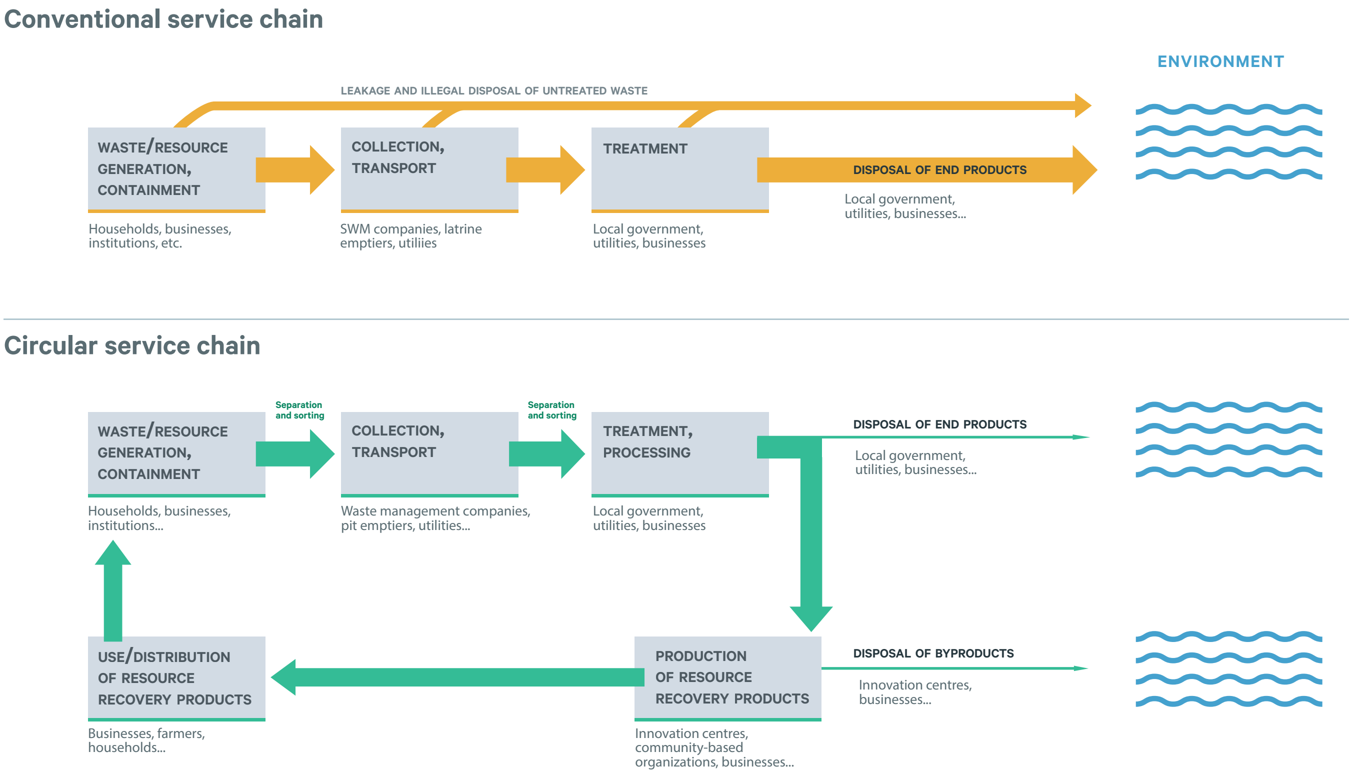
2.2 The concept of the sanitation and solid waste service chain

To identify available organic waste resources, the sanitation and waste service chain has to be understood, and the respective segments identified as well as the stakeholders. This approach improves the understanding of incentives, potentials and challenges in each segment and for the respective key stakeholders. Figure 2 presents a schematic overview of the sanitation and waste service chain and potential stakeholders involved at each link in the chain.

The concept illustrated in Figure 2 is based on the idea of the sanitation service chain that was introduced in the compendium of sanitation technologies through the various functional groups of a sanitation system (Tilley et al. 2008), and then popularized in an illustration by the Bill & Melinda Gates Foundation (2010). The service chain concept has also been applied in the solid waste management sector and in this report, we adapt it to refer to the steps in the management of organic waste resources in general.

In a sanitation or waste-management system based on a linear economy approach, the service chain comprises four key segments: organic waste resource generation; collection, emptying and transport; treatment to some extent, and finally disposal. In a circular economy approach, however,

Figure 2: Comparing typical conventional and circular sanitation and organic waste management service chains, showing the key actors involved at each stage



the aim is to reuse and recycle resources. Some additional segments are therefore introduced in the service chain: sorting or source separation, extending the treatment process to include the production of resource recovery products, and the distribution and use of the products.

2.3 Data and information sources

The findings in this report are based on a review of literature, a series of semi-structured scoping interviews and an inception workshop. A stakeholder identification exercise provided insights into the various stakeholders that are active in the sanitation and solid waste service chain. The literature sources reviewed included publications and reports from previous studies conducted in and about Naivasha.

The literature review provided a first overview of stakeholders in the sanitation and waste service chain in Naivasha. Interviewees for scoping interviews were selected based on this overview. The first round of interviews was conducted in May 2018, involving 13 stakeholders. The second round of interviews followed in August 2018, interviewing 12 stakeholders. Some of the interviewees in the second phase were selected based on references by previously interviewed stakeholders. The focus of the interviews was to identify the available organic waste resources, their quantities and physical-chemical quality, existing resource recovery initiatives, and other stakeholders engaged in the sanitation and waste service chain.

The inception workshop was conducted in May 2018 in Naivasha and involved 32 stakeholders from the case study area. The workshop introduced the UrbanCircle project and it also validated and complemented initial findings. The stakeholders identified throughout this process were categorized according to their types, roles and their specific activities along the sanitation and waste service chain as shown in Table 1. A list of stakeholders is provided in Section 3. The information obtained on available organic waste resources and existing resource recovery initiatives is provided in Section 4.

A vacuum truck discharges faecal sludge at the NAIVAWASCO wastewater treatment plant. © DANIEL DDIBA

3. Stakeholders

During the study we identified 52 stakeholders involved in the sanitation and waste service chain in Naivasha. Table 1 shows how these stakeholders were distributed among different roles, types and stages of the service chain. Table 2 gives more detail about the individual stakeholders, and how they were involved in the study.

Table 1. Stakeholder categories used for Naivasha in the UrbanCircle project

Category	Description	Number of stakeholders identified
By stakeholder role		
Decision-makers	Have explicit responsibility for polices or measures related to sanitation, waste management, resource recovery and the circular economy	15
Implementers	Implement initiatives around sanitation, waste management, resource recovery and the circular economy	24
Coordinators	Coordinate other actors working within sanitation, waste management, resource recovery and the circular economy	4
Experts	Undertake research and provide information and knowledge management related to sanitation, waste management, resource recovery and the circular economy	5
Funders	Private or public agencies that fund research and implementation of initiatives connected to sanitation, waste management, resource recovery and the circular economy	2
Others affected	Other beneficiaries or victims of policies or initiatives related to sanitation, waste management, resource recovery and the circular economy	2
By stakeholder type		
National public authorities	Responsible for policy and regulation, as well as technical and financial support at the national and regional levels	10
Local public authorities	Responsible for policy and regulation, as well as technical and financial support at the local level	10
Private sector	Develop and invest in businesses, products and services based on managing organic waste resources	17
Research and innovation institutions	Cooperate with public and private stakeholders in developing new solutions and approaches for managing organic waste resources	3
NGO and cluster organizations	Educate and raise awareness among the public and include groups and industry associations promoting or lobbying for specific policy measures	11
Citizens	General citizens and user groups for organic waste resources	1
By stage of waste service chain		
Waste generation	Involved in the generation and containment of organic waste resources at site	4
Emptying and transportation	Involved in emptying, collection and transport of organic waste resources	10
Treatment and processing	Engaged in the treatment and processing of organic waste resources and the production of resource recovery products	9
Disposal/end-use	Involved in the disposal of end-products or the distribution and use of resource recovery products	4
Policy/overarching	Others not directly involved in hands-on activities in the organic waste service chain	25

Table 2. List of identified stakeholders involved in the sanitation and waste service chain in Naivasha

Stakeholder by type	Involved in interviews	Involved in workshop
National public authorities and agencies		
Ministry of Water and Sanitation		
Ministry of Health		
Ministry of Energy		
Ministry of Agriculture, Livestock, Fisheries and Irrigation		
Ministry of Environment and Forestry		
National Environmental Management Authority (NEMA)	•	•
Water Services Regulatory Board (WASREB)		
Water Sector Trust Fund (WSTF)	•	
National Environment Trust Fund (NETFUND)	•	
Energy and Petroleum Regulatory Authority		
Local public authorities and agencies		
Nakuru County Ministry of Water, Environment, Energy and Natural Resources		•
Nakuru County Ministry of Agriculture, Livestock and Fisheries		•
Nakuru County Ministry of Health Services		•
Naivasha Sub-county Department of Public Health	•	•
Naivasha Sub-county Department of Physical Planning	•	
Naivasha Sub-county Department of Environment and Natural Resources	•	•
Naivasha Sub-county Department of Agriculture, Livestock and Fisheries	•	•
Naivasha Maximum Security Prison	•	
Naivasha Sub-county slaughterhouse	•	•
Naivasha Water, Sewerage and Sanitation Company Ltd (NAIVAWASCO)	•	•
Research and innovation institutions		
Egerton University	•	
Water and Sanitation for the Urban Poor (WSUP)	•	•
WasteAid UK		
Private sector		
Waste generation		
Keroche Breweries	•	
Wildfire Flowers (and other horticulture and floriculture farms)	•	•
Enashipai Resort and Spa (and other hotels and resorts)	•	
Delamere Farm (and other livestock farms)		
Solid waste collection service providers		
Wiper Sanitary Disposers	•	•
Flying Eagles	•	•
Taka Ventures	•	
Hadassah women's group		
Hanseligwa Enterprises		
Bidii Yetu Enterprises		
Several faecal sludge vacuum truck operators	•	
Treatment and processing of resource recovery products		
Gorge Farm Energy Park (Tropical Power/BioJoule)	•	
Sanivation	•	•
Dudutech		•
Trace Eco Solutions Ltd		
Charicon Enterprises		
Others		
ACE Environmental Consultancy		
NGOs, CBOs and cluster organizations		
Lake Naivasha Water Resources Users Association (LANAWRUA)	•	
Lake Naivasha Riparian Association (LNRA)	•	
Lake Naivasha Growers Group (LNGG)	•	•
Nakuru Solid Waste Managers Association (NASWAMA)		•
Imarisha Naivasha	•	•
Elsamere Trust	•	•
Environment and waste management community-based organizations	•	
Banda Livestock Self-help Group	•	
Lake Naivasha Disabled Environmental Group	•	•
Waste to Best Environmental Management Action Group	•	•
Kamere Environmental Self-help Group	•	•
Kwa Muhia Environmental Group	•	•
Citizens and user groups		
Informal waste recyclers at the Naivasha dump site	•	

The stakeholders include entities and individuals who are working in sanitation, waste management and resource recovery in one way or another across the public and private sectors as well as civil society. The variety of stakeholders working in areas around sanitation and waste management and interested in resource recovery provides a good basis for the establishment of cross-stakeholder collaborations to implement circular approaches in sanitation and waste management in Naivasha (Ddiba et al. 2020).

Readying vegetable waste for the biogas digester at Gorge Park Energy Farm, Naivasha. © DANIEL DDIBA

4. Organic waste and ongoing resource recovery activities

There are various organic waste resources available in Naivasha: faecal sludge, wastewater, the organic fraction of municipal solid waste, agricultural waste from commercial farms, and industrial process wastes from breweries and fishing activities. However, detailed information about quantities and the physical-chemical characteristics is available for only some of them. The following sections provide more detail about each of the organic waste resources for which sufficient information was obtained during the literature review, interviews and workshop.

4.1 Wastewater

4.1.1 Wastewater management in Naivasha

Part of Naivasha Sub-county has a sewer system that collects wastewater, including both blackwater and greywater. Some parts of the sewer network also collect stormwater. The Naivasha sewer network presently covers the Lakeview and Sokoni/Viwandani areas to the north-east of Lake Naivasha – where about 15% of Naivasha's population live – with a total length of 25.7 km (Duma 2019). There are ongoing discussions about expanding it to cover other areas (Naivasha Sub-county Citywide Sanitation Plan Committee 2018). The rest of Naivasha is largely served by on-site sanitation facilities. Wastewater produced from households with on-site sanitation is usually channelled to septic tanks with soak pits or discharged into open channels and surface water bodies.

The wastewater from the sewer network is channelled to the Naivasha Water and Sanitation Company (NAIVAWASCO) wastewater treatment plant. The treatment process at the plant involves primary treatment to remove solid waste via screens and grit-removal pits, aeration lagoons and clarifiers, and finally maturation ponds (Bohnert 2017).

Two end products are generated from the treatment plant: treated effluent, which is discharged into Lake Naivasha, and sewage sludge, which is thickened, dried on open drying beds and then auctioned off to farmers. The solid waste that is filtered out by the grit screens is disposed of at the sub-county's solid waste dump. Currently, the wastewater treatment plant is handling wastewater influent far beyond its intended capacity (Naivasha Sub-county Citywide Sanitation Plan Committee 2018) and hence the treatment efficiency is low. During rainy seasons, there is an influx of stormwater that increases the volume of wastewater received at the treatment site. The rainy season also delays the natural drying of the sludge, hence causing a backlog. The wastewater treatment plant receives up to 80 000 m^3 of wastewater per month, according to NAIVAWASCO. Table 3 shows the characteristics of wastewater received at the facility.

Besides the NAIVAWASCO wastewater treatment plant, two other entities were identified as operating treatment plants: the Enashipai Resort and Spa and the Wildfire Flowers farm. The former, a leisure and conference facility, is connected to neither the water supply grid nor the sewer network and has been operating an in-house wastewater treatment plant since 2010, with a major upgrade done in 2014. The plant consists of screens, aeration and sedimentation tanks (with a capacity of handling 40 m^3 of wastewater per day) and was constructed by a Nairobi-based company, Plumbing Systems, which also provides regular maintenance services. The wastewater from Wildfire Flowers is treated in a series of three treatment ponds before the effluent is channelled back to Lake Naivasha. The ponds handle approximately 400 m^3 of influent per day.

Table 3. Average values for influent wastewater at the NAIVAWASCO wastewater treatment plant (from routine tests carried out by NAIVAWASCO in February 2016^ and May 2018*)

Parameter	Units	Average values
pH		7.55*
Temperature	°C	21.4*
Chemical oxygen demand (COD)	mg/L	1993*
Biological oxygen demand (BOD)	mg/L	679*
Total dissolved solids (TDS)	mg/L	1082^
Phosphate (PO_4-P)	mg/L	300^
Ammonia	mg/L	395^

4.1.2 Resource recovery from wastewater

There is no formal scheme to recycle or recover resources from the effluent at the NAIVAWASCO wastewater treatment plant, and it is currently channelled to Lake Naivasha. However, as in many other countries (Bahri et al. 2009), some farmers divert the effluent to their farms for the purpose of informal irrigation. Despite efforts to raise awareness of the risks associated with this practice – as the effluent occasionally falls short of discharge standards (Bohnert 2017) – NAIVAWASCO has not been able to stop it. The Naivasha Golf Club has approached NAIVAWASCO to allow them to use treated effluent to irrigate golf courses in the town. These discussions are still ongoing, and no implementation has occurred so far.

The Enashipai Resort and Spa is a pioneer in the Naivasha area with regard to wastewater reuse. The treated effluent from Enashipai's in-house wastewater treatment plant is used to irrigate the extensive lawns around the resort. This reduces its demand for freshwater from the lake and an on-site borehole, which are its principal water sources.

4.2 Faecal sludge

4.2.1 Faecal sludge management in Naivasha

Approximately 84% of Naivasha's population is served by on-site sanitation systems, which include pit latrines and septic tanks. About 12% of the population has its faecal sludge collected by vacuum trucks and discharged at the NAIVAWASCO wastewater treatment plant. In other cases, when the pits are full they are abandoned and new latrines are set up (Bohnert 2017).

The faecal sludge discharged at the NAIVAWASCO plant is treated together with wastewater from the sewer network. This could be partly responsible for the inefficient treatment at the plant, as it was not designed to handle faecal sludge, which typically has higher contaminant loads compared to wastewater (Strande et al. 2018). According to NAIVAWASCO, about 400 to 450 vacuum truckloads of faecal sludge per month is discharged at the plant. Each truck has a capacity of 10 m^3, making an annual total of between 48 000 and 54 000 m^3 of faecal sludge discharged there. As the on-site systems of 72% of the population are never emptied, this suggests that far more faecal sludge is generated in Naivasha than is currently treated at the plant. Table 4 shows some physical and chemical characteristic of faecal sludge in Naivasha.

Table 4. Physical and chemical characteristics of faecal sludge from on-site sanitation facilities in Naivasha

Parameters	Units	Average values from residential pit latrines	Average values from residential septic tanks
pH	–	8.1	7.8
Temperature	°C	21.3	20.6
Total solids	g/l	12.8	7.5
Volatile solids	g/l	5.1	2.5
Total suspended solids	g/l	9.1	2.7
Volatile suspended solids	g/l	2.9	0.5
Total dissolved solids	g/l	3.7	4.8
Grit and sand content (by mass)	%	14.7	2.3
Settleable solids	ml/l	180.8	34.7
Fats, oils and grease	ppm	0.1	0.2
E. coli	CFU/ml	6.77×10^4	1.08×10^7
Biological oxygen demand	ppm		1000.0*
Chemical oxygen demand	ppm		2233.3*
Total nitrogen	ppm		308.3*
Total phosphorus	ppm		40.0*

Note: CFU = colony forming units
Source: Values taken from waste characterization studies by Sanivation (2018) or (*) derived from Sanivation (2017). SeeTables A1–A3 in the appendix for details.

4.2.2 Resource recovery from faecal sludge

Since the faecal sludge discharged at the NAIVAWASCO wastewater treatment plant is co-treated with wastewater, nutrients are recovered from it to some extent – through the reuse of dried sludge as well as the informal irrigation by farmers along the effluent pipeline. Examples of other initiatives for resource recovery from faecal sludge in Naivasha over the past decade are discussed below.

Water and Sanitation for the Urban Poor (WSUP), a charity headquartered in the United Kingdom with operations in Kenya, developed a decentralized partial-treatment facility for faecal sludge in the Kasarani neighbourhood on the north-west side of Lake Naivasha. The design of the facility is akin to an anaerobic baffled reactor with five chambers, the first holding settled sludge and the rest performing secondary treatment of the effluent. The effluent from the facility is used by the nearby community for irrigation of gardens and lawns. Since the sludge in the first chamber is periodically emptied and transferred to the NAIVAWASCO wastewater treatment plant, the facility therefore also acts as a faecal sludge transfer station. The facility is now owned by the Nakuru County government but run by a local entrepreneur as a social business.

The Kenya Water Sector Trust Fund (WSTF) and international donors funded the construction of a public toilet block near the Naivasha Bus Park as an ecological sanitation demonstration project and it has been in operation since 2008. The facility includes a water kiosk, public toilets, urinals, handwashing basins and showers. The excreta and wastewater from the entire facility are directed into an underground biogas digester. The resulting biogas is used for cooking in an adjacent restaurant, which serves food and beverages to passengers and other visitors. The digestate from the facility is drained into the public sewer network through a nearby connection. The facility's day-to-day management is handled by the Banda Livestock Self-help Group, a community-based organization sub-contracted by NAIVAWASCO. The group also operates the restaurant. An extensive description of this facility, the stakeholders involved in its inception and operation and the factors for its success are provided by Rieck and Onyango (2010).

Sanivation, a social enterprise, has been operating container-based sanitation services in Naivasha in the areas around Karagita, Sanctuary Farm and Mirera since 2013. The container-based toilets are urine-diverting dry toilets (UDDTs) in which the urine and faeces are collected in separate containers. By the end of 2019, about 130 container toilets had been installed in the areas served by Sanivation. Twice a week the excreta is collected by Sanivation and transported to a factory at Sanctuary Farm, where the faeces is mixed with other biomass such as char dust and agricultural residues and turned into carbonized briquettes, marketed as super balls. The urine is drained into a soak pit. As of February 2020, Sanivation had sold over 1600 tonnes of briquettes to a variety of clients including households, restaurants, supermarkets and poultry farms, all of which use them as fuel for cooking and heating.

In November 2018, Sanivation launched another factory in partnership with NAIVAWASCO that produces non-carbonized briquettes marketed as Super Logs. These are made from a mixture of faecal sludge and other biomass like sawdust, with the faecal sludge acting as a binder. Just like the carbonized briquettes, the super logs are also used for energy, though they are best suited for industrial and commercial applications. The factory presently has the capacity to process 100 tonnes of faecal sludge per month.

4.3 Municipal solid waste

4.3.1 Municipal solid waste management in Naivasha

Municipal solid waste in Naivasha is generated in residential areas, urban commercial areas, and public markets. This waste is not separated at source since there is no formal waste-separation system. Since 2016, solid waste collection in the wider Naivasha Sub-county is done by private waste-management companies that have tenders from the Nakuru County government, while collection in the central business district of Naivasha is done by the sub-county environment office using its two waste-collection trucks. The sub-county trucks are supposed to collect twice a week. However, breakdowns and lack of fuel have meant this is not always done. Businesses in the central business district can contract private waste-collection companies. The waste-collection companies contracted by the county and their awarded areas of coverage are listed in Table 5.

Table 5. List of private waste-collection companies and their awarded areas of coverage, as of September 2018

Contracted waste management companies	Assigned service area
Wiper Sanitary Disposers	Zone 1 (Industrial area, Hope Well and City Council site)
Hanseligwa Enterprises	Zone 2 (Kabati to Guest Inn – Upper and Lower)
Hadassah Digital Women Group	Zone 3 (Lakeview, Suberico and Kihoto)
Flying Eagles Youth Group	Zone 4 (Karagita Estate, Kamere, Kwa Muhia, Kongoni, Moi Dhabi and Maiella)
Bidii Yetu Enterprises	Zone 5 (Kayole, MaryLand Mall, Kinamba to NYS, Kinungu and Ihindu)
Taka Ventures	Zone 6 (Mai Mahiu and Longonot)

Source: Naivasha Sub-county Citywide Sanitation Plan Committee (2018).

The contracted private waste collection companies are often unable to cover their entire service areas due to an insufficient number of collection trucks, lack of cooperation from households, and hostility in some areas from previously organized community-based waste-collection groups (see below). The companies are supposed to be paid collection fees from households, and the Naivasha Sub-county environment office provides guidelines for a payment scheme according to household size and income. However, these are not enforced and there are no clear incentives for households to pay. Some households, especially those on individually owned land, opt to manage their own solid waste by burying or burning it, or using the organic fraction for composting or feeding livestock.

Before the introduction of the current tendering system in 2016, solid waste collection in most areas in Naivasha was done by community-based organizations and self-help groups. These groups raised some small amounts of revenue from the households they served and used the money to develop other collective income-generating activities, such as urban vegetable growing and livestock rearing. The appearance of private waste-collection companies resulted in conflict with these community-based groups, since the latter's' source of livelihood was now threatened.

The community-based groups have also complained of a lack of transparency in the tendering process, since they were not consulted prior to introduction of the new system. Moreover, they were unable to meet the stringent tender requirements and hence could not bid against the private firms. Consequently, some of these groups have refused to relinquish their former areas of operation and sought to keep the waste-collection companies out. The sub-county environment office has tried to solve these conflicts amicably, but in some of areas there is still a stalemate, which is the subject of an ongoing court case (Mbogo Mututho v. Nakuru County Government 2018) and the companies have been forced to exclude the contested areas from their operations.

There is only one official solid waste disposal site in Naivasha Sub-county, which is an open dump situated in the Karai Estate in the Kayole area. The dump is on 10 acres of open land and lacks basic infrastructure such as a fence, a gate, a weighbridge and a checkpoint. The dump is managed by two sub-county officials who report to the sub-county environment officer. Their main role is to record the details of the trucks that come in to dispose of waste and the estimated amount of waste from each truck, and to guide trucks to the best spot for dumping. Occasionally, a bulldozer operated by the sub-county compresses the waste to create more space.

Anecdotal evidence from staff at the dump indicates that the quantities of waste vary seasonally, increasing during holiday periods, such as December, and the harvest season. However, there are uncertainties about the amount of solid waste generated and collected in Naivasha and no rigorous studies have been done to date to generate reliable data. Dittmann et al. (2016) quote an estimate of 70 tonnes of solid waste delivered to the Naivasha dump site daily, hence 25 550 tonnes/year. Mott MacDonald (2017) estimates it to be 15 tonnes per day, hence approximately 5500 tonnes/year. Records from the sub-county environment office, based on counting trucks and guessing their tonnage, indicate that 11 650 tonnes of solid waste were disposed of at the Karai dump site in 2017 (Naivasha Sub-county Citywide Sanitation Plan Committee 2018).

With regard to waste generation, an often-cited estimate is from a feasibility study report for the World Bank-funded Nakuru County Integrated Solid Waste Management project (Mott MacDonald 2017). It states that 21 052 tonnes of solid waste were generated in Naivasha annually as of 2017. The report acknowledges that this estimate is based on conjecture, since it was calculated using Kenya-wide per capita annual waste generation data from Hoornweg and Bhada-Tata (Hoornweg and Bhada-Tata 2012), which in turn cites estimates made by the Kenyan Ministry of Environment as far back as 2002. The wide variation between these estimates illustrates the need for a rigorous study of waste generation and collection in Naivasha, especially considering the projected rapid growth of Naivasha's population.

When it comes to solid waste characterization, a sampling and analysis exercise was done across 15 zones within Nakuru County over eight days as part of the feasibility study by Mott MacDonald (2017). The study indicated that in residential areas, the solid waste mainly consists of biodegradable materials with organic food waste accounting for 57%. Solid waste from public market areas consisted of 97% food waste, while other commercial areas had 39% food waste. The inorganic fraction of solid waste consists of mainly plastics, glass, ferrous and non-ferrous materials, and other combustibles. Beyond this description of waste fractions across Nakuru

County, no other study has been done yet to characterize the physical and chemical quality of solid waste in Naivasha, let alone the entire Nakuru County.

4.3.2 Resource recovery from solid waste

In Naivasha, there are two main forms of resource recovery from the organic fraction of municipal solid waste: direct feeding to animals and composting. Hotels, large factories, restaurants and other commercial and institutional establishments that generate significant quantities of food waste often separate it from the inorganic fraction. The food waste is then collected regularly by livestock farmers, especially pig and poultry farmers, who use it as feed. Examples of where this is practised include Enashipai Resort and Spa and the Naivasha Maximum Security Prison.

A few community-based organizations operate composting activities using the organic fraction of solid waste. Among the most prominent examples of this are the Kwa Muhia Environmental Group (KMEG) and Waste to Best Environmental Management Action Group (Waste to Best). KMEG started operations in 2011 in the Kwa Muhia settlement, south-west of Lake Naivasha. They collect solid waste from over 1000 households in the area and sort it into organic and inorganic fractions. Waste wine bottles are cut and transformed into dining glasses, while plastic waste are transformed into pavement blocks. The organic waste is treated through composting and vermicomposting in collaboration with Dudutech,[4] a local agriculture technology company.

The leachate from the composting process was further treated and was characterized and certified in collaboration with researchers at Kenyatta University.[5] Both the compost and treated leachate were sold and used as fertilizers by farmers in nearby areas. The group's composting facility was established with funding from Imarisha Naivasha.[6] As a result of the introduction of tenders for solid waste collection by private companies in Naivasha, the group's activities have stalled in recent months. However, at the time of our study it was in dialogue with Flying Eagles Youth Group, the solid waste collection company responsible for Zone 4, about collaborating on waste sorting so that KMEG can resume composting of the organic fraction of the waste. KMEG is also collaborating with WasteAid UK to set up a community recycling centre in the area (Lenkiewicz 2019).

Waste to Best has been operating in the Guest Inn Estate of Naivasha since 2006. This is the same area that the Hanseligwa Enterprises waste-collection company is responsible for (Zone 2). The group started out doing street cleaning and then got involved in solid waste management after realizing that there were no waste-handling services provided in its area. The group has about 15 members and operates a waste-sorting and composting facility along the Nairobi-Nakuru highway. It collects waste weekly from 250 plots with about 2500 households in the estate area and transports it on donkey carts to its sorting facility. Some of the organic fraction of the waste is fed to the group's chicken and sheep, while the rest is composted. The compost is used on urban vegetable and fruit tree gardens operated by the group. The team leader of Waste to Best, James Kagwe, is very knowledgeable about waste management and composting technologies and is often invited to trainings on waste management and recycling with other community-based groups. He is also active in a network of waste-related community-based organizations in Naivasha called the Naivasha Green Grassroots Waste Management (NAGAWAM).

Municipal solid waste in Naivasha contains significant amounts of cardboard, textiles, glass, plastic, metal and other inorganic waste fractions. Since there are no recycling facilities in Naivasha, these fractions are often collected and sold to middlemen who then transport them to Nairobi where recycling companies transform them into new materials. Since solid waste in Naivasha is generally not separated at source the staff of waste-collection companies sometimes pick out recyclable materials to sell. Otherwise, all the sorting is done at the dump site by informal groups of waste pickers by informal waste pickers whose livelihood comes from selling recyclable materials to middlemen.

4 See https://www.dudutech.com/our-company/about-us/
5 See http://www.ku.ac.ke/
6 See https://imarishanaivasha.wordpress.com/

In the past, there were tensions between waste pickers competing for access to areas of the dump site with potentially high-value recyclable waste. The sub-county environment department has recently tried to resolve the issue by mediating among these conflicting groups. The groups were ordered to form a community association, Kazi ya Mikono. As of May 2019, anyone who wishes to pick recyclable materials at the dump site is required to join the association. They are also required to use protective equipment such as overalls and gloves. The group collects small sums from its membership that is used to purchase protective equipment and to support members financially in times of need.

4.4 Resource recovery from agricultural and industrial processing waste

As mentioned, Naivasha has a large horticulture and floriculture industry. The sub-county also has many subsistence farmers who grow a wide range of food crops. These agricultural activities generate significant quantities of residues. According to the sub-county agricultural office, many farmers practise composting on a small scale but some simply burn the crop residues.

There are over 40 commercial-scale flower and vegetable farms in Naivasha, ranging in size from about 3 to over 700 hectares. There are far more flower than vegetable farms, and some mixed farms. The majority of the produce from these farms is exported to Europe. The harvesting and packaging processes for both vegetables and flowers generates significant amounts of residues on the farms. Almost all farms compost these residues and spread the compost on their land, reducing their need for chemical fertilizers. Most of the certification and audit systems that apply to the farms – e.g. FairTrade[7] and Global Good Agricultural Practices (GlobalGAP)[8] – assess waste-management practices, giving farmers an extra incentive to continue with composting.

Besides composting, some agriculture residues in Naivasha are converted into energy. One commercial flower and vegetable grower, the VP Group,[9] launched a biogas plant in 2017 at the Gorge Farm Energy Park. About 5000 m^3 of biogas is generated daily at the facility and is turned into electricity and heat through gas turbines in a combined heat and power process (Owen and Ripken 2017). The digestate is separated into liquid and solid fractions and these are returned to the farm as fertilizer and soil conditioner. The solid fraction is estimated to amount to 35 000 tonnes annually (Kamadi 2017). Part of the electricity generated is used at Gorge Farm while the rest is sold to the national grid at US$ 0.10/kWh, as per an existing power-purchase agreement. The heat is partly used in the digesters and the rest is used to warm the greenhouses on the farm. The facility is owned jointly by Tropical Power Energy Group[10] and the VP Group through a subsidiary called BioJoule,[11] which is registered as an independent power producer in Kenya. The facility cost about US$ 6.9 million and has an installed capacity of 2.3 MW (Owen and Ripken 2017).

The facility has the capacity to process up to 120 tonnes of biomass per day but presently handles about half that amount, mainly residues from vegetables such as baby corn, maize stalks and cobs, broccoli, carrot and onion. This is due to constraints in the vegetable production output on the farm. Based on these figures, the facility processes an estimated 21 900 tonnes of biomass annually. There are plans for the facility to start processing flower residues as well, to make up the shortfall in vegetable biomass, even though flower waste has a lower biomethane potential than the vegetables currently processed. Project engineers at the facility estimated that about 40 000 tonnes of flower and vegetable residues are available in Naivasha daily – about 14.6 million tonnes annually. However, there are no other commercial farms that have plans to establish biogas-generating facilities. This is probably due to the relatively large capital costs involved.

7 See https://www.fairtrade.net/about/certification
8 See https://www.globalgap.org/uk_en/what-we-do/globalg.a.p.-certification/globalg.a.p./
9 See https://www.vegpro-group.com/home.htm
10 See http://www.tropicalpower.com/
11 See http://www.tropicalpower.com/what-we-do/biojoule/

There is a well-equipped laboratory at the Gorge Farm premises and both the feedstock and the outputs from the digesters are monitored frequently for quality control. With regard to feedstock quality, broccoli and maize residues are reported to have a dry matter content of 9% and 24% and a volatile solids content of 80% and 95%, respectively (Owen and Ripken 2017). The biomethane potential of the flower waste at the farm is reported to be 180–210 m^3/tonne of dry matter, while that for baby corn residues is reported as 280–290 m^3/tonne of dry matter. The liquid part of the digestate is reported to contain 5mg/l of nitrogen and apparently enables the farm to spend 30% less on fertilizers than it did before the biogas facility was established (Owen and Ripken 2017).

Besides commercial farms that produce and package flowers and vegetables, Naivasha is also home to Keroche Breweries,[12] one of Kenya's first indigenous commercial breweries. The company makes a range of beers, wines and spirits which are sold on the local Kenyan market and largely produces from locally sourced ingredients like sorghum and barley. Like most breweries, Keroche generates waste streams like spent grain and wastewater. The wastewater from Keroche is directed into the NAIVAWASCO sewer network, while the spent grain is distributed to farmers who use it as animal feed or as soil conditioner after composting. The use of brewers' spent grain as animal feed is common in Kenya (Manyara 2018).

4.5 Resource recovery from livestock manure and slaughterhouse waste

Livestock rearing is a key economic activity in Naivasha, including dairy and beef cattle, sheep, goats, rabbits and poultry. The scale of activity ranges from large cattle ranches to a few animals kept by individual households.

According to the sub-county agricultural office, the manure from livestock production is often applied to cropland. There is no data on the extent to which manure is used in Naivasha, since there is no centralized manure-collection scheme and farming is spread out. However, based on observation of farm practices in Naivasha, small-scale livestock farms often use their manure on crops on site, while herds in ranches graze on large areas of pasture, and hence the manure is spread across the entire area where it contributes to pasture growth.

Naivasha has a number of private slaughterhouses, one of which is run by the county government. The sub-county is home to one of the only two donkey slaughterhouses in Kenya. However, the donkey slaughterhouse in Naivasha has been closed for renovation since August 2019 due to public health concerns raised by the neighbouring community.

The public slaughterhouse receives livestock from Naivasha and also from the neighbouring Narok County. On average, about 10 head of cattle and 8 sheep and goats are slaughtered at the facility each day. The private slaughterhouses are smaller establishments and slaughter much fewer animals depending on the daily market demand. The number of animals slaughtered also varies with the season. During holiday periods and religious festivals, meat consumption generally increases and consequently the waste generated from the slaughterhouses also increases.

Slaughterhouse waste streams include blood, ingesta, wastewater from washing up, hooves, bones, horns, hides and skins. The public slaughterhouse, which was visited during the course of this study, does not keep records of waste amounts. Likewise, there are no records of the physical and chemical characteristics of these waste streams. Staff at the facility, however, estimated daily waste production at 400 litres of blood, 60 kg of ingesta, 200 kg of hides and skins and about 80 animal hooves. The annual equivalents of these estimates

12 See https://www.kerochebreweries.com/

are laid out in Table 6. No estimate was given of the wastewater quantities going into the NAIVAWASCO sewer network.

The blood is collected in a tank, periodically drained by vacuum trucks and transported to the NAIVAWASCO wastewater treatment plant. The ingesta are collected and dried in beds around the slaughterhouse, after which it is given to farmers in the nearby community who use it as soil conditioner on their gardens. The hides and skins are sold for leather production, and the hooves are also sold to interested clients in the sub-county. The bones are sold to dog food manufacturers.

Table 6. Estimated annual quantities of waste streams generated at the Naivasha public slaughterhouse

Waste stream	Approximate annual quantities
Blood	150 m^3
Ingesta	20 tonnes
Hides and skins	70 tonnes
Hooves	29 200 hooves

4.6 Overview of quantities of available organic waste streams

From the descriptions above, it can be seen that there is a variety of organic waste streams available in Naivasha. Each stream is currently being managed in different ways, some with treatment and resource recovery while others have not been explored to the same extent. An overview of the quantities of various waste streams described in the above sections is provided in Table 7. The values shown in the table come from both literature and interviews and hence have varying levels of accuracy and precision.

Table 7. Summary of the estimates of annual quantities of various organic waste streams in Naivasha

Waste stream	Annual quantity
Wastewater influent to NAIVAWASCO treatment plant	960 000 m^3
Wastewater generated and managed in house by Enashipai Spa and Resort	14 600 m^3
Wastewater generated and managed in house by Wildfire Flowers	146 000 m^3
Faecal sludge influent to NAIVAWASCO treatment plant	48 000–54 000 m^3
Solid waste delivered to the Naivasha dump site, of which the organic fraction is 39% to 97%	5 500–25 200 t
Vegetable residues processed at the Gorge Farm Energy Park	21 900 t
Available residues from flower and vegetable farms	14 600 000 t

5. Market demand for resource recovery products

Going by the examples of initiatives described in section 4, it is clear that resource recovery from organic waste streams is not a new thing in Naivasha. Several stakeholders seem to realize the potential benefits of recovering resources from waste and are therefore participating as producers or users of resource-recovery products.

From our literature review, field observations, interviews and proceedings of the stakeholder workshop, there is interest in the resource-recovery products listed in Table 8 in Naivasha. Each of these products is currently being produced in Naivasha or stakeholders expressed interest in it. Some of the existing initiatives in Naivasha have gained traction in the market with a significant client base for their products, as discussed below.

Sanivation's solid fuel products are sold under two main brands: super balls, which are the carbonized briquettes, and super logs, which are made of combined faecal sludge and sawdust. The super balls are sold to households, hotels and restaurants for cooking. They are also distributed via grocery stores. They are packaged in 4 kg bags, which are sold at 250 KES (approximately US$2.5), 25 kg bags at 700 KES (US$7) and 50 kg bags at 1500 KES (US$15). The super logs are sold to large commercial users, who use them in boilers and furnaces to power industrial processes. A tonne of super logs is sold at 15 000 KES (US$150).

While no one has engaged in packaging compost as an organic fertilizer for sale at large scale, there are examples of organic fertilizers based on resource recovery from waste elsewhere in Kenya. Sanergy, a social enterprise in Nairobi, makes fertilizer from composted faecal sludge and other organic municipal solid waste, which is marketed and distributed through a subsidiary to farmers as Evergrow Organic Fertilizer.[13] The fertilizer is sold at approximately US$400 per tonne (World Bank 2019).

Table 8. Resource-recovery products of interest in Naivasha and their uses

Resource	Product and use format
Energy	Biogas for cooking, lighting and heating
Energy	Biogas for combined heat and power
Energy	Briquettes and pellets for cooking and heating
Feed	Pet food from slaughterhouse waste such as bones
Feed	Animal protein feed from worms and fly larvae
Feed	Animal protein feed from brewery spent grain
Nutrients	Soil conditioner from dried faecal sludge and sewage sludge
Nutrients	Compost from organic municipal solid waste
Nutrients	Soil conditioner from dried digestate
Nutrients	Liquid fertilizer from digestate
Nutrients	Liquid fertilizer from compost leachate
Water and nutrients	Treated wastewater effluent for irrigation

It is not clear whether farmers pay for the spent grain from Keroche Breweries. However, in other areas in Kenya where there are breweries, the spent grain and other kinds of organic waste from the brewing process are sold to farmers at a price of 5 KES (US$0.05) per kg (Manyara 2018; Ndayala 2019). Farmers who use black soldier fly larvae as animal feed pay about 40 KES (US$0.4) per kg (Mugo 2018).

13 See http://farmstar.co.ke/

The electricity that is generated from biogas at the BioJoule Gorge Farm facility is sold partly to the national grid at a price of US$0.10/kWh. This is in line with the government's feed-in tariffs policy for renewable energy projects below 10 MW capacity (Ministry of Energy 2012). However, the specified tariff for biogas and biomass power installations is less than that for solar and wind. The BioJoule facility reportedly sells electricity to the farm under a private arrangement, at a higher tariff.

Besides the resource-recovery products from organic waste streams, there is also a thriving market for recyclable materials in Naivasha. The Kazi ya Mikono waste-pickers group sells recyclable polythene (from bags) at 10 KES (US$0.1) per kg; plastics and PET bottles at 5 KES (US$0.05) per kg; cardboard (from boxes) at 5 KES (US$0.05) per kg; glass at 1.8 KES (US$0.018) per kg; and scrap metal at 10 KES (US$0.1) per kg. According to members of the group, the brokers and middlemen to whom they sell these materials sell them on to recycling companies at double or triple the above prices.

The above examples are illustrative of existing markets for reuse products; they do not fully reflect the potential demand. It is also worth considering that the existing initiatives are at different levels of maturity and operate at different scales. A more detailed market demand study is needed to better understand the market potential and attractiveness of various resource-recovery products, as well as the nuances of customer preferences.

6. Conclusions

Across the globe, there is increasing interest in circular economy approaches to the management of waste in cities. This trend is motivated by the needs to get rid of growing amounts of waste and to conserve natural resources, while also contributing to water, food and energy security.

The inventory presented in this report shows that there is a foundation for scaling up circular economy approaches in Naivasha. Significant amounts of a wide range of organic waste streams are available, and as well as local knowledge and experience from the existing resource-recovery initiatives. Efforts will have to be made, however, to better coordinate the various stakeholders involved in the waste service chain so as to foster collaboration rather than conflict.

A major challenge in the production of this inventory was gaps and weaknesses in the data available on the various aspects of the sanitation and waste service chain in Naivasha. Reliable data on the quantities and characteristics of some waste streams was hard to find, simply because no previous studies had addressed those waste streams.

Moreover, there seems to be no plan by the sub-county authorities to put in place systems that routinely gather and archive data on the management of organic waste streams. This gap needs to be addressed. The sub-county authorities could partner with local stakeholders like Egerton University and the Rift Valley Institute of Science and Technology to carry out routine waste quantification and characterization studies.

Other areas for further work include detailed studies to assess the potential markets for different resource recovery products, and the needs and preferences for various products in different localities and stakeholder segments in Naivasha. It is also necessary to assess the viability of introducing source-separation schemes for municipal solid waste, since sorting waste at the source can significantly increase the value of organic waste streams and thereby enable the generation of higher-value products.

Of course, the challenges and gaps identified are not necessarily unique to Naivasha. It is the ambition of SEI’s UrbanCircle project that by addressing some of these gaps in the context of Naivasha and showcasing how to set the stage for circular economy implementation, useful insights can be drawn for other towns and cities in Kenya and elsewhere in the world that aspire to recover resources from their organic waste streams.

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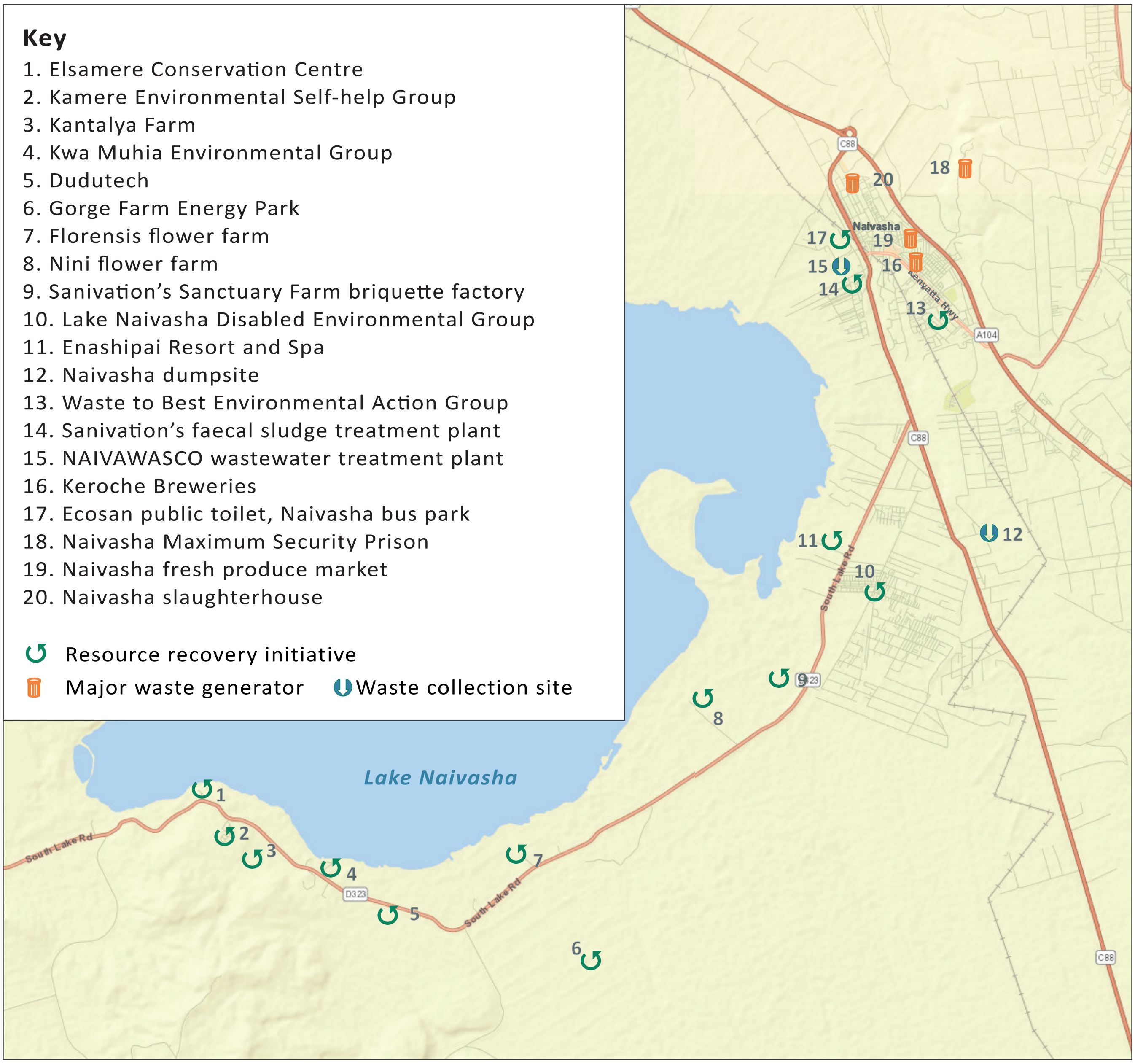
Appendix

A map of the east side of Lake Naivasha, the most urbanized part of the sub-county, showing the resource-recovery initiatives, waste streams, and waste collection centres



Source: Base map from National Geographic MapMaker Interactive (https://mapmaker.nationalgeographic.org/)

Table A1. Chemical and microbiological test results for septic tank faecal sludge samples

Parameter	Units	Sample 3	Sample 4	Sample 5	Average
Biological oxygen demand	ppm	1600.0	600.0	800.0	1000.0
Chemical oxygen demand	ppm	4200.0	800.0	1700.0	2233.3
Total nitrogen	ppm	10.0	398.0	517.0	308.3
Total phosphorus	ppm	40.7	36.2	43.2	40.0

Source: Data derived from Table 2 in Sanivation (2017)

Table A2. Physical, chemical and microbiological test results for pit latrine faecal sludge samples

Parameter	Unit	Pit 3	Pit 5	Pit 6	Pit 7	Pit 8	Pit 9	Average
pH	-	7.9	8.2	8.2	8.3	8.3	7.8	8.1
Temperature	°C	21.9	22.4	25.3	17.7	17.1	23.2	21.3
Total solids	g/l	9.7	13.1	20.9	12.3	10.7	10.3	12.8
Volatile solids	g/l	4.1	7.2	5.5	4.5	5.0	4.0	5.1
Total suspended solids	g/l	4.8	12.1	16.2	8.0	10.0	3.7	9.1
Volatile suspended solids	g/l	1.9	1.6	1.1	1.4	9.0	2.5	2.9
Total dissolved solids	g/l	4.9	1.0	4.7	4.2	0.7	6.5	3.7
Total solids in dewatered FS	g/l	218.3	202.8	127.1	120.8	153.6	158.4	163.5
Grit and sand content	%	20.0	19.0	3.0	19.0	18.0	9.0	14.7
Settleable solids	ml/l	125.0	150.0	250.0	250.0	200.0	110.0	180.8
E. coli	CFU/ml	1.1×10^5	9.0×10^4	4.0×10^3	2.0×10^3	1.5×10^5	5.0×10^4	6.77×10^4
Fats, oils and grease	ppm	0.0	0.0	0.0	0.1	0.5	0.1	0.1

Source: Data derived from Table 3 in Sanivation (2017)

Table A3. Physical, chemical and microbiological test results for septic tank faecal sludge samples

Parameter	Unit	SPP 1	SPP 2	SPP 3	Average
pH	-	7.6	7.8	7.9	7.8
Temperature	°C	20.5	20.5	20.9	20.6
Total solids	g/l	8.0	7.7	6.8	7.5
Volatile solids	g/l	3.8	2.3	1.4	2.5
Total suspended solids	g/l	3.7	4.0	0.3	2.7
Volatile suspended solids	g/l	0.5	0.9	0.1	0.5
Total dissolved solids	g/l	4.3	3.7	6.5	4.8
Total solids in dewatered FS	g/l	102.0	856.0	932.0	630.0
Grit and sand content	%	2.0	2.0	3.0	2.3
Settleable solids	ml/l	15.0	27.0	62.0	34.7
E. coli	CFU/ml	4.10×10^5	7.00×10^6	2.50×10^7	1.08×10^7
Fats, oils and grease	ppm	0.0	0.4	0.1	0.2

Source: Data derived from Table 7 in Sanivation (2017)

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