COSTED FEASIBILITY MODELS AND ACTION PLAN FOR IMPLEMENTING COMPOSTING AND RECYCLING OPTIONS FOR PRIMARY WASTE COLLECTION IN MONROVIA, PAYNESVILLE, AND SURROUNDING TOWNSHIPS

FUNDED BY THE EUROPEAN UNION

Cities Alliance
Cities Without Slums

HOSTED BY UNOPS

This study was conducted within the context of implementation of the project "Delivering Climate Resilient Solid Waste Management Services in Greater Monrovia, Liberia through Community-Based Enterprises"

Title:
Costed Feasibility Models and Action Plan for Implementing Composting and Recycling Options for Primary Waste Collection in Monrovia, Paynesville, and Surrounding Townships

3.1 Feasibility Study

Cities Alliance – 2021

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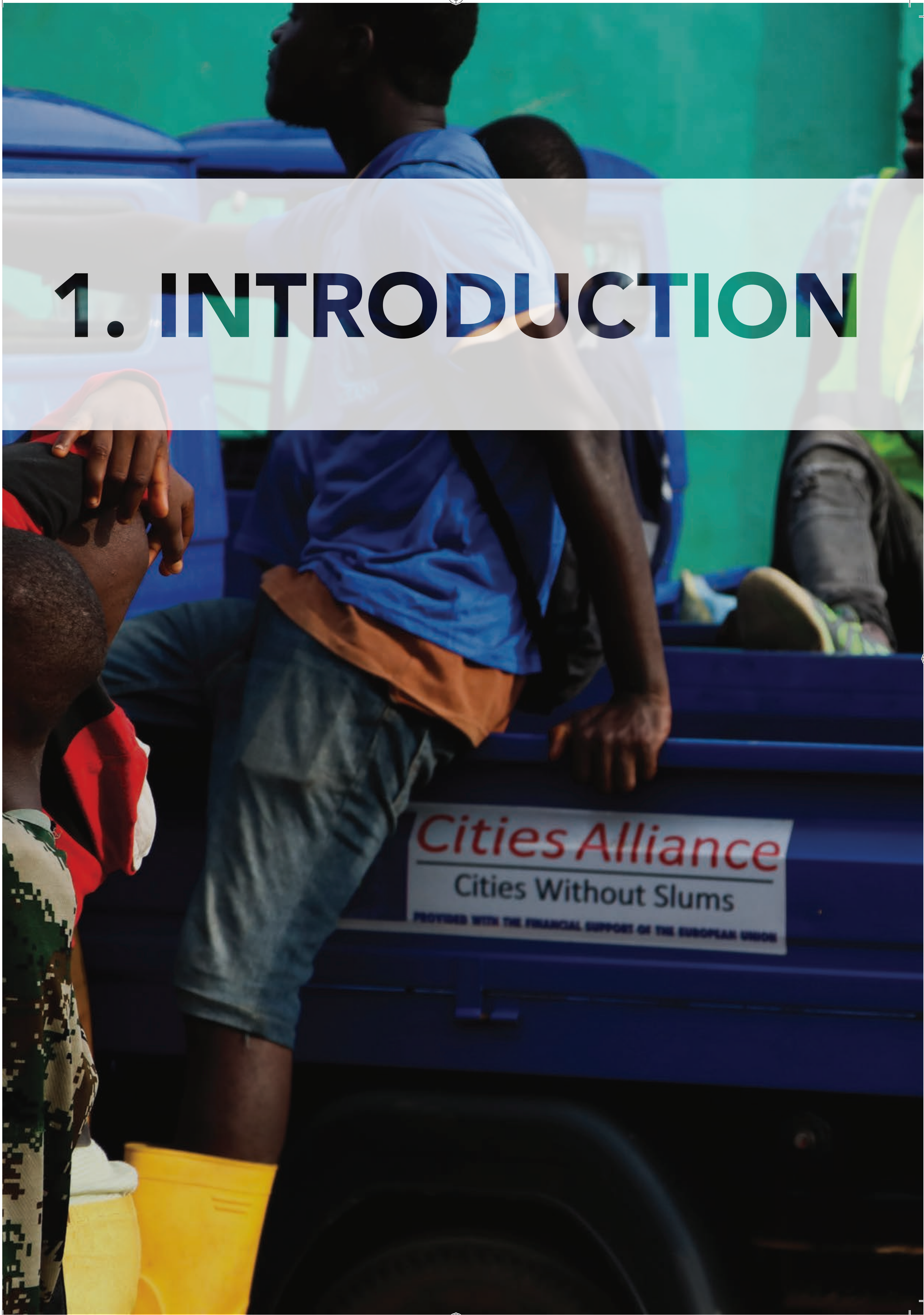
ACRONYMS

Acronym	Definition
CBE	Community Based Enterprise
CLUS	Cheesemanburg Landfill and Urban Sanitation
CMT	Community Management Team
EPA	Environment Protection Agency
EMUS	Emergency Monrovia Urban Sanitation Project
EU	European Union
FTE	Full Time Equivalent
GoL	Government of Liberia
ICEA	Ingénieurs Conseil & Economistes Associés
IMPAC	Improved Primary Solid Waste Collection in Poor Communities of Monrovia Project
LISGIS	Liberia Institute of Statistics and Geo-Information Services
LRTF	Liberia Reconstruction Trust Fund
MCC	Monrovia City Corporation
NDC	Nationally Disclosed Contribution
PCC	Paynesville City Corporation
SME	Small and medium enterprise
SWM	Solid Waste Management
UNOPS	United Nations Office for Project Services
UNDP	United Nations Development Program

1. INTRODUCTION



1.1 The Project

In March 2019 after an international tendering process, UNOPS/Cities Alliance selected ICEA, in partnership with Espelia, to carry out a study on "Costed Feasibility Models and Action Plan for Implementing Composting and Recycling Options for Primary Waste Collection in Monrovia, Paynesville and Surrounding Townships." A first field visit took place in April 2019, and in Inception Report was submitted on 6 May.

The study area covers Monrovia, Paynesville, and the surrounding townships known as **Greater Monrovia.** This area has no administrative existence, but comprises:

- **Two municipalities:** Monrovia City Corporation (MCC) and Paynesville City Corporation (PCC)
- **Twelve Townships:** Barnersville, Brewerville, Caldwell, Congo Town, Dixville, Gardnersville, Garwolon, Johnsonville, New Georgia, New Kru Town, Virginia, and West Point.

The Township of Cheesemanburg is the site of the proposed new Cheesemanburg landfill. With the existing Whein Town landfill reaching its capacity, the construction of a new landfill is planned under the Cheesemanburg Landfill and Urban Sanitation (CLUS) Project, a World Bank-operated project co-funded by the Liberia Reconstruction Trust Fund (LRTF) and the government of Liberia (GoL).

The study covers municipal solid waste, i.e. solid waste generated by households, administration, commercial and industrial activities. It does not include medical or hazardous waste that needs to be collected and treated separately.

Cities Alliance (hosted by UNOPS) is implementing EU-financed projects on Primary Waste Collection and Waste-to-Energy Alternatives for Greater Monrovia. These two projects aim to support Liberia's Nationally Disclosed Contribution (NDC) to the United Nations Framework Convention on Climate Change by improving the primary waste collection system as well as providing viable alternatives such as waste recycling, composting, and Waste-to-Energy alternatives.

These two projects seek to work directly with Community Based Enterprises (CBEs) to ensure that solid waste management in Liberia is viewed as a value chain from the household to the landfill site. This project builds on the experiences of the Improved Primary Waste Collection in Poor Communities (IMPAC) project – funded by the Bill and Melinda Gates Foundation – which established and trained CBEs and Community Management Teams (CMTs). The IMPAC project demonstrated that the CBE model is successful for primary solid waste collection and that it would benefit Monrovia, Paynesville, and surrounding townships in their mandate for waste collection.

In parallel to this study, two other studies have been carried out. Both are linked to the development of composting/recycling activities in SWM systems.

1. The *Action Plan for horizontal and vertical expansion of the Community Based Enterprise (CBE) system for Primary Waste Collection* aims to "develop a costed and financially viable Action Plan for the horizontal and vertical expansion of the CBE system, including an indicative budget for full horizontal expansion and vertical expansion into Composting and Recycling." It includes a market demand analysis for composting and recycling systems to "determine initiatives which could be implemented as pilot projects to diversify the economic model of the CBEs."
2. The *Feasibility Study on Waste-to-Energy Options* aims to develop a small pilot scheme based on dry anaerobic digestion, working with organic waste. To be successful in the long run, it will require a system for organic waste separation, most likely at source. One of the products from the system will be digestate, which can be used as composting material. The study develops concepts for organic waste separation as well as the market for, and potential value of, compost.

1.2 Context and Objectives

After the civil war, a simple but robust waste collection system was introduced in Monrovia and gradually improved. A sanitary landfill and two transfer stations were built, and the collection system was upgraded to cover a significant part of the municipal waste generated.

The Monrovia City Corporation and Paynesville City Corporation, which are responsible for solid waste service delivery as well as oversight and supervision, have been outsourcing different parts of the service to the private sector. Two collection contracts are in place with two private operators, and the sanitary landfill is operated by a third one. Pre-collection is undertaken by CBEs.

Identified as one of the highest priorities of the national and local governments, the municipal solid waste management system has also benefited from the strong support of international donors, with financing for several important projects: the World Bank's Emergency Monrovia Urban Sanitation Project (EMUS); Cities Alliance's Primary Waste Collection and Waste-to-Energy Alternatives for Greater Monrovia projects; and the Bill & Melinda Gates Foundation's Improved Primary Solid Waste Collection in Poor Communities of Monrovia Project (IMPAC).

It is clear that the CBE model is successful, and that the SWM system in Monrovia has emerged from the emergency phase. Continuous efforts are being made to expand the area served and reduce illegal dumping.

The challenge is now to offer durable solutions to improve SWM, including prolonging the longevity of the landfill, improving livelihoods, creating jobs, and generating internally alternative financial resources for stakeholders. The vertical expansion of the CBE system into composting, recycling, and reuse is the way to achieve these objectives.

1.3 The Feasibility Study

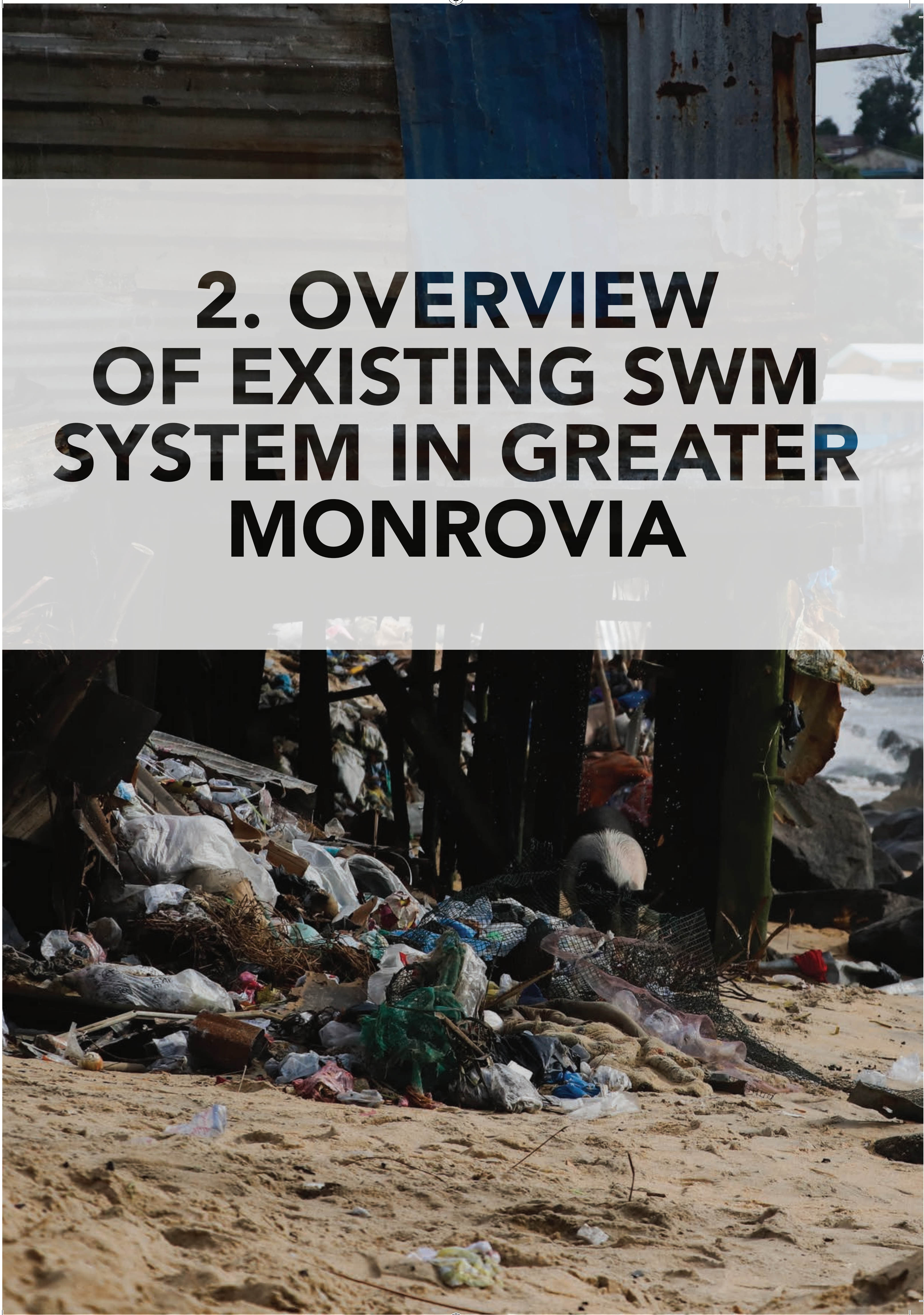
This Feasibility Study is the second report submitted within this study. Its overall objectives are to:

- **Examine the existing municipal SWM cycle and value chain** in Monrovia, Paynesville, and surrounding townships;
- **Identify entry points to create additional livelihoods and self-employment opportunities** (in particular targeting women and youth) through the processing of waste (e.g. recycling, reusing waste in products, composting, bio-gas production from waste, etc.).

It presents:

- **An overview of the existing SWM system in Greater Monrovia** (Chapter 2), its strategic, legal and regulatory framework and its organisation and recent evolution.
- **A diagnosis of the existing SW recovery and recycling value chains** (Chapter 3) based on an analysis of existing initiatives and an estimate of their development potential. Identified value chains are scored and ranked.
- **Recommendations and identification of priorities** (Chapter 4) in terms of waste collection organisation, recycling and composting processes, development strategy, and phasing and accompanying measures.
- **A cost analysis for developing each recommended value chain** (Chapter 5).
- **A global assessment of the two value chains to develop** (Chapter 6).

2. OVERVIEW OF EXISTING SWM SYSTEM IN GREATER MONROVIA



2.1 Legal and Regulatory Framework

This overview is an abstract from the report "Greater Monrovia Waste Management Baseline Study by Cities Alliance and Arup.

2.1.1 SWM POLICY AND LEGISLATION

The 1986 Constitution provides a constitutional basis for environmental law in Liberia, binding the state to adopt an active environmental policy and environmentally sustainable national development plans.

In 2003, three Acts were issued granting specific authority for waste management:

- An **act creating the Environment Protection Agency (EPA) of the Republic of Liberia.** This established the EPA as a national monitoring, coordinating, and supervisory authority for the sustainable management of the environment.
- An **act adopting the Environment Protection and Management Law.** This provides a legal framework for the EPA and specifies its role in national waste management as coordinator and monitoring body, setting policies and guidelines and outlining penalties for improper waste disposal.
- The **National Environmental Policy of the Republic of Liberia.** This includes a chapter dedicated to SWM and recommended policy measures, including establishing landfill sites for all urban areas and coordinating SWM activities, such as community involvement and sensitisation.

Over the past 15 years, however, overlapping jurisdictions across national and local organisations have contributed to preventing the long-term realisation of sustainable solutions. The responsibility of solid waste has from time to time been associated with Monrovia City Corporation. Many duties have been left to MCC, supported by investment in infrastructure and capacity building from international finance institutions.

In this context, several recent policy updates have been made in response to evolving needs and practices of SWM nationally and locally:

- **Lift Liberia, the Poverty Reduction Strategy for Liberia** (2008-2011). Post-conflict national development framework that includes mandated enactment of a national SWM policy, strategy and regulation.
- **Monrovia Letter of Sector Policy,** 2009. In the absence of national policy and reflecting the unique challenges of Monrovia, this policy establishes guiding principles for SWM in the capital including affordable service access; SWM cost recovery mechanisms for long-term financial sustainability; and environmentally conscious SWM. The policy also formalises the growing role of the private sector in MCC waste management since the end of civil war in 2002.
- **National Solid Waste Management Policy.** A draft was first created in 2015 by the Republic of Liberia and MCC in response to the need for strategic coherence nationwide in line with decentralisation of certain SWM responsibilities. A validated policy was presented in April 2017 but has yet to be formalised. With the 2009 MCC framework as a foundation,

> the draft policy sets out a national vision for safe collection, treatment, and disposal of solid waste. The draft policy outlines linkages between SWM and environmental, public health, economic, and gender-inclusive outcomes, underpinned by good local governance, public and private sector coordination, and technically sound, economically sustainable interventions.

The policy requires municipal corporations to be consistent with ten guiding principles:

1. Ensure that all people shall have access to appropriate solid waste management services at affordable cost and at all times.
2. Ensure that solid waste management is conducted in a transparent and accountable manner as an integral part of good governance.
3. Ensure that the solid waste management entities shall establish appropriate cost recovery mechanisms for long term financial sustainability.
4. Ensure solid waste management embraces public and private participation to obtain efficiency gains.
5. Ensure solid waste management is conducted in a gender-sensitive manner.
6. Encourage reduction of waste generation through reduction, recycling and reuse; control and regulate generation of waste materials.
7. Comply with national and international standards and regulatory instruments on hazardous SW.
8. Ensure that standards for occupational health and safety are instituted for all workplaces in keeping with national and international laws.
9. Ensure solid waste management is conducted in an environmentally friendly and sustainable manner to protect human health, natural resources, and the environment in general and global climate change.
10. Ensure accurate information and awareness is provided to the public in a timely, efficient manner.

In addition to providing greater coordination, nationwide direction, and coherence, the draft policy should also consider national service coverage and collection (which is currently low); a lack of public SWM awareness and education; and weak financial and resource capacity, which was compounded by the Ebola Virus Disease outbreak of 2014.

This review has not found any specific SWM laws beyond the 2003 legislation discussed above. The 2015 draft SWM policy states that a National Solid Waste Management Act shall be passed within three years of implementation of the policy. It also mentions the formulation of various bylaws. In addition, UNDP recommends that guidelines be developed for the disposal of waste from villages and rural communities.

2.1.2 OTHER RELEVANT POLICIES AND LEGISLATIONS

- **Public Health:** The Ministry of Health is mandated through its Environmental and Occupational Health division to conduct sanitation inspections and ensure compliance with the public health law.
- **Healthcare Waste:** Liberia lacks a legal framework for hazardous healthcare waste and the resource capacity to empower regulatory bodies to monitor and ensure compliance of healthcare waste management sectors.
- Liberia submitted its **contribution to the UN Framework Convention on Climate Change** in September 2015, as a platform to integrate its Low Carbon Development Strategy into the country's long-term vision for sustainable development by 2030. This highlights commitment to reduce greenhouse gas emissions in the energy and waste sectors. In this area, the government of Liberia commits to: 1) strengthening institutional and individual capacity for waste management; 2) developing waste infrastructure; 3) implementing and strengthening policy that promotes private investment in waste management; and 4) capturing methane emitted from landfills and used for vehicles, cooking or power.

2.1.3 ROLES AND RESPONSIBILITIES OF SWM ACTORS

Monrovia City Corporation and **Paynesville City Corporation** have a mandate from the national Ministry of Internal Affairs to collect and dispose of solid waste within the Monrovia and Paynesville city limits. Beyond household and business collection, this responsibility extends to enforcing ordinances which regulate residential SWM practices, as well as education and awareness initiatives. They are also responsible for the maintenance of public areas, including streets and sidewalks. MCC has arrangements with some Township Commissions to collect the solid waste under their jurisdiction.

MCC and PCC are also responsible for regulating the private sector activities in the SWM system. Both CBEs and SMEs operate under their jurisdiction. This responsibility includes issuing licenses and assigning operating zones.

At the point of collection, MCC has 25 contracts with local CBEs who collect waste door-to-door from households and small businesses, according to NACOBE. This is a lease model that registers and licenses CBEs to provide primary solid waste collection for a defined area (zone). CBEs are required to pay a fee to MCC the right to collect solid waste.

Paynesville has five CBEs currently registered with the PCC Solid Waste Management Department. The municipality states that CBEs currently have limited technical capacity to reach far into the city.

Private Sector: As formalised in the 2009 policy, over the past decade large businesses have relied on contracts with private sector suppliers, such as SMEs, who collect and transfer waste directly from large established businesses/institutions to the Whein Town landfill. Since 2016, secondary transfer from transfer stations to the Whein Town landfill has been taken over by MCC via long-haul contractors, a suggestion of the EU. World Bank analysis suggests that during recent programmes, some contractors have had failings, leading to MCC backstopping and taking over certain waste transfer.

Community dwellers, households and businesses generate the waste and pay a voluntary fee to garbage collectors and garbage tax to the municipalities.

Non-Governmental Organisations (NGOs) and the donor community have been (and remain) very active in support of developing SW activities and providing funding through various projects and programmes.

Township Commissions are local government representatives under the Ministry of Internal Affairs (MIA), and they are also actors in SWM.

2.2 SWM Organisation and Main Actors

2.2.1 THE "EMERGENCY" PERIOD

After the civil war ended, a massive clean-up of the city took place, and a simple collection system was introduced in Monrovia that was gradually improved. A sanitary landfill in Whein Town and two transfer stations in Fiamah and Stockton Creek were built, and the collection system was upgraded to cover a significant part of the generated municipal waste.

The Monrovia City Corporation has been outsourcing different parts of the service to the private sector. Two collection contracts were signed with two private operators to collect waste at designated collection points and carry it to the transfer stations and the landfill. The sanitary landfill was operated by a third private operator. Pre-collection was undertaken as a business by CBEs who, after receiving training in business management, obtained concessions in some areas to collect garbage from households to designated collection points.

FIGURE 1: "Contractual" SWM system in Greater Monrovia

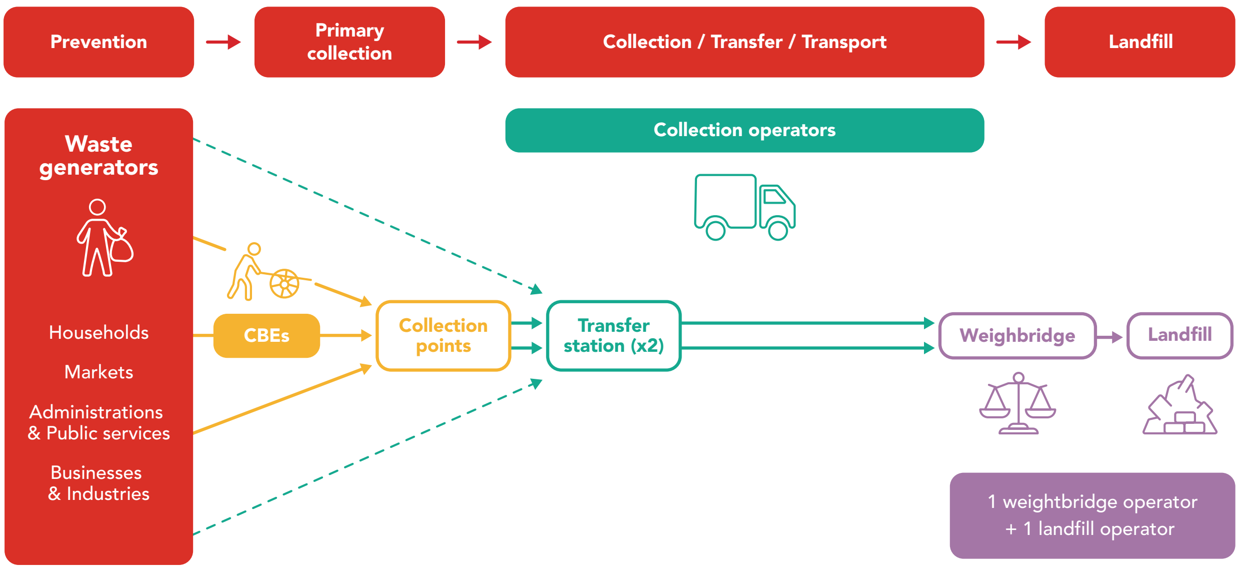
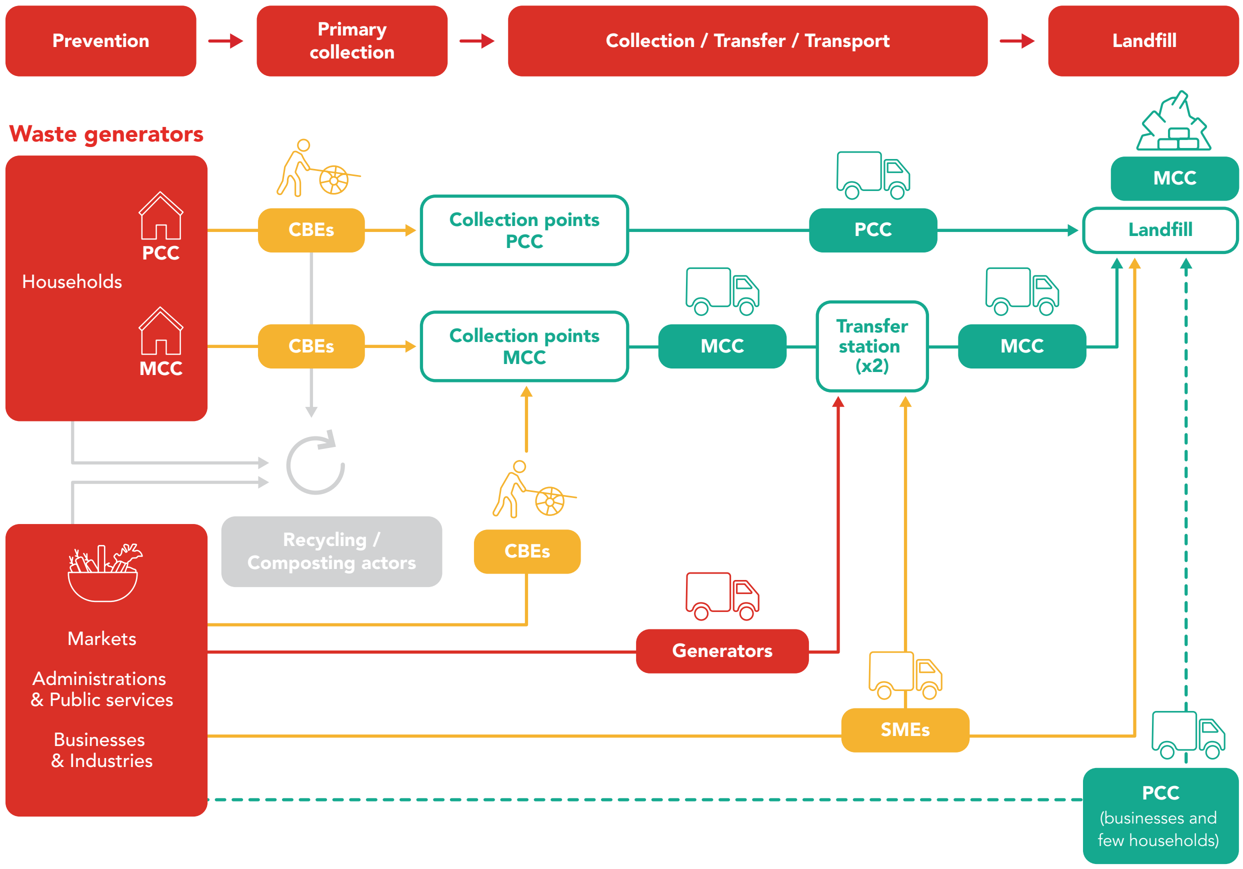


FIGURE 2: Current SWM System in Monrovia and Paynesville



The SWM system has benefited from the strong support of international donors for its financing. It emerged from the emergency phase with the development of SWM capacities within municipalities, including not only MCC, but also Paynesville City Corporation.

From zero households receiving garbage collection services in 2009, over 13,000 households were connected to regular primary waste collection and disposal by December 2016. In contrast, attempts to engage the private sector to manage the waste transfer stations and transport waste to the landfill were ultimately unsuccessful. The appointed contractors failed to achieve even 50% of their contractual obligations. This resulted in poor press coverage of the SWM sector and complaints to the city, national government, MCC, and the donor community in Liberia.

2.2.2 THE MUNICIPAL TAKEOVER

As a result, a pilot was started, with MCC and PCC staff using rented equipment to manage the transfer of waste from the city to the landfill. This pilot was successful, and responsibility for SWM was handed over to the MCC and PCC.

In parallel, a cadre of trained SWM technical staff within municipalities was developed that has carried out SWM (collection, transportation, and landfill operations) since December 2016. Citywide primary garbage collection is still developed as a business and handed to CBEs. They charge clients for services and pay yearly licensing fees to the MCC. Payment of a SW service fee is not mandatory, however, and SWM cost recovery remains difficult. A new phase aims to levy internally alternative financial resources and develop cost recovery.

2.2.3 THE PILOT PROJECT

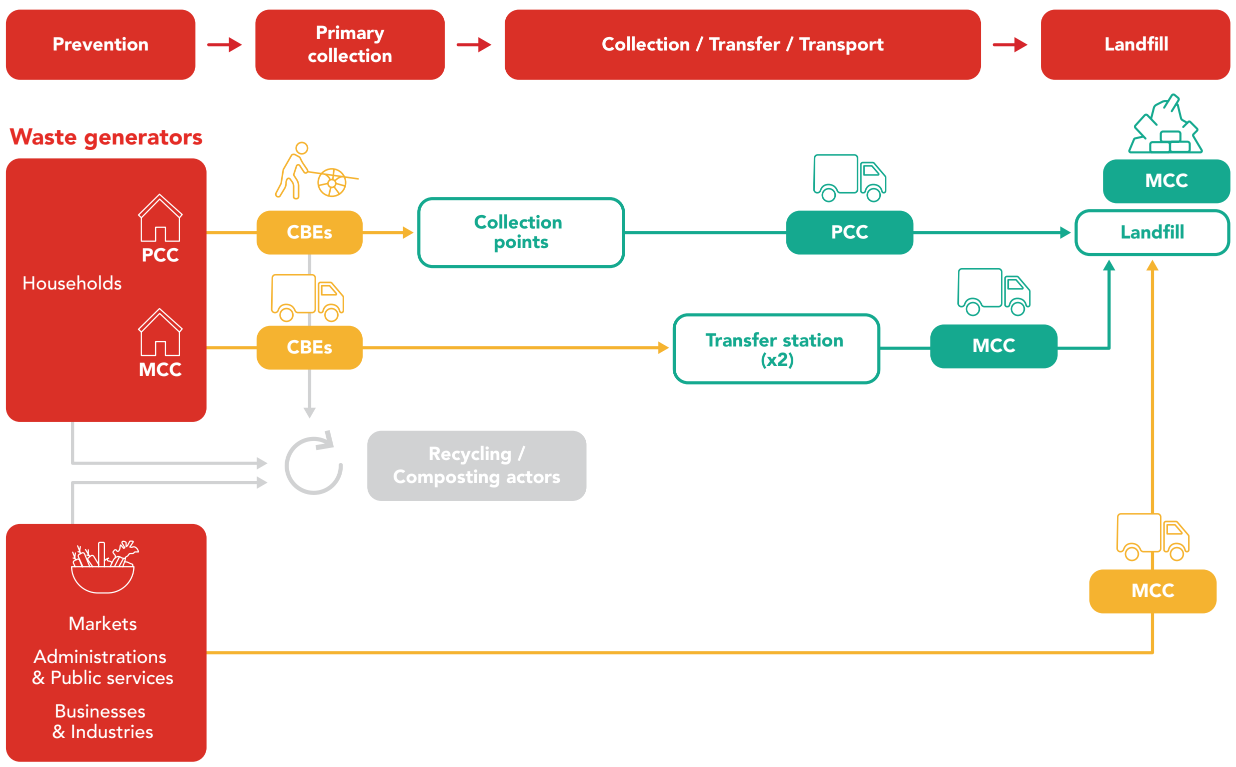
The MCC designed a new solid waste management strategy that was approved during an Emergency Solid Waste Management Stakeholders Conference in Monrovia in January. The first principle is that everyone pays for the waste.

A pilot project is implemented in Districts 7, 8, 9 and 10 gathering approximately 36,000 households and businesses in Central Monrovia. Within this pilot project:

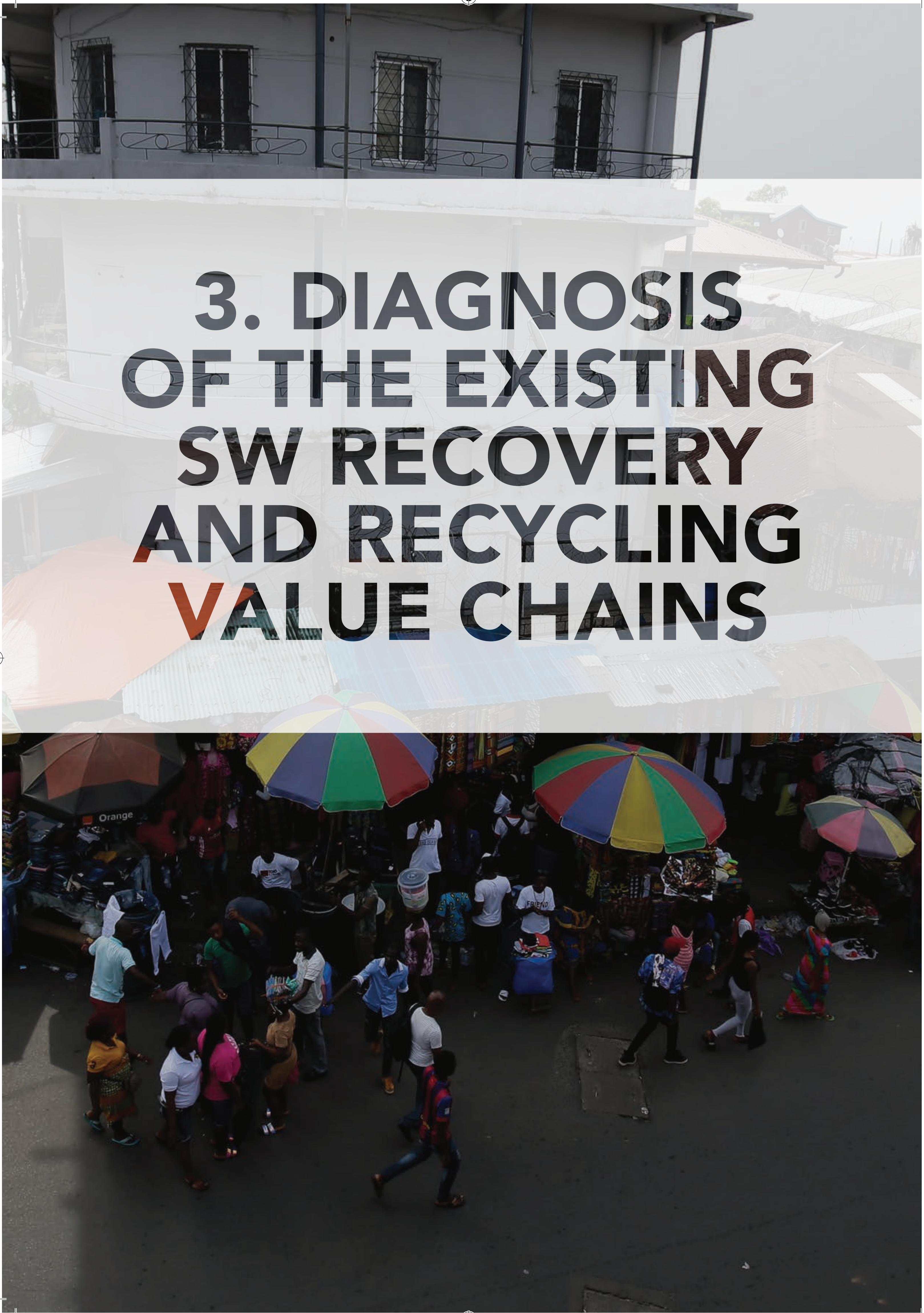
- CBEs collect waste from households and transport it to the transfer stations with the objective of eradicating collection points
- SMEs collect waste from businesses and transport it to the landfill
- No user tax will be collected by CBEs from households, but a garbage tax will be collected on behalf of MCC and the money paid to an escrow account dedicated to CBE service compensation.

The system does not envisage waste sorting for recycling and composting at the collection level or the transfer station.

FIGURE 3: "Pilot" SWM system in Monrovia and Paynesville



3. DIAGNOSIS OF THE EXISTING SW RECOVERY AND RECYCLING VALUE CHAINS



3.1 Assessment of the Recovery/ Recycling Potential

3.1.1 WASTE GENERATION

The municipal waste generation assessment is based on a previous study conducted by Arup in 2018. The forecast of waste generation in Greater Monrovia for the next five years is based on the following parameters:

- Waste generation rate: 0.42 kg/capita/day or 0.153 T/capita/year
- Population in 2018: 827,622 in Monrovia City and 440,424 in Paynesville
- Population growth: 1.95% per year
- Density of municipal waste in Greater Monrovia: 261 kg/m^3

On this basis, the current waste generation is estimated at 200,000 T/year. With population growth, it is expected to reach nearly 300,000 T/year in 2040.

TABLE 1: Waste generation in Greater Monrovia

In tons/year	2018	2020	2025	2030	2035	2040
Greater Monrovia	**194,011**	**201,651**	**222,094**	**244,609**	**269,407**	**296,719**
Paynesville	67,385	70,039	77,139	84,959	93,572	103,058
Monrovia	126,626	131,613	144,955	159,650	175,835	193,661

No recent waste characterisation survey has been carried out, and such a waste characterisation is outside the scope of this study. The data used for the evaluation of the waste composition in Greater Monrovia is that proposed by Arup in 2018, based on Pasco 2012 survey. This data includes all the municipal waste generated in Greater Monrovia, and then breaks it down by household waste and the waste generated by administrations, businesses, marketplaces, industries, etc. Table 2 estimates the weight of each waste component found in the Liberian bin.

FIGURE 4: Waste generation in Greater Monrovia

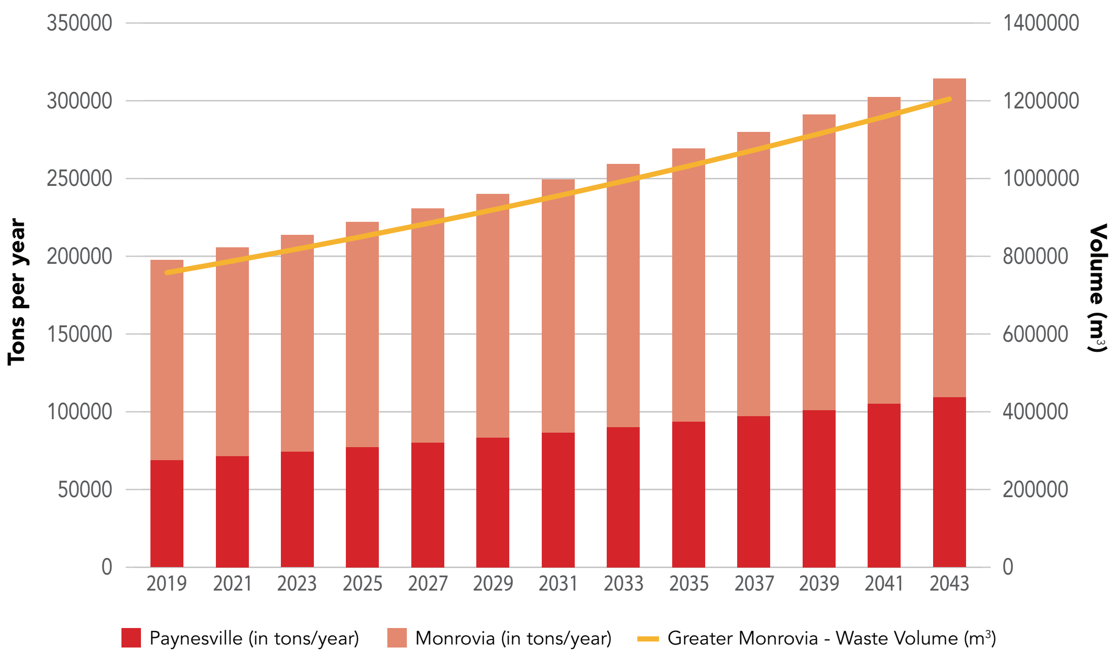


TABLE 2: Waste generation per fraction in Greater Monrovia

Component	Type	% of weight
Paper/Cardboard	Dry recyclable	7%
Glass	Dry recyclable	1%
Ferous metals	Dry recyclable	1%
Non-ferrous metal	Dry recyclable	1%
Plastics	Dry recyclable	11%
Special municipal solid waste	Non-recyclable (residual)	1%
Combustible waste	Waste-to-energy	14%
Textiles	Dry recyclable	5%
Clean organic waste	Humid recyclable	13%
Fine material	Non-recyclable (residual)	15%
Non-combustible waste	Non-recyclable (residual)	32%
Total		**100%**

Based on: ARUP_Greater Monrovia Waste Management Baseline Study_Final, 2018, Cities Alliance.

According to the Pasco study, the paper portion includes 1% paper, 4% cardboard, and 2% composite packaging (Tetrapak).

Pasco estimated combustible waste to consist of 12% contaminated organic waste (such as wood, straw, and bone) and 2% other combustible waste. This study does not consider this segment, as it is part of a study in progress on the development of a waste-to-energy activity.

This study does consider the dry and humid recyclables as indicated in the previous table. Table 3 shows the estimated quantity of waste which could be diverted from the landfill by adapted waste management collection and sorting and inserted into the recycling and composting processes.

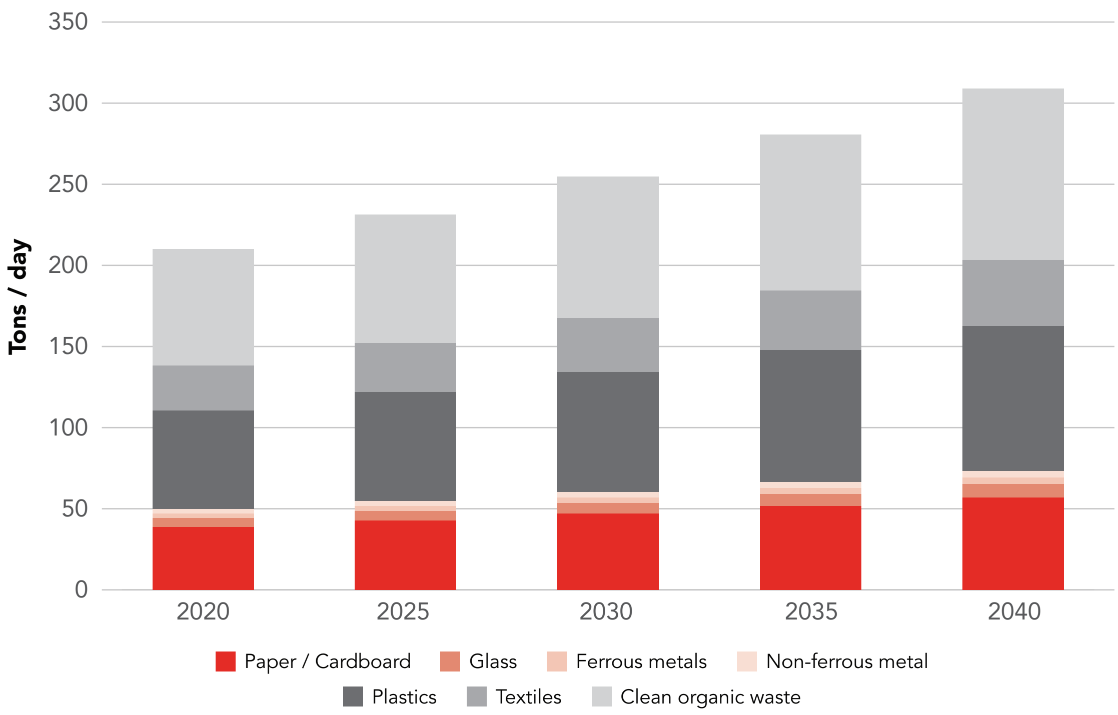
They are, in order of importance:

1. Clean organic waste: 72 tons/day in 2020; 106 tons/day in 2040
2. Plastics: 61 tons/day in 2020; 89 tons/day in 2040
3. Paper/cardboard: 39 tons/day in 2020; 57 tons/day in 2040.

TABLE 3: Waste generation by waste type in Greater Monrovia

In tons/day	2018	2020	2025	2030	2035	2040
Paper/Cardboard	**37.2**	**38.7**	**42.6**	**46.9**	**51.7**	**56.9**
Glass	5.3	5.5	6.1	6.7	7.4	8.1
Ferrous metals	2.7	2.8	3.0	3.4	3.7	4.1
Non-ferrous metal	2.7	2.8	3.0	3.4	3.7	4.1
Plastics	58.6	60.8	66.9	73.7	81.2	89.4
Textiles	26.6	27.6	30.4	33.5	36.9	40.7
Clean organic waste	69.1	71.8	79.1	87.1	96.0	105.7
Total recyclables	**202.0**	**209.9**	**231.2**	**254.7**	**280.5**	**309.9**
Non recyclables	329.5	342.5	377.3	415.5	457.6	504.0
Total	**531.5**	**552.5**	**608.5**	**670.2**	**738.1**	**812.9**

FIGURE 5: Waste generation by waste type in Greater Monrovia



These theoretical estimations have been confirmed by on-field observations (at the collection points, the transfer stations, and the Whein Town landfill), and data collected during the various interviews realised.

FIGURE 6: Municipal waste composition at the Fiamah transfer station and Whein Town landfill

Waste composition at the Fiamah transfer station

Waste composition at the Whein Town landfill

3.1.2 WASTE COLLECTION AND TREATMENT

PCC and MCC currently monitor waste collection activities. According to MCC statistics, 25,000 tons of waste was collected in 2018. Only 8% is collected by SMEs; most is collected by CBEs and MCC. The amount of waste transiting to transfer stations was 78,000 tons, meaning that a very significant part of the waste disposed in transfer stations is provided by sources other than CBE/MCC and SME. The waste disposed at Whein Town landfill was 127,000 tons, with 88,000 tons provided by MCC.

As a result, waste collection rate in 2018 – calculated as the ratio between waste disposed to Whein Town landfill (126,851 tons) and waste generated in Greater Monrovia (194,011 tons) – is around 65%. Some 35% of the waste generated is subject to illegal dumping (approx. 68,000 tons in 2018).

TABLE 4: Waste collected in Greater Monrovia in 2018

	Greater Monrovia	
	Tonnage 2018	**Average Tons/day**
Waste collected by CBEs at MCC Skip Locations Only	22,934	63
Waste collected by SMEs to Fiamah TS	672	2
Waste collected by SMEs to Stockton TS	1,332	4
Total Waste Collected	**24,938**	**69**
Waste transiting at Fiamah TS	48,710	133
Waste transiting at Stockton Creek TS	29,413	81
Total Waste transiting at TS	**78,123**	**214**
Waste disposed at Whein Town Landfill by SME/Private	7,587	21
Waste disposed at Whein Town Landfill by MCC	88,065	241
Waste disposed at Whein Town Landfill by PCC	31,198	85
Waste disposed at Whein Town Landfill	**126,851**	**348**
Waste directly disposed to the landfill *(no transit by TS)*	**48,728**	**134**
Estimate waste generation	**194,011**	**532**
Greater Monrovia's collection rate (*)	65%	

Source: MCC
TS: Transfer Station
(*) Waste disposed at Whein Town landfill/Estimate waste generation

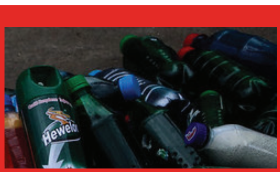
3.1.3 WASTE RECYCLING/COMPOSTING POTENTIAL

The most current waste types that are part of a value chain development (formal or informal) in similar territories are:

FIGURE 7: Waste value chains

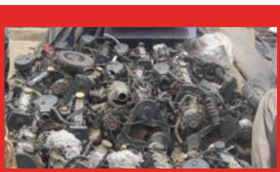
Organic waste (food and green waste)

- Composting, co-composting of green waste and wastewater residues, co-composting with farming effluents, vermicomposting…
- Reuse for animal food
- Mehtanation / biodigestion for a biogas production



Glass

- Crushing for road underlayment
- Circular economy (deposit system)
- Recycling (facilitated in case of a sorting by color)
- …



Ferrous and non-ferrous metals

- Recycling
- Reuse (artistic pursuit, repair…)

Plastics (in particular PP and PET)

- Recycling
- Waste-to-energy (solid recovered fuel - SRF)

Paper / cardboard

- Recycling as for instance manufacturing of toilet paper.

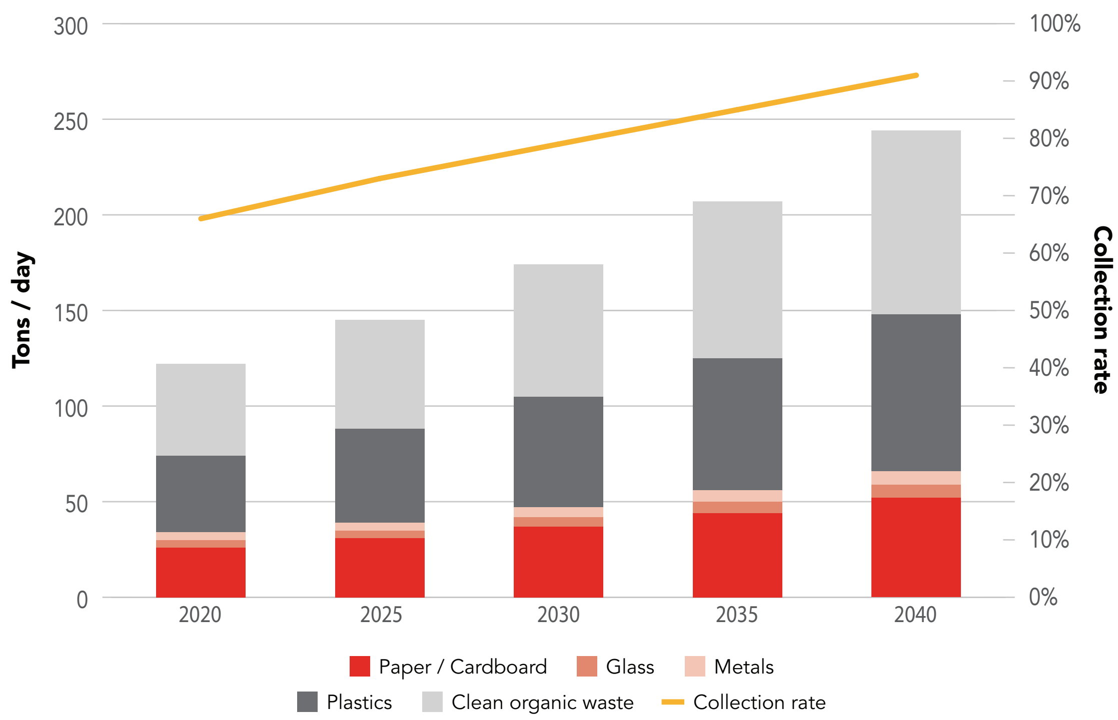
The potential quantity of recyclables which could be diverted from the Whein Town landfill or illegal dumping and then integrated into the recycling and composting processes was assessed using the composition of the waste generated in Greater Monrovia and the estimated collection rate. The hypothesis considered is a 5% increase of the collection rate every five years. As a result, the collection rate is expected to increase from the current 65% to 90% in 2040. This hypothesis needs to be confirmed and cross-checked with the hypothesis outlined in the study in progress on the expansion of CBEs.

The potential quantity of recyclables is estimated at 121 tons/day in 2020 and is expected to increase up to 245 tons/day in 2040. Of the recyclables, 40% is composed of clean organic waste, 33% of plastics and 20% of paper/cardboard.

TABLE 5: Potential quantity of recyclables

In tons/day	2020	2025	2030	2035	2040
Paper/Cardboard	26	31	37	44	52
Glass	4	4	5	6	7
Metals	4	4	5	6	7
Plastics	40	49	58	69	82
Clean organic waste	48	57	69	82	96
Total	**121**	**146**	**174**	**207**	**245**

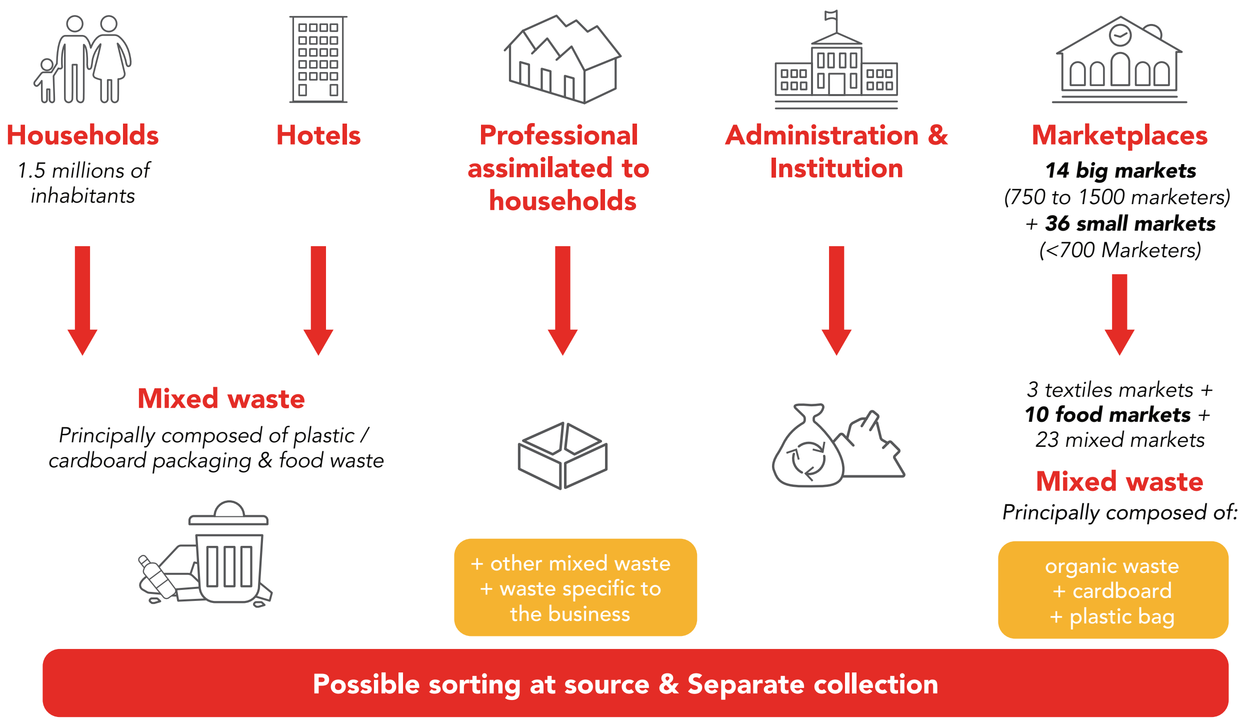
FIGURE 8: Potential quantity of recyclables



In order to complete the assessment of recyclables and their availability, we need to estimate the waste generated by the administration, the marketplaces and the main businesses (in particular hotels and supermarkets/groceries) These establishments generate high quantities of waste types that are easy to separate.

- **Marketplaces:** There are 50 identified marketplaces in Greater Monrovia, including 14 big markets with between 750 and 1,500 traders. According to the data provided by the Liberian Marketing Association, which is in charge of managing and cleaning the marketplace, 10 food markets[1] and 23 mixed markets[2] generate an estimated 19 and 22 tons/day of clean, organic food.
- **Administration and institutions:** Their numbers are unknown, but it is estimated according to international standards that administration generates 0.5 kg/staff/week and schools and universities generate 0.25 kg/student/week. The waste generated is mainly paper waste.
- **Hotels:** The number of hotels in Greater Monrovia is not precisely known, but according to international standards the waste generated is 0.30 kg/visit/day, mainly composed of mixed waste (food waste, plastic, cardboard).
- **Other businesses** (supermarkets, groceries, stores, etc.): Their number is not precisely known but it is estimated that their waste generation is 1 kg/staff/week, mainly cardboard and plastics.

FIGURE 9: Main waste generators and recyclables quantity assessment



[1] Hypothesis on waste composition at food markets: 90% of clean organic waste, 6% of cardboard, and 4% of plastics.
[2] Hypothesis on waste composition at mixed markets: 50% of clean organic waste, 15% of cardboard, 10% of plastics, and 25% other waste.

These estimations of waste generation by main generator must be completed by data to be provided by the Ministry of Commerce and Industry (type and size of businesses and industries registered) and the Ministry of Information, which houses the Bureau of Tourism (list of hotels, their capacity, number of beds, and visit statistics.

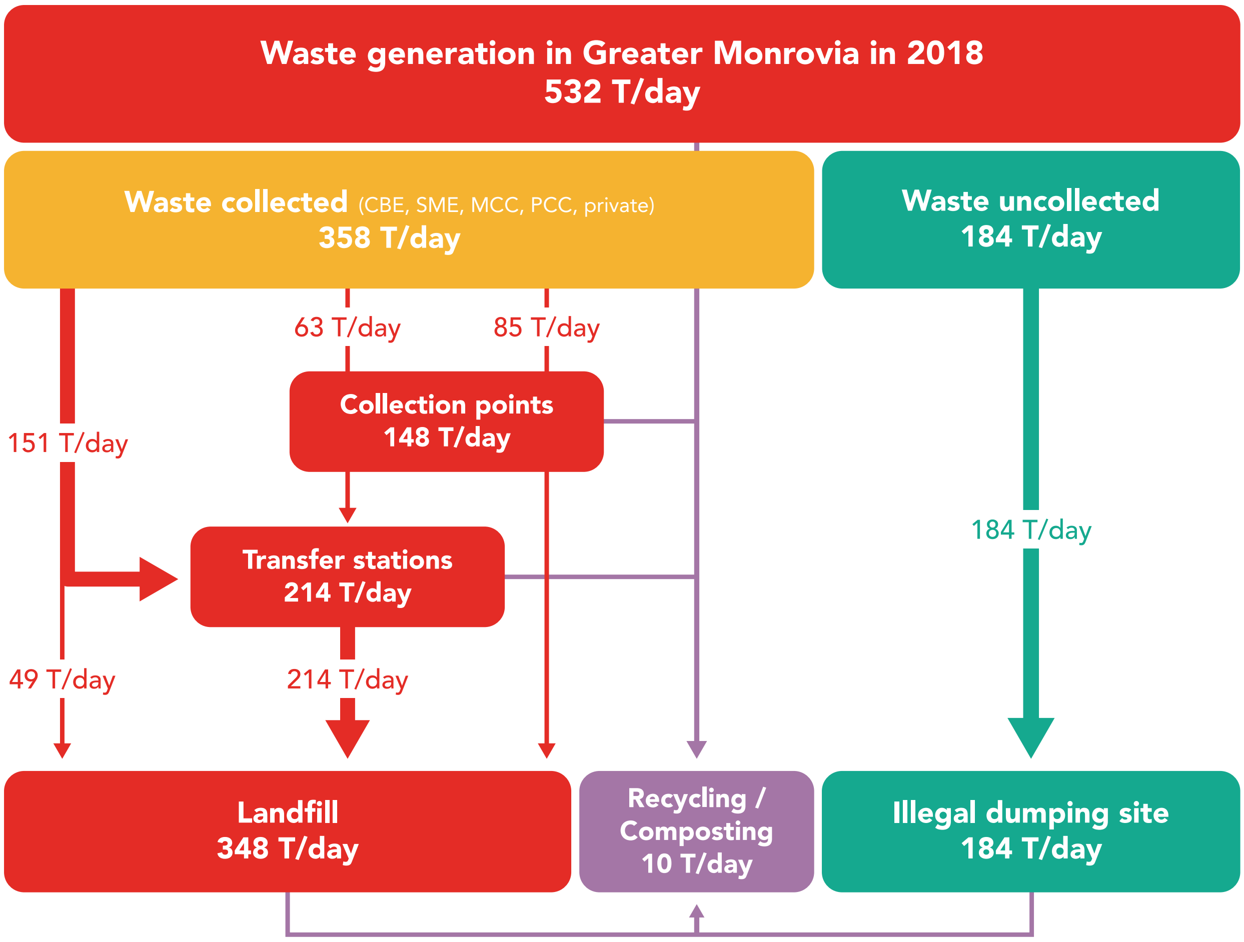
For the purposes of this study, the waste quantity of these generators was assessed using available data. Figure 9 illustrates the main waste generators to consider in an assessment of their potential for recycling and composting.

3.1.4 SYNTHESIS OF THE WASTE FLOWS FROM GENERATION TO TREATMENT

Figure 10 presents the waste flows in Greater Monrovia in 2018. Highlights are:

- Around 34% of municipal waste is disposed in illegal dumpsites
- Only 1% is recycled or composted, based on data collected in the field from actors interviewed
- 65% is disposed in the Whein Town landfill

FIGURE 10: Waste flows chart (2018)



3.2 Inventory of recycling/composting value chains

3.2.1 OVERVIEW

According to data and information collected from identified recycling/composting stakeholders:

- There is no formal value chain for glass and paper/cardboard recycling.
- The existing plastics recycling operators have already reached their highest production capacity.
- There are no recycling activities for metals in Liberia, but all the scrap metals collected/sorted/cleaned are exported. The scrap dealers' capacity for sorting and exporting is already reached, according to North Star and Universal Impex.
- There are some emerging and existing actors for clean organic waste composting and recycling. Their production plant could absorb a higher amount of waste with an awareness campaign of the beneficiaries and institutional support from, for example, the ministry in charge of agriculture for the composting.

TABLE 6: Waste recycled/composted/exported in Greater Monrovia

	Current quantity of waste recycled/composted/exported		Maximum capacity of recycling/composting/exportation	
	(in T/year)	(%)	(in T/year)	(%)
Paper/Cardboard	0	0%	0	0%
Glass	0	0%	0	0%
Metals	2,200	111%	2,200	111%
Plastics	1,272	6%	1,272	6%
Clean organic waste	306	1%	1,230	5%
Total	**3,778**	**6%**	**4,702**	**7%**

There are some limits/attention points on the work done there:

1. For the scrap metals, the evaluation is complex because there is sorting at each link of the value chain. The share of exported waste generated by households or businesses could not be identified by the scrap dealers encountered. They were unable to provide statistics on the individuals/CBEs/SMEs from whom they buy scrap metals.
2. Some recycling actors were unable or unwilling to share information related to their activities (ex: some scrap dealers).

3.2.2 ORGANIC WASTE

3.2.2.1 Main value chains in other developing countries

Three main value chains are identified concerning organic waste:

- Composting, vermicomposting, or co-composting (organic waste with fecal sludges, farming effluents, or digestate, etc.)
- Reusing food waste from households for subsistence farming or pet feeding, or recycling food waste from agro-food industries for feeding farm animals. Japan makes extensive use of this option, using central processing plants to sterilise the waste to destroy any pathogens which may carry animal diseases.
- Methanation or biodigestion for biogas production (waste-to-energy)

Only the first value chain is considered in this study, which focuses on composting and recycling. Reuse for animal feeding and methanation (or anaerobic digestion) are outside of the scope of this study. Recycling of food waste generated by agro-food industries for farming animal feeding is also excluded due to the lack of commercial farming in Liberia and Greater Monrovia. According to an analytical report on population in agriculture published in 2011 by the Liberia Institute of Statistics and Geo-Information Services (LISGIS), animal rearing is not well institutionalised in Liberia. Most livestock and poultry are produced by households through the free-range system and in backyards (small scale). This chapter presents the results of an analysis of data collected on livestock, poultry, and fish farming.

If reuse value chains are not studied here, MCC and PCC are encouraged to raise awareness among households about this practice in order to reduce waste generation at source, thus reducing the waste collection/transport costs and slowing down the filling speed of the landfill cells.

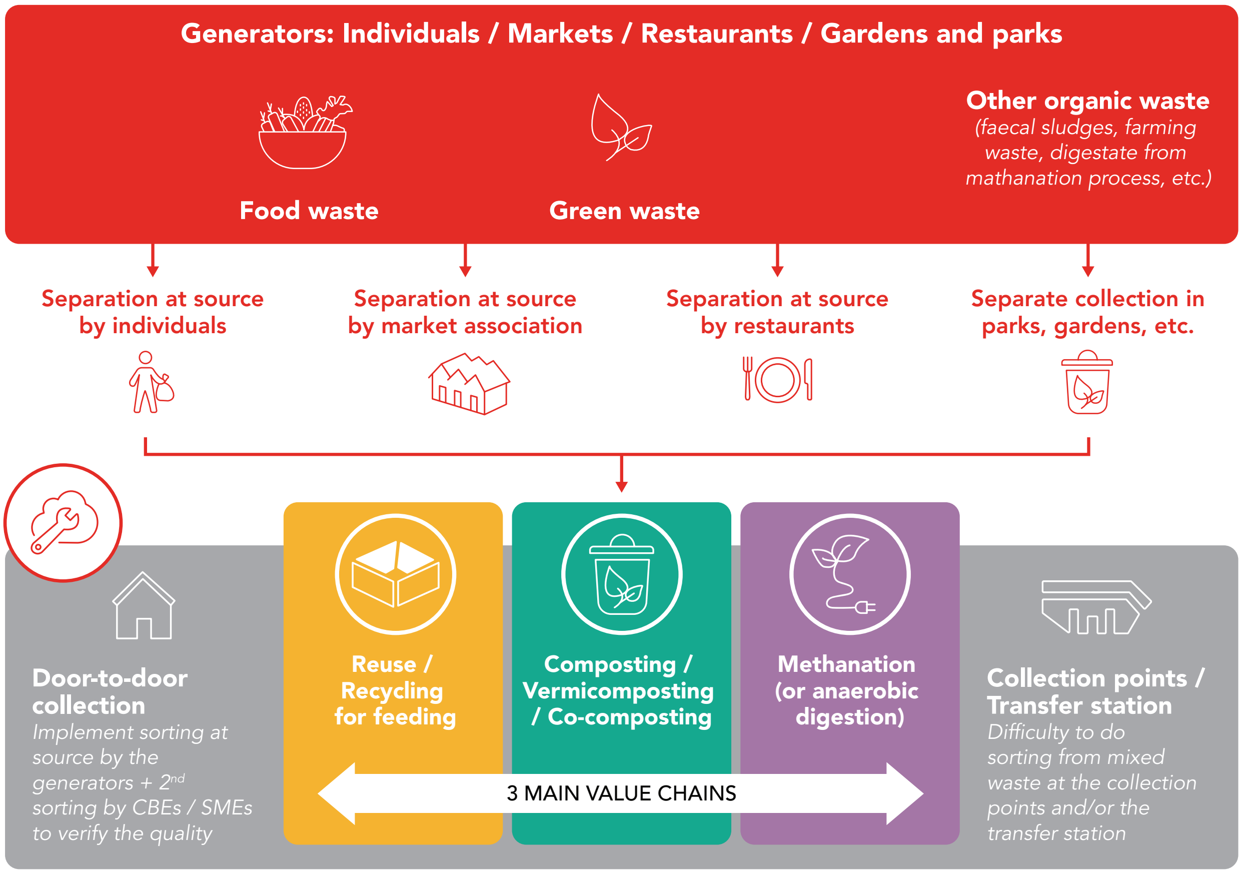
In addition, it is important that the development of the recycling (composting) and energy recovery (methanation) value chains is coordinated and the waste flows considered using the same generators. The organic waste value chains must be complementary and not in competition.

3.2.2.2 SWOT analysis of existing Liberian value chain

Numerous CBEs have developed, or tried to develop, composting activities, but most of them have stopped. The reasons for stopping are: (i) the lack of space to process and store, (ii) the absence of separate collection and the difficulties in adequately sorting the mixed waste collected, (iii) the lack of market for products, and (iv) the non-profitability of this activities.

Some SMEs have also developed composting activities based on the collection of specific waste resources from markets or professional customers. For instance, Organic Matters produces compost and organic fertilizers (9-10 tons per month) from organic waste collected in the Red Light market in Bensonville. Green Cites, based in Sinkor, collects organic waste from its customers to produce compost (5-6 tons per month). And NC Sanitors has recently bought land to develop recycling and composting activities.

FIGURE 11: Organic waste value chains



All these initiatives need to be encouraged with some technical, financial, commercial support.

Lessons learned from the past experiences show that:

- **There is probably a potential market for compost and organic fertilizers,** but some incentives, awareness campaigns, training and demonstration farms are needed to develop the demand for farmers who are currently more confident and accustomed to chemical fertilizers.
- **The process must be secured and professionally managed** in order to produce high-quality compost able to compete in terms of efficiency and cost with chemical fertilizers.
- **The organic waste deposit must be homogenous and stable enough;** mixed waste is inadequate, and market waste sorted at source preferred.
- **Large space is required** for processing compost, and there is more available in the city outskirts, which are also closer to potential customers.

FIGURE 12: SWOT analysis for composting development

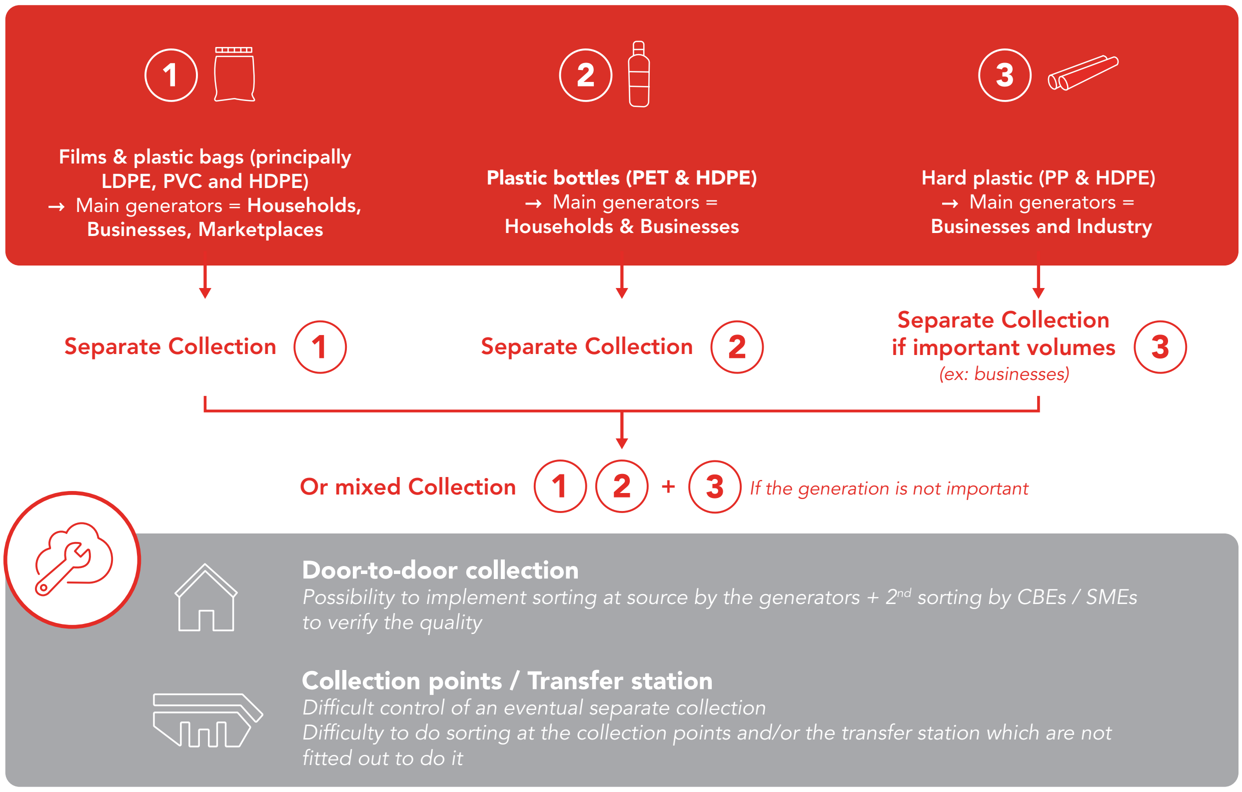
STRENGTHS	WEAKNESSES
Separate collection done at market level with the support of some SMEs (Organic Matters). High quantity of organic waste generated (mainly in marketplaces). Competitive output price compared to chemical fertilizers. Emerging operators (Organic Matters, Green Cities). In previous years, the Ministry of Agriculture and some NGOs have delivered training for farmers on how to make compost. The agricultural sector has a high potential demand for compost; agriculture represents 70% of the population employed and 40% of the GDP (according the World Factbook of Central Intelligence Agency, 2017).	No separated collection of household waste. No more sorting at source, which implies decrease in cleanliness and then prices and/or running costs decline. Potential market not fully effective due to farmers' lack of confidence (reluctance to adapt their agrarian practices) and competition from chemical fertilisers. Lack of production capacity of the existing producers and some local experiments unsecured. Lack of space for some interested operators (which results in remote production sites).
OPPORTUNITIES	**THREATS**
Possibility to collect organic waste easily and separately in marketplaces (high quantity generated and high quality thanks to the separation at source from the other waste). Possibility to implement separate collection at household level in exchange for compensation. CBEs are therefore able to implement separate collection and households could be aware of doing it. Incentives, awareness campaigns, trainings and demonstration farms could develop the demand for farmers.	Competition from imported chemical fertilisers. Capacity of operators to develop a secured and professionally managed process to produce a high-quality product at a competitive price. Capacity to identify and collect homogenous and stable organic waste. Few CBEs are interested in collecting organic waste separately in order to compost it (much more interested in plastic and metal sorting).

3.2.3 PLASTIC WASTE

3.2.3.1 Main value chains existing in other developing countries

There is a high diversity of plastics which can be classified in three categories: films and plastic bags, plastic bottles, and hard plastic (see Figure 13). Each category could be sorted at source or sorted from mixed waste on a sorting chain at the collection points, the transfer stations, or eventually the landfill. The first option (separate collection with sorting at source) allows greater cleanliness and avoids a primary step of sorting, as it is done directly at source by generators. A secondary sorting is nevertheless necessary to control the quality and maybe separate different sub-categories of plastics if asked by the plastic recyclers (technical requirements, generally associated to better prices).

FIGURE 13: Generated plastic waste and collection options in Greater Monrovia context



Regarding plastics value chains in other developing countries, there are several options to recycle them in Greater Monrovia (see Figure 14). They are

- Plastic waste after sorting (primary and/or secondary) and washing operations could be baled and then exported to other countries (such as China or India) for recycling. This could cover, for example, PET bottles, which are not recycled in Liberia. PET is generally reused for cold-climate textiles and carpet manufacturing, which have no significant market in Liberia. PET bottles might also be used in (re)manufacturing.
- Used plastic bottles are currently collected or sorted by individuals/CBEs/ scavengers, washed and then sold to marketers who reuse them (to sell beverage, oil, fuel, for instance). The washing operations are not mechanised and cannot ensure a total innocuousness, presenting a sanitary risk. In some countries (as in some Pacific islands and countries), the plastic bottles are integrated into a deposit-return system, the model used for glass bottles. The plastic bottles are then reintegrated into the bottling process in order to produce new bottles (circular economy). There is currently no remanufacturing of plastic bottles in Greater Monrovia or Liberia. PET waste quantities on the market linked to water bottling (and importing) activities are very significant in Monrovia.
- Plastics could be also used for waste-to-energy activities to produce solid refused combustibles (SRFs) which are substitutes for primary fossil fuels (such as coal, petroleum coke or natural gas). SRFs contain plastics but also a variable part of biogenic components such as paper, cardboard, or wood

according to the original waste. They are principally used for co-incineration facilities to produce electricity and/or gas, mainly in Europe (notably France, Italy, Germany, Finland, Netherlands, Austria, Ireland, and Norway). Except for a healthcare waste incineration unit, there is currently no incineration facility in Greater Monrovia or in Liberia. Plastics can also be recycled into fuel, as in Norway. The processing line (the several melting and condensation steps) need to be environmentally controlled and secured (smoke treatment and inerting). Evergreen, a local association in Greater Monrovia, has built a pilot unit which is currently operational.

- In several developing countries, plastic waste is sorted and melted for integration into the production process of building elements such as roofing tiles, interlocked tiles, bricks, and blockworks. The recycling facilities are generally not mechanised and do not include smoke treatment. Melting plastic does not contradict major international directives, as long as it is not burned. There are two notable points about this process. There is currently no study on the micro-plastics content of storm water. Moreover, when building elements produced from plastic waste become waste themselves, the plastic will be released into (and impact) the environment.
- Plastic waste could also be recycled for manufacturing kitchen items, bins, buckets and basins, and garden and urban furniture. Technology for secondary raw plastic material consists of a plant that crushes, washes and melts plastic into rounded small chips.

3.2.3.2 SWOT analysis of the existing Liberian value chains

The private sector is already active in recycling plastic materials in Greater Monrovia:

- Green Cities is currently studying a project for grinding HDPE, LDPE, PET and PVC. The process is not yet operational, but sorted and washed plastics are stored awaiting the purchase of equipment.
- Duraplast (subsidiary of SETHI Brothers) currently recycles PVC and LDPE with an industrial process line. The company does not recycle PET and HDPE, although it is willing to do so. This recycling unit was initially created to treat the waste generated by the SETHI Brothers and produce plastic bags for their shops in Greater Monrovia. The plant has reached its highest production capacity and it is not possible to extend capacity of the recycling line without significant investments.
- Evergreen is a recent association of young people which is developing a plastic recycling process. The pilot unit they used produced a small quantity of construction elements (roofing tiles and bricks), fuel and gasoil, and paint thinner. The collection and production capacity are currently low and the process line rudimentary.
- Center for the Plastic Waste Management and Recycling (CEPWAMAR) is a registered corporation created in 2017, with EPA permits in progress. It produces interlocked tiles from films, plastic bags, and sand. The production capacity is currently low and the process line rudimentary. It is working with community leaders to raise awareness among the population and encourage them to separate waste at source.

FIGURE 14: Theoretical plastic waste value chains existing in other developing countries

FIGURE 15: SWOT analysis for plastic recycling development

STRENGTHS	WEAKNESSES
Separate collection previously done by the CBEs thanks to the sorting at source by households in exchange for compensation. CBEs are therefore able to implement separate collection, and households could be aware enough to do it. High quantity of plastic generated (mainly plastic bags, water bags, plastic bottles). Interest of the CBEs and emerging recycling operators (Evergreen, Green Cities, CEPWAMAR).	No more sorting at source, which decreases the cleanliness and then the prices and/or running costs. For plastic recycling: • No local plastic bottles manufacturer to re-integrate used plastic bottles into their processing line. • No industrial recycling facilities except Duraplast, which has reached the highest production capacity and was initially dedicated to its own waste recycling.

STRENGTHS	WEAKNESSES
Support of MCC and PCC for transport (vehicles provided). For plastic reuse: • Informal value chain currently exists (plastic washed and sold on marketplaces).	• Lack of production capacity among existing recyclers (Duraplast and Green Cities) and some local experiments unsecured (Evergreen and CEPWAMAR). • No bottling company with the necessary extruder. They use imported bottles pre-form bottles (and blow them locally). • Plastic waste purchase prices are currently very low, discouraging collectors (Duraplast has a monopoly for buying plastic waste to individuals/enterprises). For plastic reuse: • Local small demand • Sanitary risk due to unsecured washing operations
OPPORTUNITIES	**THREATS**
Local demand for tiles and bricks from low-income population. High demand for fossil fuel substitutes. Easy to export due to the port proximity. Labour-intensive activities and high unemployment rate.	Imported products (plastic goods, fuel) that can compete with local production. Eventual decree to ban plastic bags and sachets (intended by EPA). Lack of land/space to implement facilities. Plastic recycling for producing fuel needs adequate equipment to avoid toxic gas emissions dangerous for the environment and employees' health.

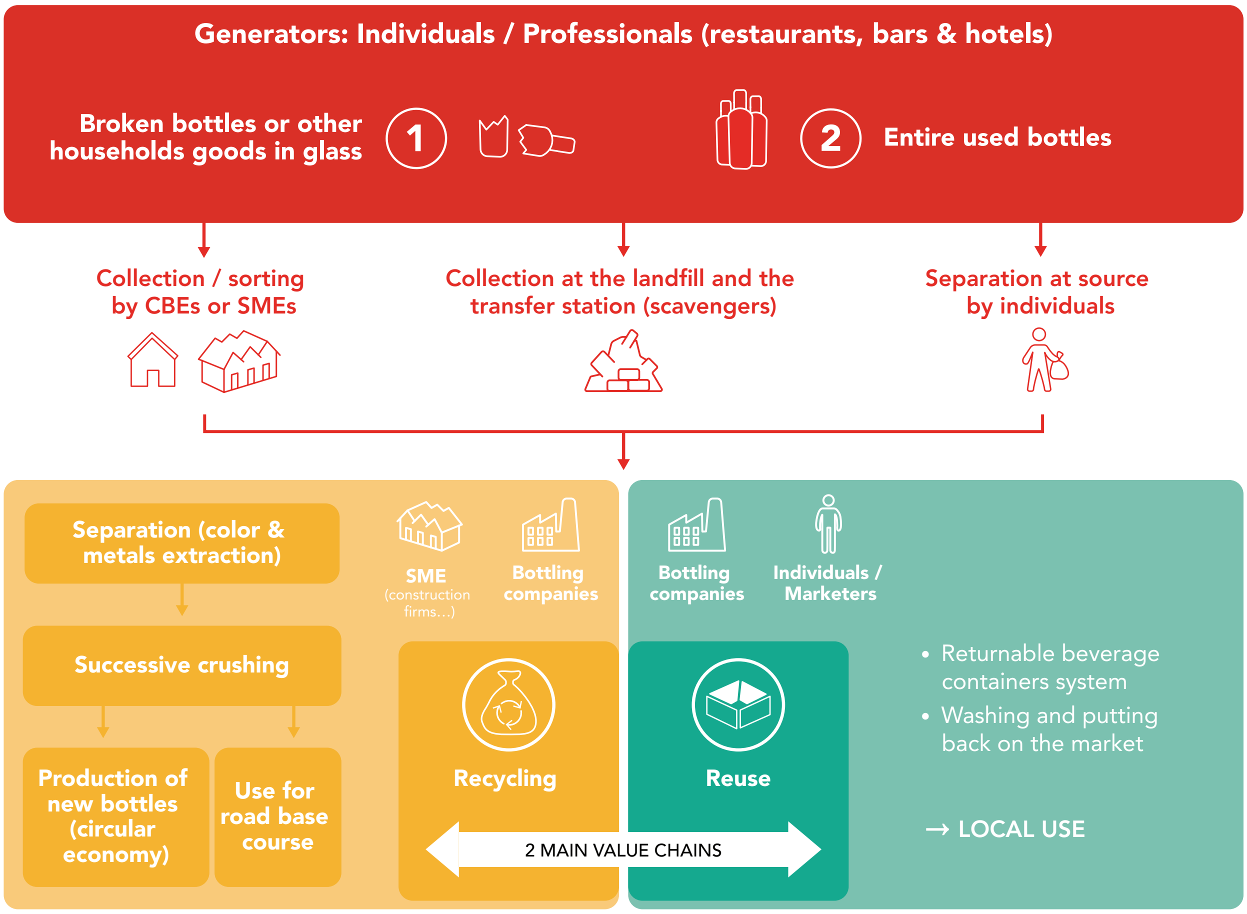
3.2.4 GLASS RECOVERY

3.2.4.1 Main value chains existing in other developing countries

Glass is a hardened material made principally from silica, transparent (mainly) or colored. This study considered household glassware products including bottles (entire or broken), jars, pitchers, and cups. Glassware items and bottles which are put on the market are mainly imported (in the case of Liberia), but they can also be produced in the country. They are then sold by companies as Coca-Cola, Heineken or wine and spirits sellers to individuals and businesses.

Two ways of reducing the amount of waste glass and recovering glass have been identified in similar municipalities: recycling and reuse. The figure below presents these value chains from glass generation to recovery.

FIGURE 16: Illustration of the two main value chains of glass recovery adapted to the Greater Monrovia context



The figure presents the generators of glass waste: individuals and businesses, such as restaurants and hotels. The easier way to collect clean glass waste is to separate it at source from the mixed waste (by the individuals), as represented in Figure 16. Glass sorting can also be done after collection by the CBEs or SMEs (at the transfer station), and by scavengers (collection points, transfer station or landfill). After collection, sorting, and eventually cleaning, glass waste can be integrated in two different value chains:

Recycling value chain (1):

The recycling process is achieved by a glassmaker industry and involves:

- Separation (colour and metals extraction) and successive crushing of the glass and production of new products (these two steps can be done by an intermediate company that sells the crushed glass to the glassmaker);
- Production of new bottles by the glassmaker industry. The bottles are put back onto the market by bottling companies (which can also be the glassmaker, as Heineken) and sold to individuals and businesses (mainly restaurants and hotels).

There is no glass recycler in Liberia. Bottling companies such as Club Beer have to import the broken bottles in order to ensure their recycling.

Reuse value chain (2):

The entire glass bottles are sent back to the bottle seller (marketers or bottling companies) by the generators (households or businesses), usually in exchange for a modest payment. Bottles are cleaned, disinfected and put back onto the market by the seller.

In conclusion, the two value chains presented comprise local recovery of waste by recycling it to produce new glass items or by reusing it directly. The recycling value chain requires the presence of a local glassmaker. The reuse value chain depends on the will of the sellers to introduce a returnable beverage container system.

3.2.4.2 SWOT analysis of the existing Liberian value chains

FIGURE 17: SWOT analysis for glass recycling/reuse development

STRENGTHS	WEAKNESSES
(2) Existing deposit-refund system: Entire glass bottles are sent back to some bottling companies (Coca-Cola, Master, Club Beer, etc.) by the generators (households or businesses), in exchange for a modest payment. Current sorting by individuals/scavengers to reuse the bottles for the sale of beverages and other liquids at the marketplaces.	(1) and (2) No formal sorting is done currently (only informal by scavengers). (2) In recent years, glass bottling companies such as Coca-Cola have substituted glass bottles for plastic bottles and cans, which are much less reusable than glass bottles. Sanitary risk due to the handmade cleaning operations. (1) No glass manufacturer in Greater Monrovia, a precondition for glass recycling. Broken glass bottles and other glass waste cannot be recycled.
OPPORTUNITIES	**THREATS**
(1) Process for recycling glass is quite simple and glass can be recycled "endlessly" and in its entirety. Presence of construction firms which could be interested in glass for road base course. (1) and (2) Glass sorting is quite simple and can be done at source by the generators (or at collection points, transfer stations and landfill).	(1) Recycling glass implies expensive material investments (for washing and crushing glass). Some specific glass items are not recyclable such as mirrors, windshield and crockery. Importing of glass bottles could compete with local production of glass bottles (with recycled glass).

(1) Recycling/(2) Reuse

3.2.5 METALS RECOVERY

3.2.5.1 Main value chains existing in other developing countries

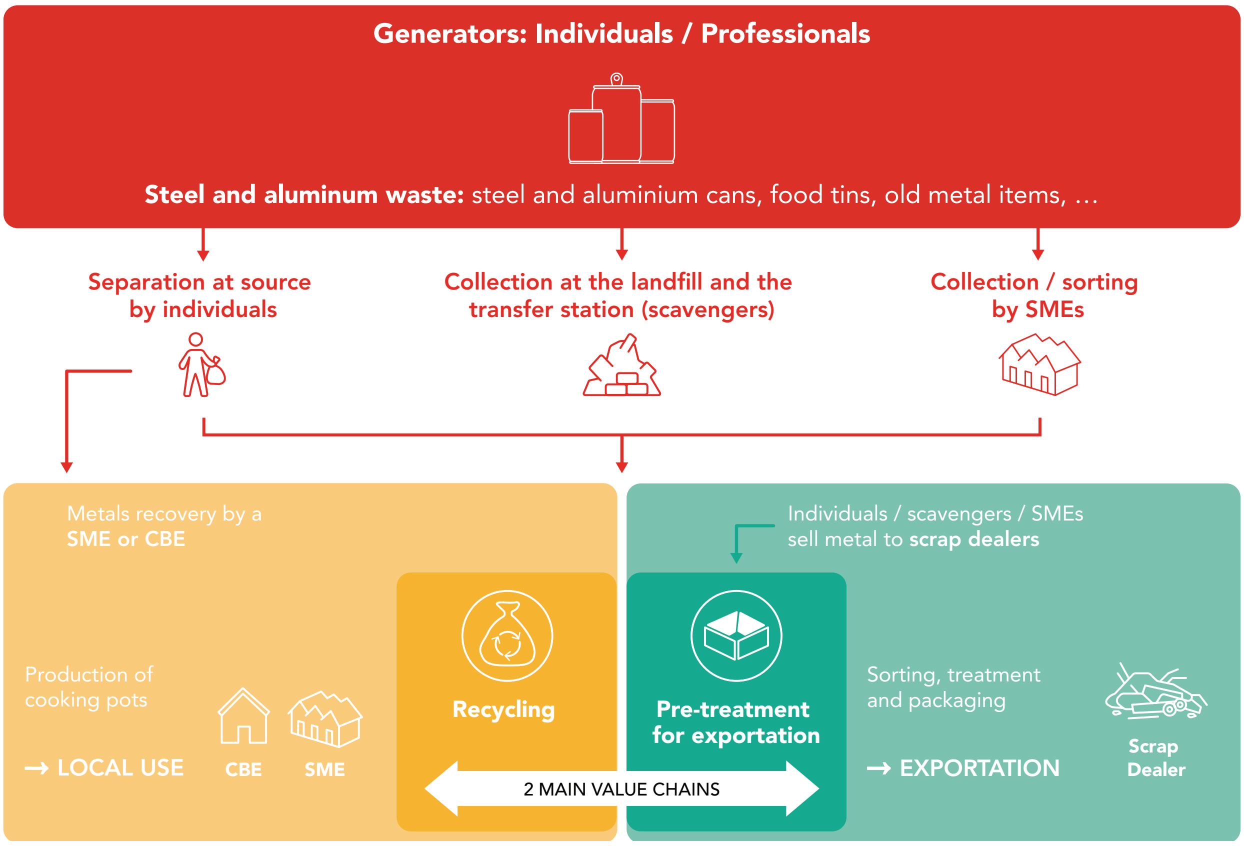
Scrap metals can be found anywhere. It can be used to produce several kinds of recycled items that are more affordable compared to the products that were created with the use of raw metals. This study identifies two main value chains as relevant for Greater Monrovia:

- Local metals recycling by production of cooking pots and cauldrons (1)
- Pre-treatment of metals for exportation (2)

Another value chain could be the direct treatment of the metal waste in Liberia. There is currently no treatment facility in Liberia, although SETHI Brothers may be planning to build a steel mill in Greater Monrovia. This option is not considered because of the high investment required for such equipment.

The value chains are presented in Figure 18, which illustrates the different stages of metals value chains: generation, collection/transport, recovery/treatment and market opportunities.

FIGURE 18: Illustration of the two main value chains of metals recovery adapted to the Greater Monrovia context



Collection of metal items

The two value chains imply the separation of items containing aluminum from the other metals. This separation can be made:

- At source by individuals
- By CBEs during the primary collection or by SMEs at transfer station;
- By scavengers (collection points/transfer stations/landfill)

Metals recycling value chain (1)

The supply of aluminum comes from scrap metal sellers and is then picked up by an SME in charge of cooking pot production. Those SMEs are usually small, artisanal, family-run businesses that make and sell sand-cast aluminum spherical pots. Starting such a business requires little expertise, basic foundry equipment and little capital.

The manufacturing process is as follows: molten metal is poured into a pot mold (into handmade boxes packed with mixed sand). After the "shake out," the pots are checked for imperfections and rough spots are filed. The final products are spherical aluminum pots which can make their way to the market (while poorly cast pots head back to the fire).

In conclusion, metal resources are easily separable from other waste. The manufacturing process is straightforward and does not require too many investments and skills. Finally, there is a demand for cooking pots, which are used by the majority of households.

Metals exportation value chain (2)

The metal items are bought by the scrap dealers from the individuals/CBEs/SMEs/scavengers. They can also be collected from business establishments.

The requirement for a scrap metal business is the ownership of a scrap yard – a place where the collected scrap metals can be segregated by size and stocked, waiting for new buyers. The place should preferably be isolated to make sure that the harmful chemicals in the scrap metals will not affect the neighbors. After purchase, the metals are sorted, compressed, baled and exported.

In Greater Monrovia, three scrap dealers have been identified: North Star, Universal Impex and Edgail Recycling Inc.

To conclude, leading such activities needs some property investments (yard place). There are already three firms in Monrovia treating metal and sending it to exportation. There are market opportunities (exportation) for this value chain. However, the resources are recycled and valued in other countries so it cannot be considered as a local recycling value chain.

3.2.5.2 SWOT analysis of the existing Liberian value chains

FIGURE 19: SWOT analysis for metals recycling/exportation development

STRENGTHS	WEAKNESSES
(1) & (2) There are already organised activities of picking up and sorting of metals (scavengers, 2,000 agents, 100 bookers and scrap dealers). Many CBEs are interested in collecting metal separately. (1) One firm makes pots with recycled aluminum. (2) There are 3 scrap dealers in Monrovia treating metal and exporting it (North Star, Universal Impex and Edgail Recycling Inc.). 1,500 T/month gathered by the major scrap dealer (information declared by North Star). High value component (if there is no monopoly of a scrap dealer); high incomes for the scrap metal scavengers.	(1) Few metal recycling operators in Greater Monrovia. Only one firm doing aluminum recycling. (2) Monopoly for aluminum (only one scrap dealer buying aluminum cans, thanks to their baler – Edgail Recycling Inc.), which negatively impacts prices and discourages collection operators. Recycling in other countries is a loss of local value. It could create more value with a local recycling process – sales in Liberia and creation of employment. Export taxes increase expenses for scrap dealers and consequently impact the scavengers. (1) and (2) Low generation of metal waste.
OPPORTUNITIES	**THREATS**
(1) and (2) Metals are easy to separate from other waste (cans, food tins, metal items easily identified) at the different links in the value chain: separation at source, pick-up at collection points, transfer stations or landfills. (1) Manufacturing of sand-cast aluminum spherical pots needs few investments and skills, and can be made by small artisanal, family-run businesses. Market demand for cooking pots (households and restaurants). According to Hysaa, SETHI Brothers plans to build a steel mill in Greater Monrovia. The progress of the project is unknown. (2) Existing high demand from international market for exportation of metals and proximity of the port.	(1) and (2) Washing processes are needed. (2) Need for space/Lack of land

(1) Recycling/(2) Pre-treatment for exportation

3.2.6 PAPER/CARDBOARD RECOVERY

3.2.6.1 Main value chains existing in other developing countries

Paper/cardboard is a waste stream made up of three main types of waste: Graphic and printing papers, cardboard and bricks food, and cardboard boxes.

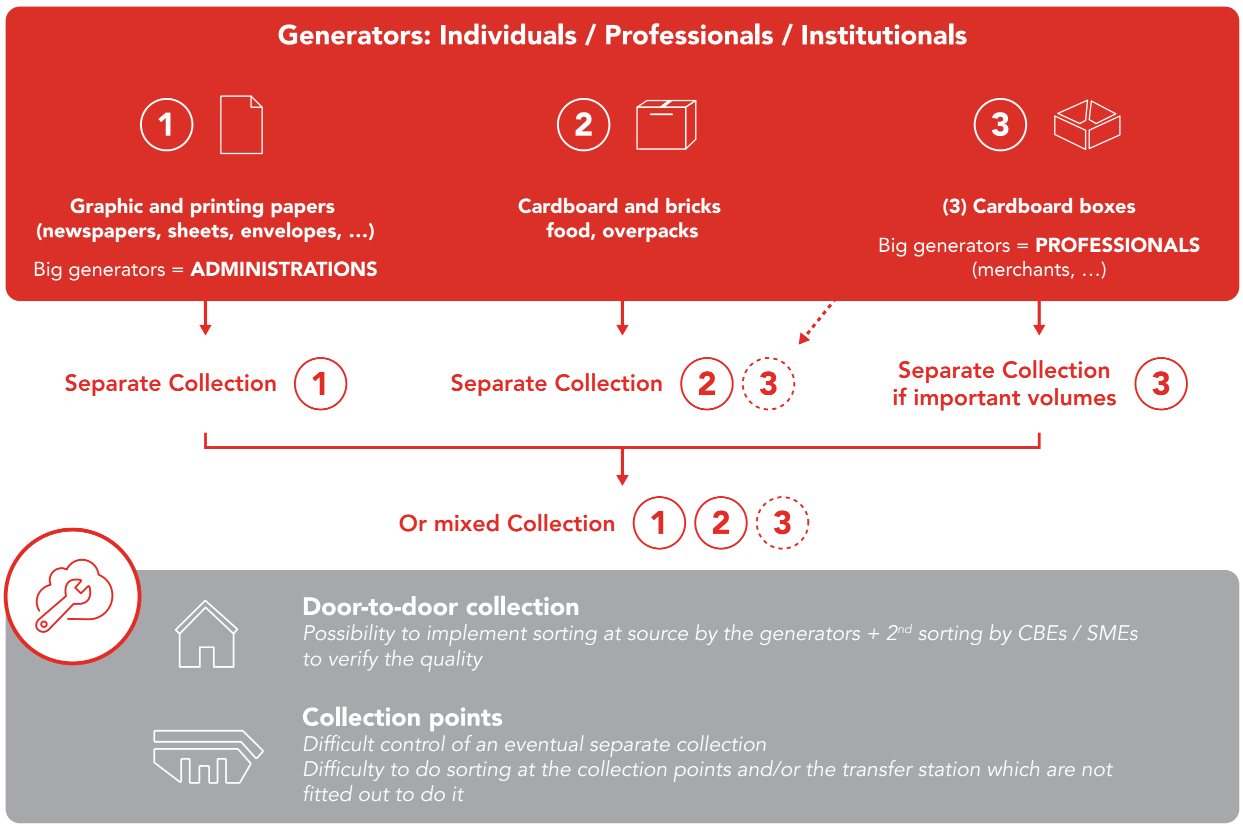
This study identifies four recycling value chains as relevant to the Greater Monrovia context:

- Pre-treatment (baling) for exportation (1)
- Integration in composting and soil covering process (2)
- Production of combustible splints (3)
- Production of materials for the building sector and other goods such as containers for eggs (as SPMC, in Cameroon) (4)

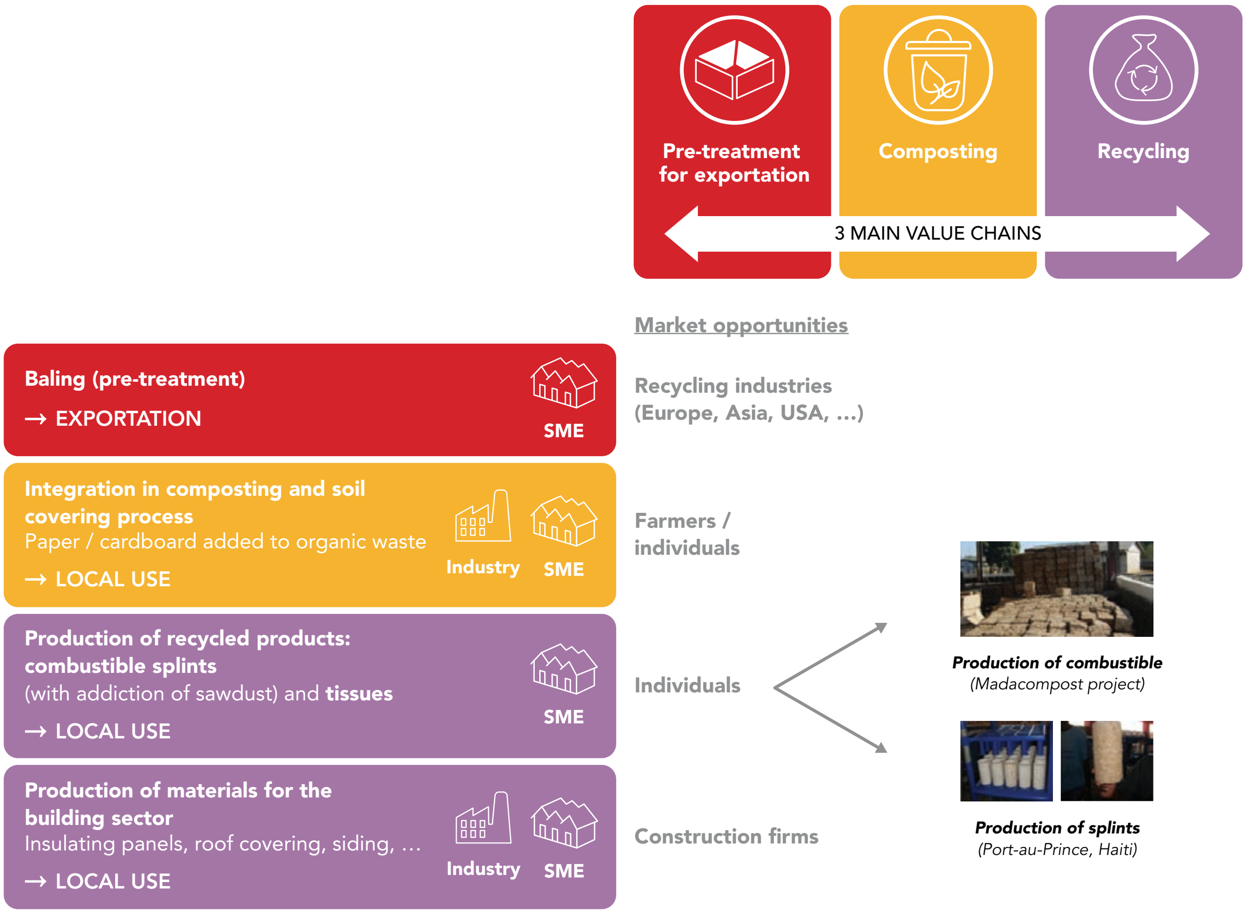
The value chains are presented in Figure 20, which illustrates the different stages of the paper/cardboard value chains: generation, collection/transport, recovery/treatment, and market opportunities.

FIGURE 20: Illustration of the two main value chains of paper/cardboard recovery adapted to Greater Monrovia context

(a) Generation and Collection



(b) Focus on paper/cardboard market and recycling opportunities



<u>Collection:</u>

As detailed in the first scheme (a), collection of paper/cardboard can be done in various ways:

- Paper/cardboards (and low volumes cardboard boxes) collected separately; or
- Papers and cardboards (and low volumes of cardboard boxes) collected jointly.

The cardboard boxes can be collected with the cardboard stream if the amount is low. In case if important volumes (businesses), it is preferable to collect it separately.

Door-to-door collection enables to collect these streams more easily, because the generators can be asked to do a first sorting at source. Sorting the waste dumped in skip buckets is more difficult.

Recycling/treatment opportunities

After collection and separation of the papers and cardboards from the other waste streams, various recovering activities can be led:

1. Massification, compression and baling of the paper/cardboard for exportation: the materials will be recycled in the countries of exportation (it is not a local recycling value chain).
2. Integration in compost and soil covering processes (the papers and cardboard are added to organic waste): this value chain needs a supply of organic waste (major waste resources needed for the process). The compost can then be sold to farmers (high quantity) or to individuals (lower quantity).
3. Production of combustible splints: this type of production exists in other countries (Madagascar) and is a straightforward process (mixing paper and cardboard with sawdust and needing mostly molds and press). The product is intended to be bought by individuals (at stores of marketplaces) who need combustibles for daily use.
4. Production of materials for the building sectors: roof covering, siding, etc. The final products are bought by construction firms.

To conclude, after collecting paper/cardboard, various recycling opportunities exist:

- *Pre-treatment for exportation (1) is a way of disposing of the paper/cardboard waste streams, which will be recycled. However, it is not a value chain that creates high value from waste locally.*
- *Local recycling and composting value chains (2) (3) (4) create much more value (products sold at a higher price, creation of businesses and employments). However, the composting value chain needs to use a high amount of organic waste.*

3.2.6.2 SWOT analysis of the existing Liberian value chains

FIGURE 21: SWOT analysis for paper/cardboard recycling development

STRENGTHS	WEAKNESSES
Some cardboard boxes are collected and reused (scavengers and individuals). Availability of a high quantity of cardboard at the port of Greater Monrovia, according to Hysaa, which has an agreement with the port for the waste collection and the cleaning.	No initiatives or projects led in any of the value chains. Paper/cardboard hardly separable from the mixed waste if there is no separation at source (dirty and wet when it arrives at the collection point or transfer station). No current demand, only informal and local reuse.

OPPORTUNITIES	THREATS
(1) Existing demand for exportation of paper/cardboard and proximity of the port. (2) (3) (4) (5) Local recycling and composting value chains create high value (products sold at a higher price, creation of businesses and employments). (5) Existence of 2 tissue factories in Greater Monrovia that could potentially be interested in integrating the paper/cardboard waste in their production processes for producing tissues. (1) (2) (3) (4) (5) Households are able to sort at source if asked by the CBEs (and in exchange for financial compensation). (4) Green Cities plans to implement a paper/cardboard recycling process in order to produce containers for eggs.	(1) Exporting and recycling in other countries is a loss of local value. It could create more value with a local recycling process: sales in Liberia and creation of employment. (2) Composting value chain needs a supply of organic waste (not only paper/cardboard), and there are some technical specifications.

(1) Pre-treatment for exportation, (2) Integration in composting and soil covering process, (3) Production of combustible splints, (4) Production of building materials and other goods, (5) Production of tissues

3.2.7 OTHER SPECIAL WASTES

Regarding e-waste, there is one e-waste recycling operator identified in Greater Monrovia. Green Cities has a partnership with the institute Computer for Schools Liberia. The e-waste which can be refurbished has a potential second life. The other e-waste is exported after a manual separation of plastic and metal. Nevertheless, the capacity is not sufficient to ensure the development of the activity, according to the CEO of Green Cities.

Used oil (produced by garages and gas stations) is collected by Edgail Recycling Inc. After decantation and separation of used oil, the aqueous phase and the pasty phases are extracted, and the remaining oil phase is exported to be recycled. The oil regenerated is placed back on the Liberian market.

Medical waste is subject to a specific collection and treatment chain. The hospitals are in charge of the medical waste they generate. The technology used is incineration, in particular to inert infectious waste. For instance, the John F. Kennedy Medical Center in Monrovia has an operational incinerator.

Other special waste is not taken into account in this study.

3.3 Value chain assessment

3.3.1 EXISTING VALUE CHAINS AND EXISTING DEMAND

The kick-off mission helped clarify the existing recycling/composting value chains, and it was decided to include the following waste streams:

- Organic waste (green and food waste)
- Plastic (water bags, films, plastic bottles, hard plastic, etc.)
- Paper/cardboard (graphic and printing papers, cardboard and brick food, cardboard boxes)
- Metals (steel and aluminum cans, food tins, old metal items, etc.)
- Glass

The study found that organic waste stream is involved in one value chain (composting), plastic stream in three value chains (recycling and minimally waste-to-energy and reuse), paper/cardboard stream in one minority value chain (reuse) and glass in one value chain (reuse). (See Table 7.)

Although metal is not subject to local recycling, it is picked up and packaged for exportation, which can be considered as a recycling value chain.

3.3.2 COMPETITION FROM IMPORTED PRODUCTS

Recycled products should face competition from imported products. The Ministry of Commerce and Industry has been contacted about collecting the data necessary to assess the competition from imported products: statistics on importation of plastic goods (bins, buckets, basins, garden furniture, etc.), coal, fuel and gasoline, chemical and organic fertiliser, construction elements (tiles, bricks, interlocking tiles, etc.), toilet paper and tissue.

3.3.3 RANKING OF VALUE CHAINS

A decision-making grid helps prioritise waste components to focus on. The criteria were defined according to available data. Five criteria are used: availability (ease of collecting and separating), quantity, quality, presence of recycling and composting actors/facilities in Greater Monrovia, and demand level. (See Table 8.)

Some criteria that were initially considered, such as existing competition from imported products, were too difficult to assess (data non available) and not included.

TABLE 7: Identification of the current recycling/composting value chains identified in Greater Monrovia

Waste resources	Primary collection	Collection/Transfer/ Transport	
ORGANIC WASTE RECYCLED IN SOLID AND LIQUID ORGANIC FERTILISERS	**Collection on marketplaces or door-to-door** Organic waste is collected: • By individuals at the Red Light market (for Organic Matters) • Door-to-door (businesses) by green cities (or partner CBEs) with separation at source by the generators **Internal waste Collection (BWI)**	**Transport by the SMEs** (Organic Matters or Green Cities)	
PLASTIC WASTE RECYCLING	**Collection by CBEs/SMEs/individuals** Film and low-density plastics except bottles for Duraplast All plastics for Green Cities	**Transport by the collectors** They bring and sell the plastics to Duraplast or Green City production sites.	
PLASTIC WASTE REUSE	**Collection by CBEs/SMEs /individuals and scavengers** PET (plastic bottles)	NC	
PLASTIC WASTE-TO-ENERGY	**Collection by Evergreen and individuals** All types of plastic found in the street	NC	
PAPER/CARDBOARD REUSE	**Collection by individuals/CBEs**	NC	
METALS EXPORT	**Picking up metal and selling to scrap dealers** Scavengers/CBEs/SMEs pick up the scrap metal and sell it to scrap dealers or to their agents.	**Collection/Transport by scrap dealers for high quantity** **Direct delivery by pickers to scrap dealers for lower quantities**	
GLASS REUSE	**Glass deposit-return system (formal):** individuals/collectors bring back the bottles where they bought it (Coca-Cola Company, Club beer, Master…) **Informal glass reuse by individuals** (fences, beverage/oil /fuel containers)	NC	

	Recovery/treatment	Current beneficiaries	Demand evaluation
	Composting and vermi-composting processes **Liquid fertiliser production**	**Sale of the compost** to small farmers and individuals. No big farmers (such as Sandstone) for now. **Use on-site**	High potential demand but not effective because farmers lack knowledge on how to use organic fertilisers and to adapt their agrarian practices. NB: Agriculture represents 70% of the population employed and 40% of the GDP (according the World Factbook of Central Intelligence Agency, 2017).
	Washing/Crushing/ Granulation of the plastics • Production of plastic bags by Duraplast • Production of plastic items by Green Cities: rules, squares, plastic jars, etc.	**Sale of the recycled products** in stores or marketplaces	No industrial recycling facilities except Duraplast, which has reached the highest production capacity, and which was initially dedicated to its own waste recycling. Low prices that discourage the collectors
	Washing	**Return to the market** Bought by marketers to sell home-made beverages/oil/fuel	Informal value chain and small local demand Sanitary risk due to unsecured washing operations.
	Production of fuel	**Sale of the fuel on marketplaces**	High potential but low capacity of production to develop a demand.
	Reuse	**Reuse by collectors**	No current demand, only informal and local reuse Two tissues manufacturers in Greater Monrovia could eventually integrate the paper/cardboard waste into their production processes.
	Pre-treatment for exportation Sorting, baling by scrap dealers (North Star, Universal impex and Edgail)	**Exportation** Bought by metal industries	High demand from international market. Only one scrap dealer buying aluminum cans (Edgail, thanks to the specific baler). Monopoly negatively impacts prices.
	Reuse Cleaning and reuse of the bottles.	**Return to market** Product put on the market again.	Local bottling companies use the deposit-return system. There is no bottle manufacturing process so broken glass bottles and other glass waste cannot be recycled.

TABLE 8: Criteria description

Availability of the waste	**Description**	**Ease of collecting and separating**
	0/3	Not available/No collection possible for the waste stream
	1/3	Availability limited/Low easiness to collect separately
	2/3	Medium easiness to collect separately
	3/3	High easiness to collect separately
Quantity	**Description**	**Potential stockpile regarding the waste generation**
	0/3	Mark = (Volume evaluated/Volume the most important) * 3
	1/3	
	2/3	
	3/3	
Quality	**Description**	**Quality of the stockpile to be recycled/composted**
	0/3	No value/No possibility to recycle it
	1/3	Possibility to recycle, but produces low-quality product
	2/3	Value but requires considerable sorting and cleaning to have a good quality stockpile
	3/3	High-value waste possible to recycle without important preparatory operations (only one sorting)
Existing actors	**Description**	**Presence on the market of recycling/composting actors**
	0/3	No existing and lasting actors
	1/3	Existing young actors doing experimentation
	2/3	Few/one existing actors monopolising the market and/or with operators expressing the will to investigate the market
	3/3	Several existing actors established for over 3 years
Demand	**Description**	**Assessment of local demand based on actor's declaration/ assessment**
	0/3	No demand
	1/3	Low demand regarding the current system (ex: returnable deposit system for glass bottles)
	2/3	Medium demand due to the importance of the export
	3/3	High local demand/needs materials of some industry to produce more or to improve the process (ex: farmers need organic fertiliser to renew/ take care of the soil and improve the growth of their plots)
Gender	**Description**	**Capacity to develop directly and indirectly activities managed by women and their revenues**
	0/3	No impact on women's employment or development of their activities and revenues
	1/3	No or low impact on women's employment, but potential impact on revenues by the sales of new products

Gender	Description	Capacity to develop directly and indirectly activities managed by women and their revenues
	2/3	Medium impact on women's employment or women's revenues
	3/3	High direct and indirect impact on women's employment and revenues

TABLE 9: Scoring and ranking of the recyclables

	Availabi-lity	Quantity	Quality	Actors	Demand	Gender	Total	Ranking
Paper/ cardboard	2	2	2	0	0	1	**7**	**4**
Glass	1	0	2	1	1	0	**5**	**5**
Metals	1	0	2	2	2	0	**7**	**3**
Plastics	2	3	2	3	3	2	**15**	**2**
Clean organic waste	3	3	3	3	3	3	**18**	**1**

The results (scoring and ranking) of the studied waste flows (or recyclables) are presented in Table 9. No coefficient was applied to the criteria. Each criterion has the same weight in the recycling/composting potential assessment.

Availability: Clean organic waste obtains the highest mark because it is easy to collect separately at the marketplaces. There is no comparable location that concentrates or generates high quantities of paper/cardboard and plastics. The separate collection of these waste flows is thus more difficult than for clean organic waste. The mark related to the availability of paper/cardboard and plastic waste was therefore downgraded.

Quantity: For the second criterion, the mark is proportional to the quantity generated. Clean organic waste again receives the highest mark, with glass and metals (ferrous and non-ferrous) receiving the lowest.

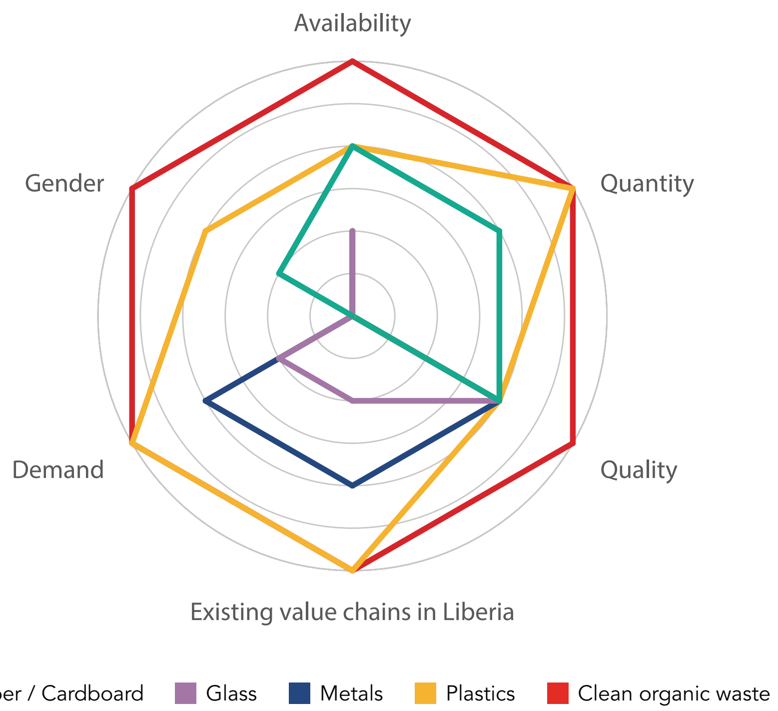
Quality: Clean organic waste, collected separately at marketplaces, can be composted/recycled without big sorting operations, and therefore receives the highest mark for quality. For paper/cardboard, plastics, metals, and glass – which are generally collected at the collection points, the transfer station, or the landfill site – the cleanliness is downgraded and requires washing operations. To facilitate the recycling of these waste flows, they have to be sorted by colour, fiber (for paper/ cardboards), or polymers/monomers (plastics).

Actors: Currently, there are existing and emerging actors involved in recycling and composting activities in Greater Monrovia for plastics and organic waste. For metals, there is no recycling actor, but there are intermediaries making massification and export. The mark for metals is thus lower than those for plastics and organic waste.

Demand: The demand was assessed based on solid waste management actors' declaration. According to them, the demand is higher for organic waste and plastics than for the other waste flows. Agriculture is the largest sector of Liberia's economy, and organic fertiliser is an opportunity to increase soil fertility. For metals, there is demand for export, but only one actor is able to bale household metals (mostly cans and cups) and the demand is limited to the capacity of this actor.

Gender: The development of composting activities could impact, directly and indirectly, the employment and the revenues of women in Greater Monrovia. Women might be hired to prepare waste, to process it, to manage the demo-farm, or to sell final products in the markets. Women would also be positively impacted by securing and increasing their crops, which would impact their revenues. According to a 2011 report on gender dimension in Liberia by LISGIS, although men are believed to be the main actors in agricultural activities, women's active involvement in agriculture is important. In 2008, females constituted half of the agricultural workforce in Liberia. Women might also be hired for the sorting and the washing operations necessary for preparing plastic waste for recycling. Similarly, paper/cardboard recycling activities could create women's employment considering the necessary sorting operations (colour and fiber).

FIGURE 22: Ranking of waste flows according to their recycling/composting potential



According to the ranking grid, the two priority waste fractions are unquestionably clean organic waste and plastic waste. Therefore, this report will focus on the relevant activities/value chains to develop in order to recycle/compost these waste flows.

4. RECOMMENDATIONS AND IDENTIFICATION OF PRIORITIES

4.1 Waste collection organisation

4.1.1 WASTE GENERATORS TARGETED

The targeted waste flows are organic waste and plastics in view of their availability, the quantity and quality of the considered stockpiles, the existing and emerging actors, the local demand and the potential positive impact on women's employment and revenues.

There are several possible value chains for both these waste flows. Each value chain has to be considered in its entirety, link by link, from the source (preparation by generators) to the sale of the final manufactured products.

Identifying the main big generators sheds light on an important quantity and can help improve quality of the waste collected by awareness and coaching. It is the ideal pilot project to improve the process and collection modalities before extending them to other generators, such as households, which are numerous and more difficult to monitor for quality.

The interviews conducted for this study confirmed this approach. Several CBEs already tried to implement separate collection at source of plastic and organic waste, but the low quantity and quality of waste collected resulted in low purchase prices.

Some SMEs, such as Hysaa, Green Cities and Organic Matters, have chosen this option and confirm the higher quality obtained. If some of them have their own recycling activities, the blocking point for collection operators as Hysaa is finding outlets with sufficient recycling capacity to absorb the quantity of waste collected and sorted at source. Green Cities and Hysaa have stopped developing separate collection, instead waiting for recycling facilities.

It appears more efficient to implement recycling/composting value chains according to the following temporal phasing:

1. Collection at source of the major waste generators – available/easy to collect, in high quantity and quality waste flows (marketplaces, businesses)
2. Integration of the household waste flows collected by CBEs, sorted at source by household, with a consistent awareness campaign

Extension of the separate collection systems has to be gradual, in particular by first targeting some pilot districts and/or focusing on specific categories of waste generators.

4.1.2 MIXED COLLECTION VS. SEPARATE COLLECTION

Collection is the first and necessary step for any solid waste management value chain. An adapted collection system is the starting point for implementing recycling/composting activities and has to fulfil the following requirements:

- Provide **a high quality of the waste flow** targeted for the recycling/composting processes:
  - Cleanliness, to reduce the expensive, time-consuming steps of washing and cleaning
  - Low quantity/absence of unwanted waste, in order to minimise the effort needed during the inevitable second sorting
  - No contamination (absence of toxic elements)
  - Protection from degradation due to bad weather
- Enable collecting **enough quantity of the solid waste flow** targeted.

Two types of collection can be implemented: **mixed collection**, which implies a later sorting at the collection point or the transfer station; or **separate collection** done **at source** by the waste generators. The capability of mixed and separate collection to give access to a high quality/quantity waste flow is detailed in Table 10.

In conclusion, it clearly appears that separate collection at source allows having a **higher quality** of waste collected, mainly due to better cleanliness and reduced quantities of unwanted waste. It reduces the direct costs related to the second sorting (the work is "partly done" by the generators) and to the washing and cleaning. As a result, it increases the profitability of the recycling/composting value chain. Furthermore, the higher quality of the collection implies less waste is refused for recycling/composting processes and so there is a higher quantity of available waste.

Considered non-profitable, mixed collection is not recommended. The only collection system considered in the scenarios is the sorting at source of the waste flows by the waste generators (individuals and businesses). The scenarios of the feasibility study will relate to the practicable processes and market opportunities linked to recycling and composting.

TABLE 10: Comparison between the different types of collection

Criteria for collecting a high quantity and quality of waste flow	Mixed collection: No separation of the targeted waste flow by the generators	Separate collection: Separation at source of the targeted waste flow by the generators
Cleanliness/Pollution	– – Plastic waste: The plastic is heavily soiled by the other waste flows, in particular by degradable waste. Organic waste: The presence of hazardous waste in mixed waste could pollute organic waste and consequently the soil and crops benefitting from the compost.	+ + + Plastic waste: The separation at source reduces plastic waste dirtiness and the **financial and human assets** deployed for the cleaning. Organic waste: Separate collection is the better way to avoid pollutants in the compost.
Low quantity of unwanted waste	– – Plastic waste: The waste flows are mixed up, which implies an expensive, time-consuming, and lowest-quality sorting. Organic Waste: The previous remark is valid for organic waste, in particular for glass residue which could injure farmers/beneficiaries and thus negatively impact compost consumption.	+ + + Plastic waste: A second sorting is inevitable, but the separation at source reduces the **financial and human assets** deployed for this sorting. Organic Waste: A second sorting will not be sufficient to extract some components, such as glass residue. Separate collection is the better way to ensure a high-quality compost and to avoid unwanted elements.
No contamination	– The risk of contamination is high due to contact with other waste flows.	+ The separation reduces the risk of contamination.
Protection from degradation due to bad weather	+ Communication can be done regarding the protection of the waste (in particular organic waste) from bad weather by individuals/businesses.	+ Implementing a sorting at source can be the occasion for communicating more about protection of the waste flows (in particular organic waste).
Quantity of waste collected	There is no significant difference between the collection systems regarding the quantity of waste collected. However, in the case of separate collection, the quality of the waste is higher; less waste is refused and thus more is available for recycling/composting processes.	

4.1.3 MATERIAL REQUIREMENTS

As noted above, collection has to ensure a high quality/quantity of waste flows targeted for recycling/composting. To guarantee a high quality of waste collected, the organisation of the collection may fulfil some essential requirements, detailed below.

Adequate vehicles

Vehicles have to be:

- **Covered** in order to avoid degradation of the waste flows collected
- **Adapted** to the roadway: it implies a necessary coordination with urban services to ensure the accessibility of the roadways

The vehicles should preferably be motorised to collected a high quantity of waste, ensure an efficient , and improve working conditions,.

Appropriate collection schedules

Waste collection schedules have to be drawn up to reduce the number of kilometers travelled and the travel time, avoiding traffic jams as much as possible. Evening or night collection, when the amount of traffic is low, is recommended.

It is recommended to study carefully road traffic in Greater Monrovia in order to optimise the collection schedules.

Transport optimising by increasing the waste density

In order to optimise the transport and associated costs, the collection operators could make beneficiaries aware of how to increase the density of the waste and reduce volume in the dedicated bins. Evacuating air from the plastic bottles or folding packaging are some examples of waste density optimising.

4.2 Recycling/composting processes

Technologies chosen for sorting, recycling and recovery must comply with main international directives, best practices, and international conventions (Basel, Stockholm). Some technologies have been proven through a significant number of projects all over the world. In the particular context of Greater Monrovia, more empiric technologies for treatment can be envisaged, provided environmental and economic safeguards are verified.

4.2.1 COMPOSTING/VERMICOMPOSTING ACTIVITIES

Composting is the process of biological transformation of organic materials (green waste, food waste, manure, etc.) under aerobic conditions, producing a compost for agriculture use.

Composting is applicable to a wide range of organic wastes. Residence times are typically longer for ligneous components and woody waste.

Waste accepted in composting units is household or similar waste, non-hazardous, mainly composed of putrescible/compostable organic waste. Non-compostable waste is removed by sorting at source (done by the waste generators) or by sorting on the composting unit. (See Table 11.)

Compost is a soil improver, rich in organic matter, that stabilises the structure of agricultural soils (role of physical fertiliser). Compost also has a secondary function of organic fertiliser (role of chemical fertilizer with NPK and micronutrients for plants). This product has three major characteristics:

- Constancy of composition, or the stability and invariability of the product
- Agronomic effectiveness (under good conditions of use)
- Safety (with regard to humans, plants, animals and the environment), or the absence of sanitary risks in terms of pathogenic germs, parasites and seeds of weeds, or various pollutants (such as heavy metals, synthetic organic pollutants).

TABLE 11: Compostable and non-compostable waste

Compostable	Non-compostable & Non-hazardous	Non-compostable & Hazardous
Food waste (household, businesses, agro-food industry, etc.), green waste (from garden, public green areas, etc.), organic waste from marketplaces, water plants (seaweed, water hyacinth, etc.), paper/cardboard, crop waste, manure, animal residue (bones, horns, rumen, etc.), etc.	Plastics, textile, metals, inert waste (glass, stones, earth, sand, dust, etc.), packaging, etc.	WEEE (waste of electrical and electronic equipment), aerosol, batteries, chemical products, and contaminated packaging (such as phytosanitary products, paint cans, etc.), healthcare waste (medicine, needles, etc.)

The primary function of composting plants is to treat organic waste to reduce the associated nuisance. Moreover, the compost produced has to be a high-quality fertilizer in order to ensure farmer compliance and sales. Thus, the collected and treated waste must be rich in fermentable matter. That is why unit operators target specific waste generators (such as marketplaces, agro-food industry or farmers) and do co-composting of waste, integrating a combination of several types of waste in the process to balance the compost quality, in particular very carbonaceous or very nitrogenous waste.

TABLE 12: Carbonaceous and nitrogenous characteristics of waste

Waste	Ratio C/N	Nitrogenous waste	Carbonaceous waste
Household waste	35 - 80	●	●
Green waste	200 - 800		●
Leaves	40 - 80		●
Vegetables & Fruit waste	10 – 50	●	
Manure	2-4	●	

Source: Decentralised composting for cities of low- and middle- income countries, a users' manual, Eawag/Sandec & Waste Concern, 2006.

Figure 23 presents a synthesis of the waste which could be integrated in the composting/co-composting/vermicomposting processes. Compost produced by vermicomposting or co-composting is generally richer in nitrogen and nutrients. Vermicomposting requires controlling the segregation of citrus fruits, garlic and onions, animal manure, as worms have a limited tolerance for these components.

Various operators have experimented with co-composting:

- Brooklyn Washington Institute (BWI), in Liberia, co-composts food and green waste generated by the institute with animal manure.
- Madacompost, in Madagascar, co-composts the contents of household waste with rumen. The rumen accelerates the process of degradation. However, special measures have to be taken to control of odors and ensure hygienic conditions.
- ENPRO, in Lomé, regularly co-composts household waste with agro-food waste from fruit juice production companies. Companies are seeking a solution for managing their waste and financing their supply of waste on-site. The resulting compost is richer in organic material. This Togolese operator has conducted some conclusive tests of co-composting of the distillers' grains (production residue of the breweries) and water hyacinths. The experiments were not renewed because of the high access costs (pickup, purchase, transport).

The composting process is schematised in Figure 24. There may be variants to this process, which could also be applied to manual composting units and industrial mechanised plants.

FIGURE 23: Waste integrated in composting/co-composting/ vermicomposting processes

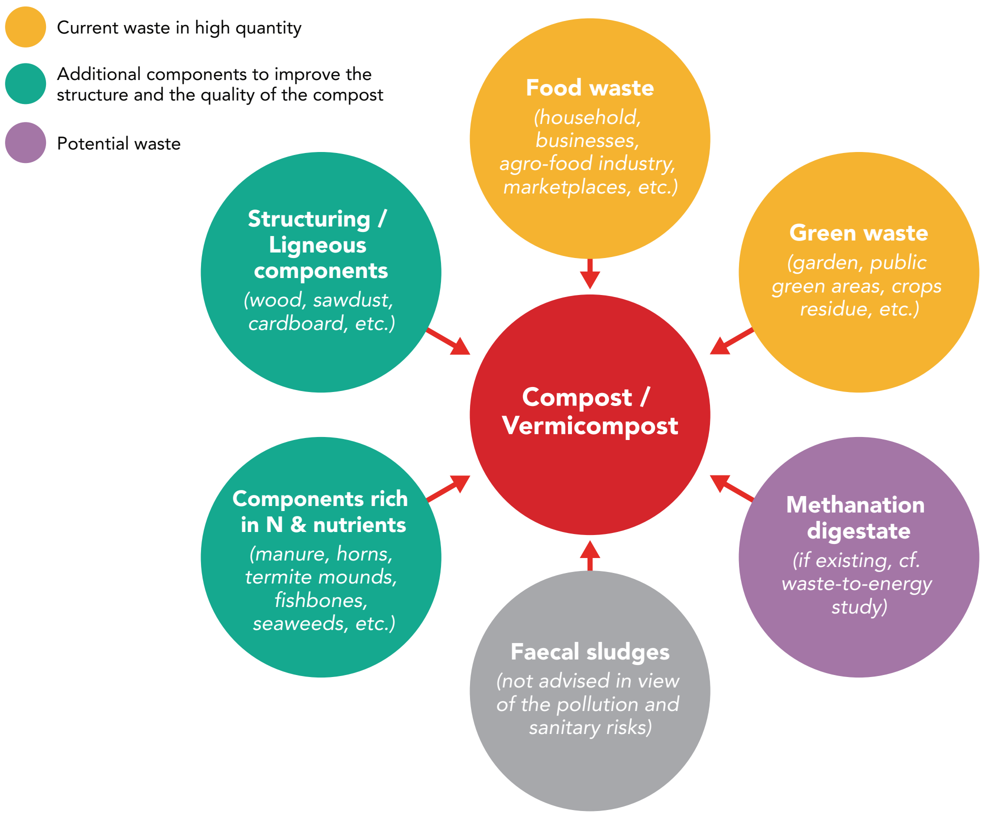
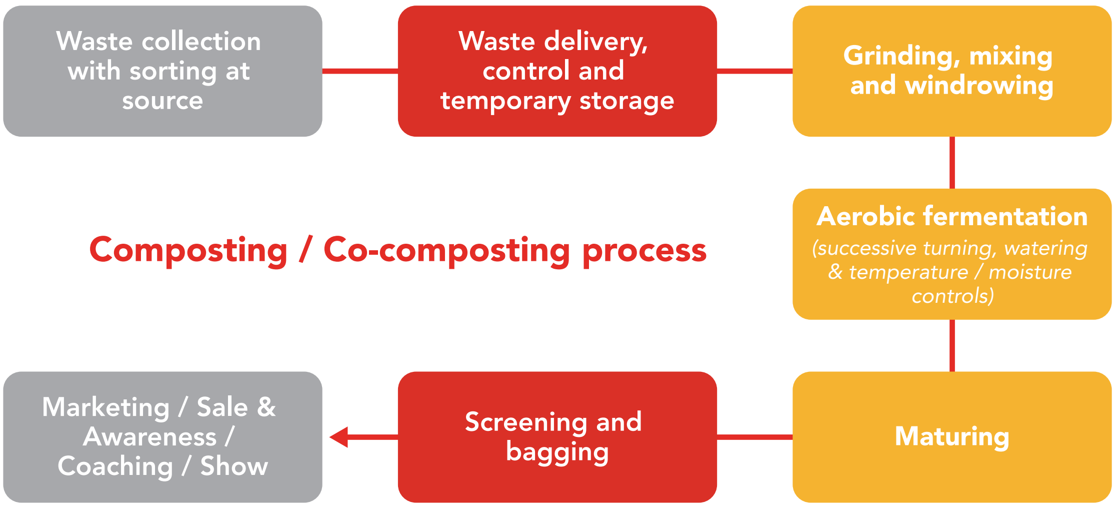


FIGURE 24: Composting/co-composting process steps



Grinding, mixing and windrowing	Waste can be crushed roughly before being windrowed. Grinding increases the ratio surface/mass and promotes the activity of microorganisms. Grinding mixed household waste is not recommended (risk of crushing glass, plastics, batteries, etc.). The quality of sorting ensures the absence of undesirable elements (only presence of putrescible components) for effective grinding. The presence of glass in the grinding product leads to premature wear of the grinders. Grinding is particularly useful for the ligneous fractions of organic waste, such as wood, which is more difficult to biodegrade, but which is useful as a structuring agent favoring aeration of the windrow. Grinding is recommended upstream from vermicomposting process to facilitate the worms' work. Waste is put in windrows (circular or in length) to allow fermentation and maturation of the organic matter. The production of windrows in length saves space. However, for low capacity units, circular windrowing can be sufficient. A windrow gathers sorted waste for up to 2 or 3 days.
Fermentation	The fermentation phase is the first phase of composting. During this phase, the most easily biodegradable organic matter is converted into carbon dioxide and water, under the action of microorganisms initially present in the waste. This activity is characterised by a strong rise in temperature (hence the term hot fermentation), a loss of moisture, and high oxygen consumption. Therefore, this phase requires control of humidity, temperature, and air supply. Aeration can be done by turning or air insufflation. Insufflation can be done passively using a perforated pipe that runs through the windrow or forced by a mechanised ventilation system. The insufflation systems are not currently used in low- and middle-income countries. For vermicomposting, the windrows have to be covered (by banana leaves or cardboard), in order to retain moisture and protect worms. Duration of the fermentation phase lasts from 1 to 3 months, depending on type of waste and climate conditions. *NB: Anaerobic composting is a waste-to-energy process which allows the production of biogas from putrescible waste and is not in the scope of this study.*
Maturing	Also done in window form, the maturation of the compost does not require any reversal of the material (passive aeration is sufficient because the need for aeration is less than in the fermentation phase) or watering during the necessary period required for stabilisation. The duration of maturing is around 1 month.

Some operating points:

- Sorting at source is a way to reduce the cost of producing compost and reduce risks associated with hazardous waste, but it is very difficult to integrate into the habits of urban populations.
- Some 10,000 tons of waste per year can be composted without mechanisation, according to the Africompost programme.[3] For higher treatment capacity, partial mechanisation is strongly recommended.
- For medium and large-scale composting, large areas in the middle of the city are necessary. It is also important not to neglect the necessary proximity to the beneficiaries (in particular farmers, located in periphery of the city).

4.2.2 VERMICOMPOSTING

There is an alternative to increase fertilising qualities of the compost – a natural digestion of the organic waste by earthworms. The specific steps of vermicomposting process are outlined in Figure 25.

Vermicomposting requires the following process:

- Mixing carbonaceous and nitrogenous waste (after a preliminary grinding step) in the right proportions
- Preparing the bed by providing shade, completely removing surrounding vegetation, and sweeping away plant debris that might serve as food and induce the earthworms to migrate outside
- Filling the bed with the appropriate organic materials[4] and covering the pile with plastic sheets (or any substitute materials, such as banana leaves) to conserve moisture and heat.
- Controlling the temperature and moisture to introduce earthworms after a rapid increase of the temperature (around 35°C), followed by a gradual decrease (almost 15 days after filling the bed).
- Adding components to prevent excessive loss of moisture (such as coconut coir dust or grasses) and covering them with a nylon net (or any substitute material, such as banana leaves) to serve as a barrier against birds and other earthworm predators.
- Maintaining sufficient moisture and aeration.

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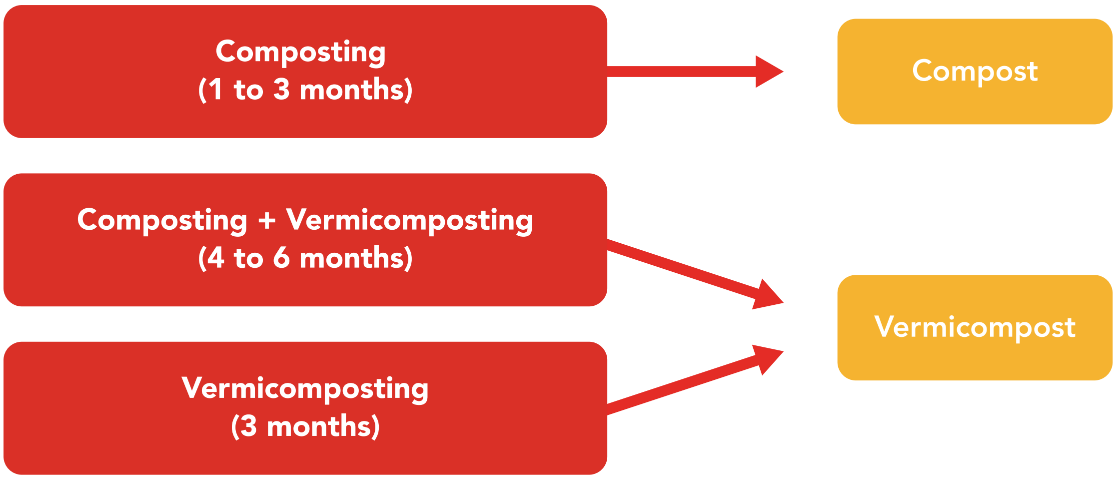
[3] Africompost is financed by the Agence Française de Développement (AfD) and the French Global Environment Fund (FFEM).

[4] The size of the pile can vary but in general, a volume of at least 1 cubic meter is desired to allow thermophilic heating. A pile 1 m wide, 2 m long and 0.5 m high will have this volume.

FIGURE 25: Comparison of the duration of composting/vermicomposting processes



4.2.3 GREEN COAL PRODUCTION

Wood energy remains the main source of cooking energy in sub-Saharan Africa, with a representation of 75% of household energy consumption. Green coal is an attractive alternative to wood energy. The green coal is produced from carbon-rich biodegradable residues, mainly from agricultural and household residues. It comes in the form of briquettes or balls, in a size compatible with ovens used in southern countries.

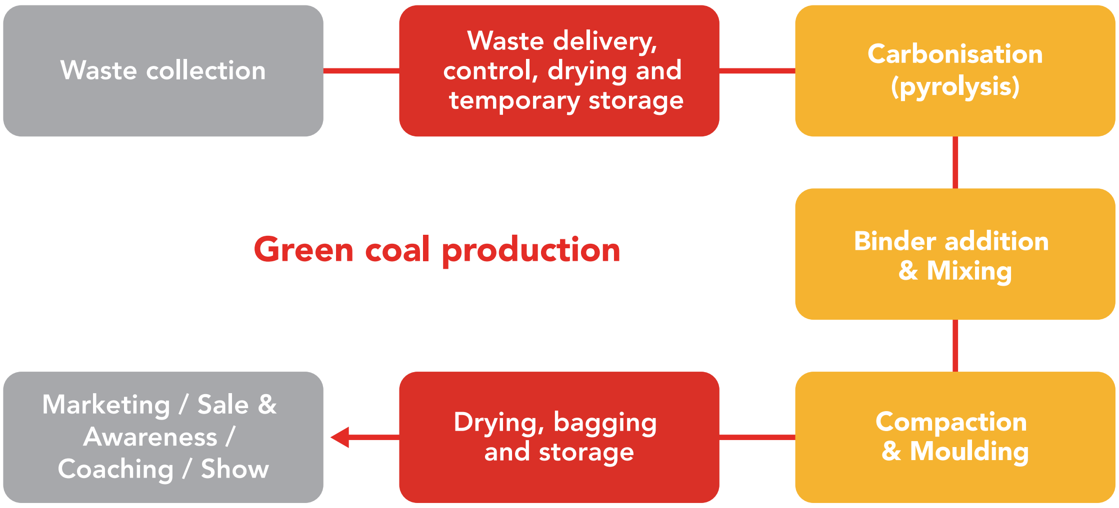
It is necessary to be careful with waste used to produce green coal. Not all residues give the same quality of coal; some (like plastics) can produce a coal that is toxic for users. The most interesting waste to make green coal is organic residue, such as peelings from bananas, cassava, and ears of corn.

The following figure presents the waste which could be integrated in the process of green coal production. The sources of supply for green coal production are the same as for compost production. It is therefore necessary to ensure a complementarity between both value chains without competition.

The green coal production process is schematised below. Variants to this process may be encountered. This process might be applied for manual and industrial mechanised plants.

FIGURE 26: Current waste used to produce green coal

FIGURE 27: Green coal production process



Carbonisation	Preliminary drying step for the organic waste is necessary to ensure good carbonisation. Carbonisation is the thermal decomposition of organic waste. Various types of equipment are used for this step. Small-scale producers use simple ovens built from recycled iron cans/barrels. Producer groups can have access to equipment with greater capacity and better control of combustion. Large green coal production companies have mechanised equipment. After carbonisation, coal dust has to be dried and sieved (in general manually). The grinding of the raw material (coal after or biomass before carbonisation) is motorised in the majority of projects encountered.
Binder addition & Mixing	The residues obtained from the pyrolysis are generally in powder form. This powder is mixed with a binder to allow compaction. The main binder used is cassava flour, but it would be interesting to produce a binder from waste (banana peelings for example). Clay is also a good binder for the composition of green coal, as it increases the burning time for briquettes. The mixing can be manual or motorized, depending on the desired production capacity. Small facilities do the mixing with shovels in a wheelbarrow or on the ground when cemented. The higher production capacity facilities are passed to motorised mixers. Most work with adapted concrete mixers, which allow easy access to spare.
Compaction, Molding, Drying	Once the mixing done, it is necessary to carry out the molding of the briquettes. There is limited time to make the briquettes once the mixing is complete; it is not possible to leave a mix on hold and come back later to make the briquettes. Compaction is intended to reduce the level of moisture to improve the combustion of briquettes. It can be done with the help of a manual or industrial press, depending on the level of mechanisation chosen. The choice of press depends on the desired production capacity. An important aspect of this step is the choice of shape for the briquettes and level of compaction. The level of compaction, which will directly affect the rate of burn, will be less homogeneous with manual compaction than with mechanical compaction. Drying can be done in the open air in regions with low rainfall.

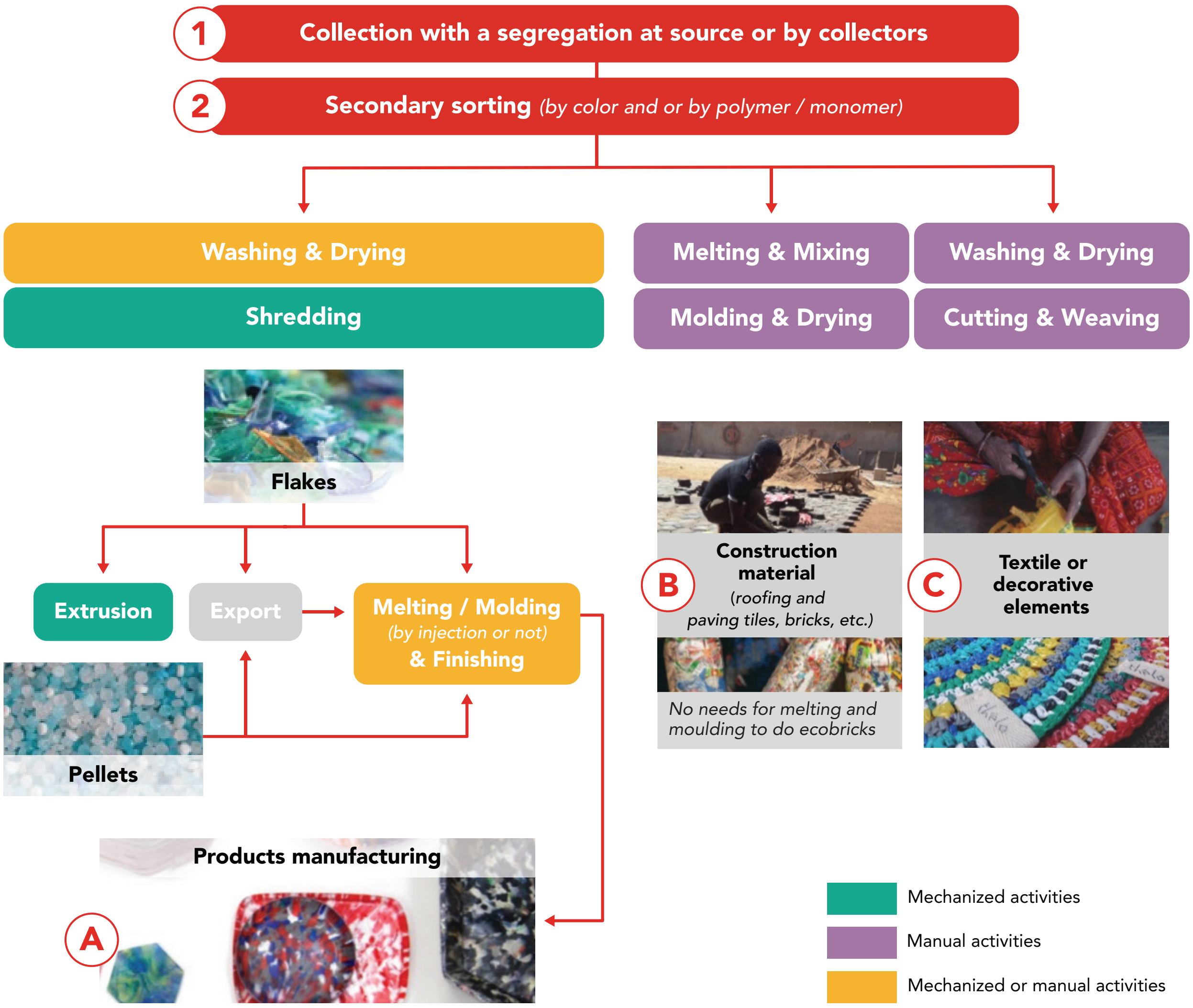
Green coal production has environmental benefits: The wood resources are preserved, and the fuel is a renewable, abundant energy and neutral in terms of carbon cycle. It also has economic and social benefits. Green coal is almost two times cheaper than fossil coal over time. While green coal is more expensive at acquisition, it lasts longer than traditional coal, and so decreases related costs over time.

4.2.4 PLASTICS RECYCLING

Plastic waste-to-energy value chains, such as fuel or Solid Refused Combustible (SFR) production, are not studied in this report. A specific study about the development of waste-to-energy activities from municipal waste is ongoing. Nevertheless, the development of the plastics value chains needs to be coordinated in order to ensure the value chains are complementary and not in competition.

Three main value chains are considered here. Figure 28 presents the related recycling processes.

FIGURE 28: Recycling activities value chains



As explained previously, it is recommended to segregate plastic waste at source in order to reduce the sorting and washing activities, and thus related costs.

Data for local plastic products manufacturing and importation are not available. It is therefore difficult to know if it is possible to introduce recycled plastics into the current industry. Export is, however, not recommended due to current worldwide difficulties in plastics recycling.

It is possible to manufacture plastic goods locally without high mechanisation. The Dutch company Precious Plastic[5] developed a system that can be exported and offers support to facilitate replication in other territories.

It is recommended to mechanise the melting activities to capture smokes, which are characterised by a high pollutants content. If this activity is managed manually, it is necessary to ensure that sanitary measures are taken to secure working conditions.

The production of ecobricks, textiles, and decorative elements have no negative impact on the environment. The profitability of these activities is unknown, but there is no need for investment or specific skill requirements. These activities are reachable by everyone, especially those with difficulty accessing the labour market (such as women and youth).

The cost of integrating recycled plastics into construction elements and household goods, such as tiles and bricks or bins and buckets, is lower than traditional products.

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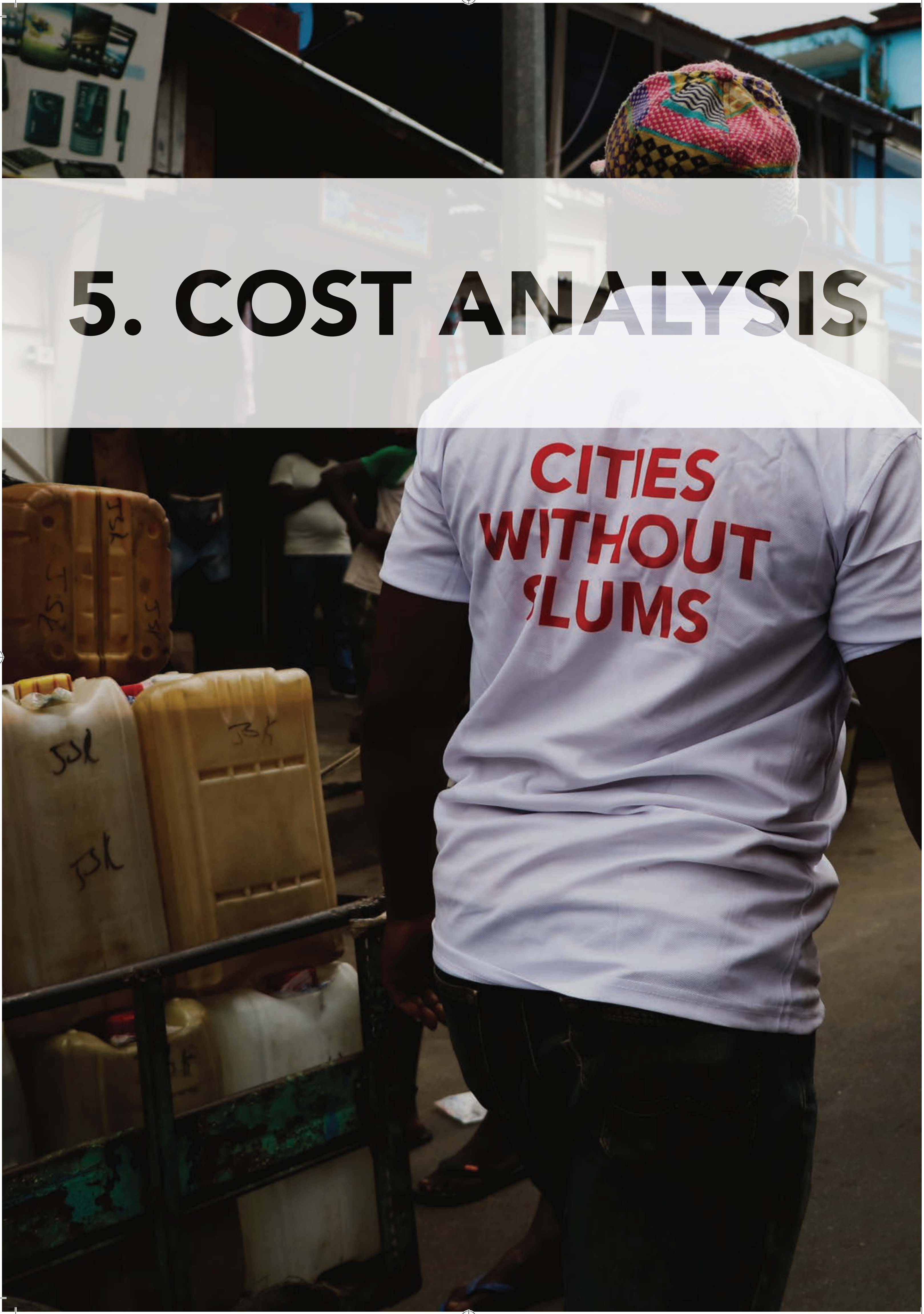
[5] https://preciousplastic.com/

5. COST ANALYSIS



This section describes the technical and human resources needed for the different recycling/composting processes presented previously. It also provides cost estimates and a tentative profit and loss analysis for the development of each composting/recycling activity.

This analysis should be considered preliminary, to be completed, amended and detailed in specific feasibility studies.

See the Annex for details on the basic assumptions.

5.1 Composting/co-composting (manual) and vermicomposting

5.1.1 HUMAN RESOURCES

On average, 0.2 FTE are needed per ton collected per month for composting (and 0.3 for vermicomposting). Most staff are involved in production. The distribution of time for collection, production and marketing is estimated at 20% for collection, 60% for production, and 20% for marketing.

5.1.2 TECHNICAL RESOURCES

Collection

8 m^3 truck for collection and deliveries
Prices ~ USD 60,000 - 90,000

One truck can collect up to 200 tons per month. Above 200 tons, a second truck is needed.

Production and marketing

An 8 m^3 truck can transport 10 tons of compost per trip.

At least 12 m^2 of surface is needed per ton of organic waste treated per **month.**

5.2 Mechanical composting

Mechanical composting is relevant and profitable; more than 10,000 tons of compost are treated every year (at least 830 tons per month).

5.2.1 HUMAN RESOURCES

For processing 10,000 tons of waste per year (830 tons per month), it is estimated that more than 25 FTE are needed (0.03 FTE per ton treated per month).

5.2.2 TECHNICAL RESOURCES

Collection

20 m^3 truck
Purchase prices ~ USD 110,000 - 160,000

One truck can collect up to 600 tons per month. For collecting between 600 and 1,200 tons (recommended for a profitable activity), two trucks are needed. Above 1,200 tons per month, a third truck is needed.

Production and marketing

Building and infrastructures with enough space	Mechanical composting plant with is the combination of a conveyor belt (facultative), a shredder, a screening plant and a turned windrow equipment	20 m^3 truck for bags deliveries	20 m^3 hookloader for bulk compost deliveries	Truck loader
Building costs ~ 8.50 USD / m^2	**Prices ~ 200,000 - 240,000 USD**	**Purchase prices ~ 110,000 - 160,000 USD**	**Purchase prices ~ 110,000 - 160,000 USD**	**Purchase prices ~ 110,000 - 140,000 USD**

A 20 m^3 truck can transport 25 tons of compost per trip.

Utilisation of a turned windrow equipment is needed to treat 25,000/30,000 tons per year. It can be used for 10,000/15,000 tons treated per year, but with less profit.

5.3 Green coal

5.3.1 HUMAN RESOURCES

On average, it is considered that 0.5 FTE/ton treated are needed. Most staff are needed for production. The following repartition between collection, production and marketing is used: 20% is for collection, 50% for production and 30% for marketing.

5.3.2 TECHNICAL RESOURCES

Collection

8 m^3 truck
Prices ~ USD 60,000 - 90,000

One truck is sufficient for collecting until 200 tons per month. Above 200 tons, a second truck is needed.

Production and marketing

Vehicles	Buildings	Equipment
Vehicles for transporting green coal to marketplaces (tricycles or cars) Same truck than for collection	Building and infrastructures with different areas: waste drying area, production process area, green coal drying area,) **Building costs ~ 8.50 USD / m²**	Green coal production equipment **Purchase prices ~ 60,000 - 100,000 USD**

On average, it is considered that the production site should have a size of 50 m² per ton of green coal treated per month.

5.4 Construction materials production

5.4.1 HUMAN RESOURCES

On average, at least 1 FTE per ton of plastics treated per month is required. The majority of the staff is needed for production. The distribution of time for collection, production and marketing is estimated at 20% for collection, 60% for production and 20% for marketing.

5.4.2 TECHNICAL RESOURCES

Collection

It is assumed that in the first instance, no truck is needed (payment of pickers/CBEs for collecting and transporting plastics).

Production

Vehicles for delivering the products **Prices ~ USD 60,000 - 90,000** (8 m^3 truck)	Building and infrastructures with different areas: (waste storage, production process and bags storage) **Building costs ~ 8.50 USD / m²**	Equipment for melting and mixing the raw materials Included in operational costs

On average, the surface of the production site is 80 m² per ton treated per month.

5.5 Plastic pellets/HDPE granulates

Technology for secondary raw plastic material consists of a plant for crushing, washing and melting plastic into rounded small chips. Green Cities is currently studying a project for grinding HDPE, LDPE, PET and PVC. The process is not yet operational, but sorted and washed plastics are stored awaiting the purchase of an adapted equipment.

5.5.1 HUMAN RESOURCES

Refer to human resources for collection presented for the tiles and bricks production value chain.

The distribution of time for collection, production and marketing is estimated at 20% for collection, 50% for production and 30% for marketing.

5.5.2 TECHNICAL RESOURCES

Collection

Refer to material resources for collection presented previously (construction materials: roofing and interlocking tiles and bricks).

Production and marketing

Vehicles for deliveries	Building and infrastructures with different areas: (waste storage, production process and bags storage)	Plastic pellets making machine
Prices ~ 60,000 - 90,000 USD (8 m^3 truck)	**Building costs ~ 8.50 USD / m^2**	**Purchase prices ~ 15,000 - 30,000 USD**

On average, the surface of the production site is 120 m^2 per ton treated per month.

5.6 Other products (plastic items) PP, PEHD, PET

In this process, plastic waste is recycled for manufacturing items including kitchen articles, bins, buckets and basins, garden and urban furniture.

5.6.1 HUMAN RESOURCES

On average, at least 1.3 FTE per ton of plastics treated per month is required. Most staff are needed for production. The distribution of time for collection, production and marketing is estimated at 20% for collection, 50% for production and 30% for marketing.

5.6.2 TECHNICAL RESOURCES

Collection

Refer to material resources for collection presented for construction materials (roofing and interlocking tiles and bricks).

Production and marketing

Vehicles for deliveries	Building and infrastructures	Platic molding machine
Prices ~ 60,000 - 90,000 USD (8 m^3 truck)	**Building costs ~ 8.50 USD / m^2**	**Prices ~ 15,000 - 30,000 USD**

5.7 Synthesis of human and technical requirements

Table 13 summarises the main findings of the technical and human resources required for the different recycling/composting processes presented previously.

These requirements are costed according to a panel of unit cost assumptions and compared to expected incomes resulting from sales of product. The average selling prices from a market overview are:

- Traditional compost (manual composting): US $5 per 50 kg bag
- Vermicompost (manual composting): US $10 per 50 kg bag
- Compost (mechanical composting): US $6 per 50 kg bag
- Green coal: USD 5 per 20 kg bag (US $12.5 per 50 kg bag)
- Plastic tiles: LD 75 per tile (or US $73 per ton sold)
- Plastic pellets/HDPE granulates: US $115 per ton sold
- Plastic items (average): US $600 per ton sold

TABLE 13: Composting processes – resources required

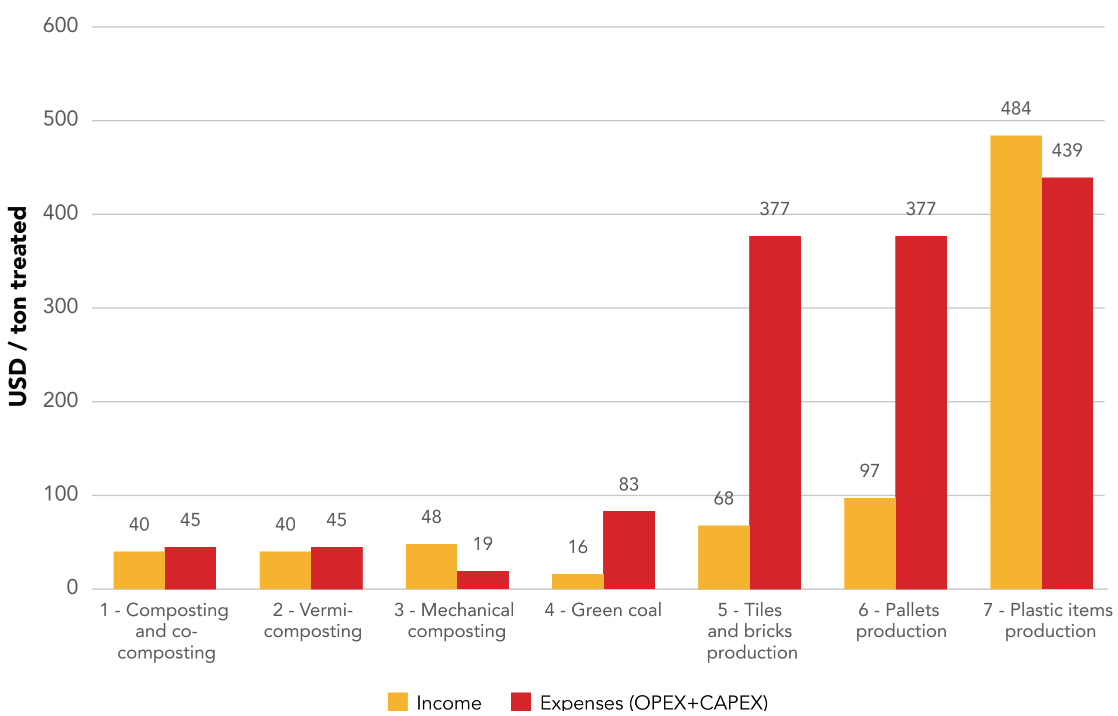
	Composting	Vermicom-posting	Mechanical composting	Green coal	Tiles and bricks production	Pellets production	Plastic items production
Production site surface (m^2 per ton treated per month)	12	12	11	56	79	118	79
Facilities surface (m^2 per ton treated per month)	4.8	4.8	7	28	39	59	59
Construction of the facilities (USD per ton treated per month, including depreciation)	0.2	0.2	0.4	1.3	1.9	2.8	2.8
Human resources (FTE required per ton treated)	0.2	0.3	0.03	0.5	1.0	1.0	1.3

This preliminary analysis indicates that:

- Composting activities could be profitable, even if the expected profit is low. For composting, co-compositing and vermicomposting, provisional expenses are slightly higher than provisional income, but the gap is not significant. Mechanical composting seems to be more profitable than manual composting. Green coal does not seem profitable.
- Plastic recycling is hardly profitable, mainly due to capital expenditure. Expenses to produce tiles and bricks or pellets significantly exceed expected income. The production of plastic items could only be profitable if the items produced are adapted to market demand.

These results must be treated with caution, as some assumptions have to be discussed and cross-checked to be more conclusive. Moreover, indirect benefits from recycling and composting activities must be taken into consideration, such as avoiding transport and disposal cost due to the reduction of waste handled by SWM system.

FIGURE 29: Preliminary profit analysis



6. ORGANIC AND PLASTIC WASTE VALUE CHAIN ASSESSMENT

6.1 Objective and method

According to the priority analysis, the two priority waste components are unquestionably clean organic and plastic waste. Several processes and products result from the implementation of these recycling and composting activities, each with their advantages and disadvantages.

For the different processes and products identified, a ranking analysis is carried out based on five criteria and 15 sub-criteria. Each criterion is noted from 0 to 3 and a weighting factor (1 or 2). The criteria and sub-criteria chosen are listed below.

1. **Ease of implementation and monitoring**
   a. Land needed
   b. Investment required
   c. Awareness of the beneficiaries and waste generators
2. **Adequacy for the demand**
   a. Existence of local demand
   b. Existing competition from local and/or imported goods
   c. Existing actors and maturity of these actors
3. **Environmental impact**
   a. Waste diversion
   b. Recyclability and sustainability
   c. Mitigation measures to implement
4. **Social aspects**
   a. Employment creation
   b. Gender issue
   c. Accessibility of products to disadvantages population
5. **Sustainability of the activity**
   a. Profitability
   b. Flexibility (capacity to develop the activities, diversification)
   c. Institutional aspects (adequacy of the current SWM system and legal and institutional framework)

The following table describes the various criteria, sub-criteria, weighting factors and scoring rules used to assess the relevance of waste value chains.

TABLE 14: Overall ranking matrix

Criteria	Sub-criteria	0/3	
1. Easiness of implementation & monitoring	**1.1 Surface necessary for the recycling facilities**	Mark = 3*Surf. less important/ Surf. Evaluated	
	1.2 Investment necessary to purchase equipment	Mark = 3*Invest less important/ Investment evaluated	
	1.3 Awareness of the beneficiaries & waste generators	Potential beneficiaries not aware of the characteristics and quality of the recycled products and reluctant to buy them & Waste generators not aware of the good practices in favour of recycling activities and reluctant to apply them	
2. Adequacy to the demand	**2.1 Assessment of the local demand based on actors' declaration/ assessment**	No demand	
	2.2 Competition	High competition from local and imported products with a lower price	
	2.3 Existing actors/VC	No existing and lasting actors	
3. Environmental impact	**3.1 Waste diversion**	Mark = (Waste quantity diverted evaluated/ waste quantity diverted the highest) * 3	
	3.2 Recyclability & Sustainability	Single use products with a short life duration	

	1/3	2/3	3/3	Coeff.
				2
				2
	Potential beneficiaries not aware of the characteristics and quality of the recycled products and reluctant to buy them, but waste generators aware of the good practices in favour of recycling activities OR Potential beneficiaries aware of the characteristics and quality of the recycled products, but waste generators not aware of the good practices in favour of recycling activities and reluctant to apply them	Potential beneficiaries aware of the characteristics and quality of the recycled products and waste generators aware of the good practices in favour of recycling activities, but unnecessary additional campaign necessary to ensure efficiency of collection/recycling /marketing activities	Potential beneficiaries aware and convinced of the characteristics and quality of the recycled products and waste generators aware and applying good practices in favour of recycling activities	1
	Low demand regarding the current system/products	Medium demand due to the importance of the export/ current products	High local demand/some industry needs materials to produce more or to improve the process (ex: Farmers need organic fertiliser to renew/take care of the soil and improve the growth of their plots)	2
	Medium competition with prices of the recycled products equal to or higher than traditional products	Medium to low competition with prices of the recycled products lower than traditional products	New products with no competition	1
	Existing young actors doing experimentation	Few/one existing actors monopolising the market and / or with operators expressing the will to investigate the market	Several existing actors established for more than 3 years	1
				2
	Single use products & long life duration OR Low to medium recyclability products (due to the mixing of various materials/polymers) and short life duration	Medium to high recyclability (without materials/polymers mixing) and long life duration	Circular economy approach with an endless recyclability	1

Criteria	Sub-criteria	0/3	
	3.3 Measures to implement in order to mitigate the processing impacts on the environment	High investments necessary to mitigate the impacts on environment (ex: smoke treatment system) and high GHG emissions if the necessary mitigation measures are not taken	
4. Social aspects	**4.1 Employment creation**	Mark = (no. employees evaluated/ highest no. employees) * 3	
	4.2 Gender	No impact on women's employment or development of their activities and revenues	
	4.3 Accessibility of recycled products to disadvantaged populations	Non-essential products with high prices unreachable for disadvantaged populations	
5. Sustainability of the activity	**5.1 Profitability**	Mark = (Profitability evaluated/ Profitability the highest) * 3 If no profitability, mark = 0	
	5.2 Flexibility *(capacity to develop the activities, diversification)*	No possibility to develop the production capacity and to diversify the activities/products with the same facilities (or low additional investments)	
	5.3 Institutional aspects *(adequacy of the current SWM system & legal and institutional framework)*	Legal/institutional framework non-existent/critical & Current SWM system unadapted	

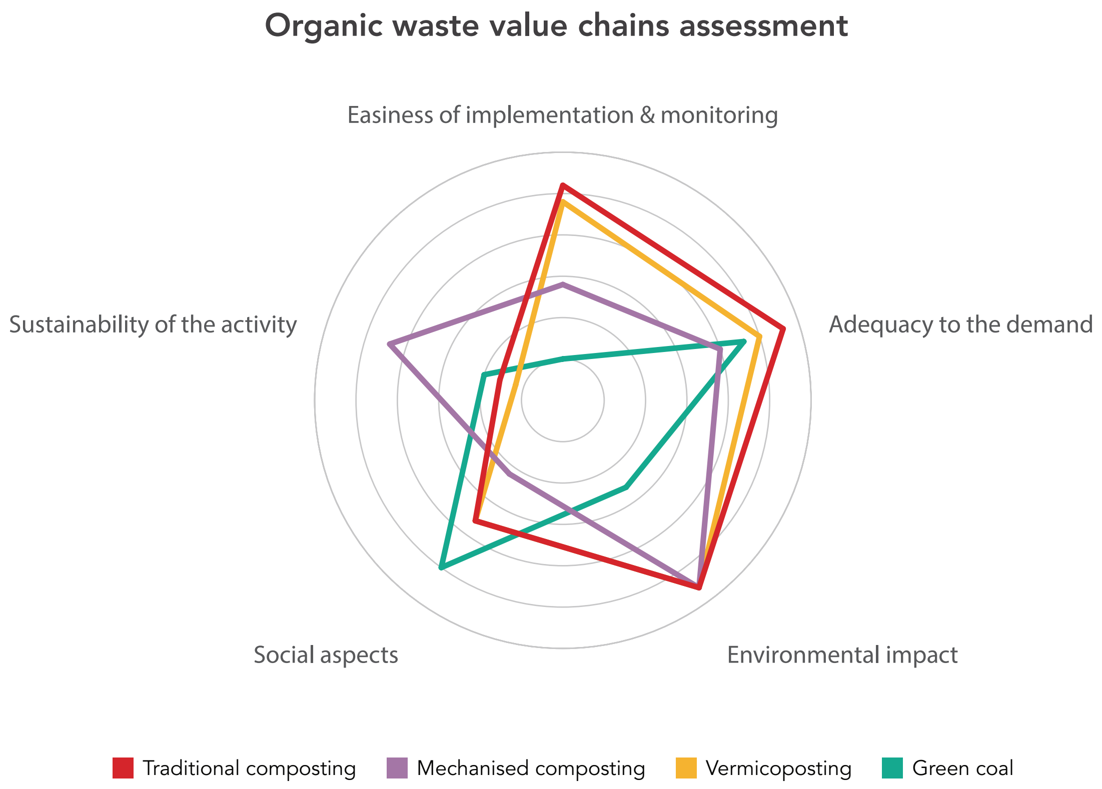
	1/3	2/3	3/3	Coeff.
	Medium investments necessary to mitigate the impacts on environment and medium GHG emissions if the necessary mitigation measures are not taken	Low/no investments necessary to mitigate the impacts on environment and low GHG emissions	No investments necessary considering the absence of impacts on the environment (no GHG emissions)	1
				2
	No or low impact on women's employment but eventual impact on their revenues by the sales of new products	Medium impact on women's employment or women's revenues	High direct and indirect impact on women's employment and revenues	1
	Products of first necessity with high prices unreachable for disadvantaged populations OR Non-essential products with prices of recycled products similar to traditional products	Products of first necessity with prices of recycled products similar to traditional products OR Non-essential products with prices of recycled products lower than prices of traditional products	Products of first necessity with prices lower for recycled products than for traditional products	1
				2
	No possibility to increase the production capacity, but possibility to diversify the activities/products (regarding the processing duration)	Possibility to have a medium increase of the production capacity AND/OR Possibility to diversify the activities/products	Possibility to increase considerably the production capacity and/or to diversify the activities/products with the same facilities (or low additional investments)	1
	Legal/institutional framework existent but improvable & Current SWM system unadapted	Legal/institutional framework satisfying and current SWM system to adapt	Legal/institutional framework existent and satisfying and current SWM system adapted	2

6.2 Organic waste value chains assessment

This analysis shows that **traditional composting and vermicomposting are better than the other options.** Both are easy to implement, their products are adequate to the demand and the market, and they have positive social impacts. Nevertheless, the profitability of these options is not guaranteed. From this point of view, mechanised composting – which requires higher investments and generates fewer job opportunities but is more profitable – could be an option. Green coal production is not a recommended option according to the criteria analysed.

Criteria		Sub-criteria		Marking	Coeff.	Organic waste value chains			
						Traditional composting	Mechanised composting	Vermi-composting	Green coal
1	Ease of implementation & monitoring	1.1	Surface necessary for the recycling facilities	/3	2	2.5	3.0	2.5	0.6
		1.2	Investment necessary to purchase equipment	/3	2	3.0	0.1	3.0	0.1
		1.3	Awareness of the beneficiaries & waste generators	/3	1	2	1	1	1
			Total C1	**/3**	**1**	**2.6**	**1.4**	**2.4**	**0.5**
2	Adequacy to the demand	2.1	Local demand	/3	2	3	3	3	3
		2.2	Competition	/3	1	2	2	1	1
		2.3	Existing actors/VC	/3	1	3	0	3	2
			Total C2	**/3**	**1**	**2.8**	**2.0**	**2.5**	**2.3**
3	Environmental impact	3.1	Waste diversion	/3	2	3.0	3.0	3.0	1.5
		3.2	Recyclability & sustainability	/3	1	3	3	3	1
		3.3	Measures to implement to mitigate the processing impacts on the environment	/3	1	2	2	2	1
			Total C3	**/3**	**1**	**2.8**	**2.8**	**2.8**	**1.3**
4	Social aspects	4.1	Employment creation	/3	2	1.5	0.2	1.5	3.0
		4.2	Gender	/3	1	2	2	2	3
		4.3	Accessibility of recycled products to disadvantaged populations	/3	1	2	2	2	1
			Total C4	**/3**	**1**	**1.8**	**1.1**	**1.8**	**2.5**

Criteria		Sub-criteria		Marking	Coeff.	Organic waste value chains			
						Traditional composting	Mechanised composting	Vermi-composting	Green coal
5	Sustainability of the activity	5.1	Profitability	/3	2	0.0	3.0	0.0	0.0
		5.2	Flexibility	/3	1	2	3	1	3
		5.3	Institutional aspects	/3	2	1	1	1	1
		Total C5		**/3**	**1**	**0.8**	**2.2**	**0.6**	**1.0**
		Global mark		**/15**		**10.7**	**9.5**	**10.0**	**7.5**
		Ranking				**1**	**3**	**2**	**4**



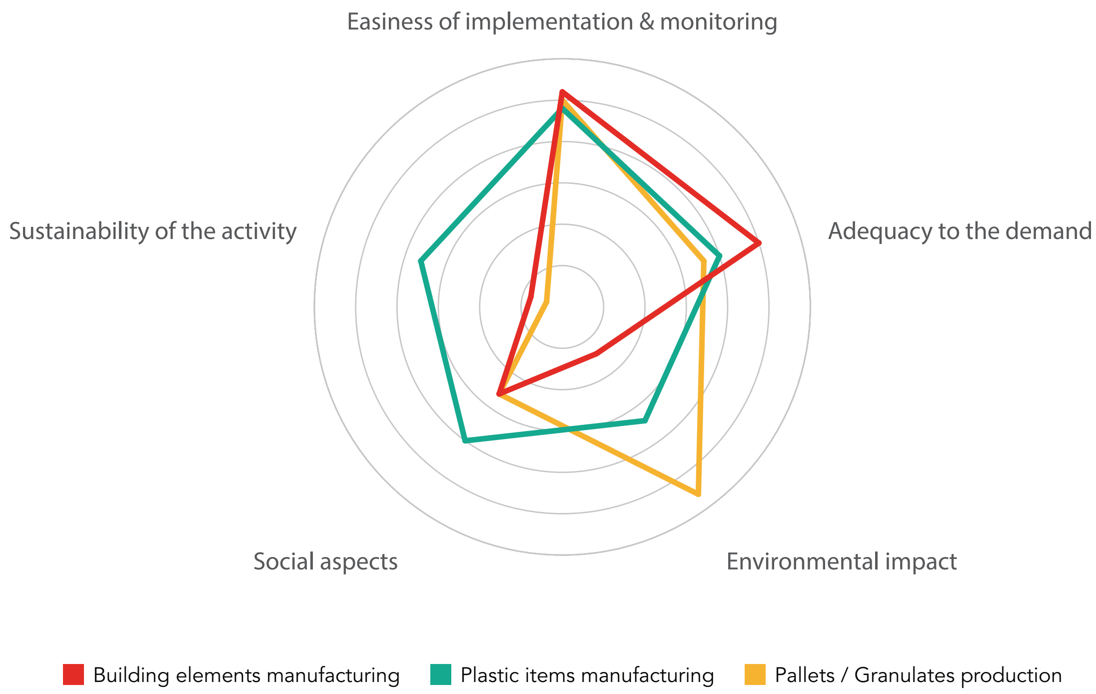
6.3 Plastic waste value chains assessment

It results from this analysis that **plastic items manufacturing is better than the other options.** It is easy to implement, the products are adequate for the demand and the market, it has positive social impacts, and it is profitable. Nevertheless, this activity has environmental impacts and mitigation measures must be implemented. Pallets and granulates production could be an alternative – it is easy to implement and monitor, and its environmental impacts less – but sustainability is not guaranteed. Tiles and brick manufacturing are not an option to recommend due to environmental impact and low sustainability.

	Criteria		Sub-criteria	Marking	Coeff.	Plastic waste value chains		
						Building elements manufacturing	Plastic items manufacturing	Pallets/ Granulates production
1	Easiness of implementation & monitoring	1.1	Surface necessary for the recycling facilities	/3	2	3.0	3.0	3.0
		1.2	Investment necessary to purchase equipment	/3	2	3.0	2.5	2.6
		1.3	Awareness of beneficiaries & waste generators	/3	1	1	1	1
			Total C1	**/3**	**1**	**2.6**	**2.4**	**2.5**
2	Adequacy to the demand	2.1	Local demand	/3	2	3	2	1
		2.2	Competition	/3	1	2	1	3
		2.3	Existing actors/VC	/3	1	2	3	2
			Total C2	**/3**	**1**	**2.5**	**2.0**	**1.8**
3	Environmental impact	3.1	Waste diversion	/3	2	0.9	2.4	3.0
		3.2	Recyclability & Sustainability	/3	1	1	2	2
		3.3	Measures to implement to mitigate the processing impacts on the environment	/3	1	0	0	3
			Total C3	**/3**	**1**	**0.7**	**1.7**	**2.8**
4	Social aspects	4.1	Employment creation	/3	2	1.6	3.0	1.6
		4.2	Gender	/3	1	1	1	2
		4.3	Accessibility of recycled products to disadvantaged populations	/3	1	1	1	0
			Total C4	**/3**	**1**	**1.3**	**2.0**	**1.3**

Criteria		Sub-criteria		Marking	Coeff.	Plastic waste value chains		
						Building elements manufacturing	Plastic items manufacturing	Pallets/ Granulates production
5	**Sustainability of the activity**	**5.1**	**Profitability**	/3	2	0.0	3.0	0.0
		5.2	**Flexibility**	/3	1	2	3	1
		5.3	**Institutional aspects**	/3	2	0	0	0
		Total C5		**/3**	**1**	**0.4**	**1.8**	**0.2**
		Global mark		**/15**		**7.5**	**9.9**	**8.4**
		Ranking				**3**	**1**	**2**

Plastic waste value chains assessment



7. DEVELOPMENT STRATEGY AND ACCOMPANYING PHASING

7.1 Development strategy and phasing

The development for recycling/composting activities is based on a three-phase strategy from 2020 to 2040.

Composting:

The three-phase development strategy is:

- Phase 1: From now to 2030, focus on marketplace organic waste collection with the objective to increase collection from the current 1% of organic waste to 10% in 2030.
- Phase 2: From 2031 to 2035, extend organic waste collection to food businesses and identified pilot district with the objective of collecting 30% of organic waste in 2035.
- Phase 3: From 2036 to 2040, gradually extend to all districts and generators with the objective of collecting 50% of total organic waste in 2043.

TABLE 15: Organic waste – objectives and strategy for composting

	Current	Phase 1	Phase 3	Phase 4
Target (% of clean organic waste collected)	1%	10%	30%	50%
Target (tons/day of waste treated)	2.4 tons/day	5.8 tons/day	20.7 tons/day	41 tons/day
Target year	2020	2030	2035	2040
Strategy		Focus on marketplaces	Extension to food businesses & pilot districts	Gradual extension to all districts and generators

Plastic recycling:

The three-phase development strategy is:

- Phase 1: From now to 2030, focus on business located in pilot districts and marketplaces with the objective of increasing collection from the current 6% of plastic waste to 15% in 2027.
- Phase 2: From 2031 to 2035, extend to households and administration in pilot districts and to businesses in other districts with the objective of collecting 25% of plastic waste in 2035;
- Phase 3: From 2036 to 2043, gradually extend to all districts and generators with the objective of collecting 35% of total plastic waste.

TABLE 16: Plastics – objectives and strategy for recycling

	Current	Phase 1	Phase 3	Phase 4
Target (% of plastic organic waste collected)	6%	15%	25%	35%
Target (tons/day of waste treated)	0.5 tons/day	6.9 tons/day	24.6 tons/day	48 tons/day
Target year	2020	2030	2035	2040
Strategy		Focus on businesses located in pilot districts and marketplaces	Extension to households and administration in pilot districts and to businesses in other districts	Gradual extension to every district *(marketplaces, businesses, administration and households)*

These objectives should consider the objectives of waste-to-energy targeted. The development of recycling activities will also depend on the regulatory framework. For instance, a regulation to ban plastic bags would have an impact on recycling activities concentrated on this specific waste flow.

The indicators proposed to monitor the development of the value chains are:

- Quantity of organic waste at the entrance of the recycling/composting units (unit to confirm)
- Quantity of plastic waste at the entrance of the recycling units (unit to confirm)
- Quantity of waste disposed at the landfill in order to assess the diversion from landfill rate (unit to confirm)

The indicators are deliberately simple in order facilitate the data collection and the monitoring. The unit used will depend on the existence of functional weight-bridge or other weighting systems.

These monitoring indicators will be detailed in the next part of the study.

7.2 Accompanying measures and pre-requisites

In addition to the priority actions to be implemented, some accompanying measures are necessary to develop recycling/composting activities. This section outlines these measures.

7.2.1 MARKETING/SALES OF THE RECYCLED PRODUCTS AND COMPOST

The development of recycling/composting activities will be successful only if the products meet an effective demand.

On supply side, it implies that the product is adapted to demand in terms of marketing mix (product, price, place, promotion). Producers must be aware of the absolute necessity to develop a customer-oriented product. Some support could be provided to producers in order to assist them in developing the marketing component of their business plan.

On demand side, customers must be aware of the product quality, efficiency, value for money compared to others (compost vs chemical fertilisers, recycled materials compared to original ones, etc.). Promotion campaigns for recycled products, demo-farms for compost, and testing could be implemented to prove the appropriateness of the product to the customer.

7.2.2 LEGAL AND REGULATORY FRAMEWORK

Some adaptations of the legal and regulatory framework are likely to secure recycling/composting activities. A clear and transparent legal and regulatory framework regarding these activities and the characteristics of a marketed product is necessary in order to guarantee its quality. Moreover, this framework must be reliable and constant to secure investment profitability in the medium to long term.

The development of local products could also be supported by tariff and custom protection to limit competition from imports.

All institutional stakeholders, at national and local levels, must be in line with sector objectives to ensure the complementarity of the different value chains and avoid competition between them.

All these measures imply strong political support and commitment.

7.2.3 AWARENESS-RAISING COMMUNICATION OF BEST PRACTICES

The quality and quantity of solid waste collected and targeted for recycling/composting depends largely on the sorting at source done by the solid waste generators (households, markets, businesses, etc.). A proper sorting reduces dirtiness, the presence of unwanted waste, risk of contamination (notably because of the contact with hazardous waste) and facilitates reuse and recycling.

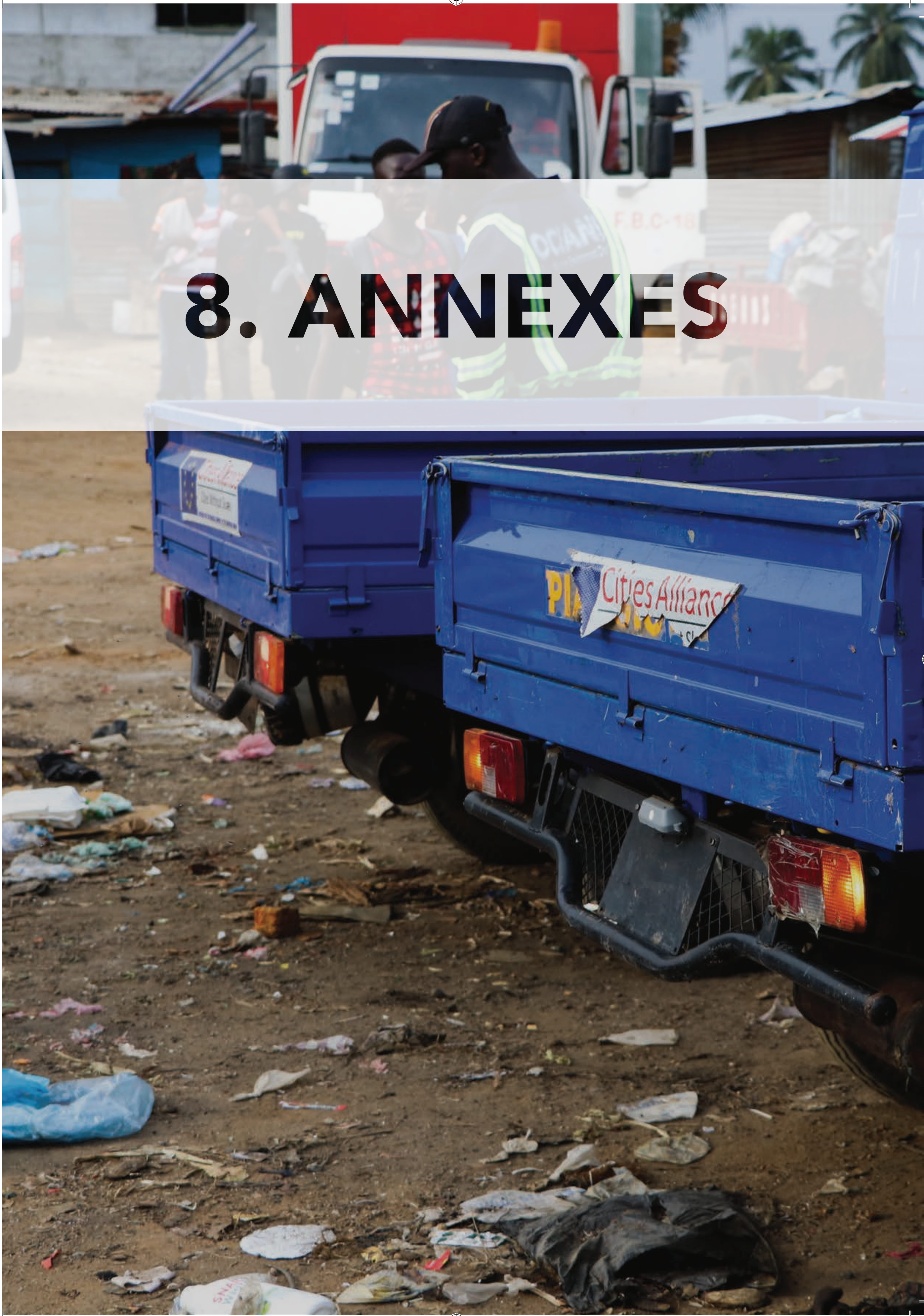
The local and national authorities should assist the CBEs and SMEs in making waste generators aware of how they could sort their own waste. Communication to waste generators is thus an integral part of the local authority recycling service (MCC/PCC) because, to participate fully, residents need to know clearly what their services are, what their service rules are, and what happens to their recycling after it is collected. It is also part of the national institution service (Environment Protection Agency), which can define messages to be passed on and lead national communication campaigns.

Local and national authorities should produce documents (guidelines about recycling) and use a range of communication materials such as recycling point signs, vehicle panels (for collection vehicles), and stickers. Municipalities can also communicate through local actors including community leaders, religious leaders, and griots.

Communicating about sorting is also an opportunity to make households aware of solid waste prevention, which:

- Improves resource security and well-being
- Reduces the costs for the actors who operate during the different steps of the value chain: collection, sorting, transport, valorisation/landfilling activity
- Encourages jobs creation and creates value from waste through increase of repair, reuse and manufacturing activities

8. ANNEXES



8.1 Basic assumptions for cost analysis

8.1.1 COMPOSTING/CO-COMPOSTING (MANUAL) AND VERMICOMPOSTING

8.1.1.1 Human resources

Staff is needed at the different steps of the process.

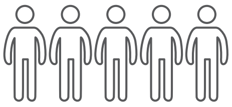
Collection


Markets' staff


SME's staff

Collectors are needed in marketplaces (for gathering all the organic waste and loading it in the trucks). SME employees deal with charging waste and transporting it until the production site. Such a system is implemented by Organic Matters (OM). **20% of the staff** is dedicated to collection (from OM).

Production


Markets' staff

Employees and trainees are needed for the compost production process, the packaging, and testing (field work). The production requires a lot a staff, notably for turning the windrow manually. Cleaning, packing and field work are opportunities for women's employment. **60% of the staff** is dedicated to production (including production on farmers' fields) (from OM).

Marketing


SME's staff

Employees are needed to sell the products at the office, delivering them, communicating about them and finding new farmers interested. **20% of the staff** is dedicated to sales (from OM).

TABLE 17: Benchmark of staff needs for manual composting activities

	Liberia (2019)	Togo (2016)	Madagascar (2015)	Cameroun (2016)	Côte d'Ivoire (2016)
Waste collected/ treated per year	840 T	4 155 T	7 200 T	1 951 T	928 T
Waste collected/ treated per month	70 T	345 T	600 T	136 T	77 T
Number of production sites	1	1	2	2	2
Compost produced per year	170 T	500 T	1 200 T	380 T	90 T

	Liberia (2019)	Togo (2016)	Madagascar (2015)	Cameroun (2016)	Côte d'Ivoire (2016)
Number of FTE	15 (assigned to composting)	50	-	21	5
Number of FTE per ton collected per month	0.21	0.15	-	0.15	0.06

Source: Liberia: Kick-off mission, Organic Matters; Togo: Africompost programme, ENPRO; Madagascar: Africompost programme, Madacompost; Cameroun: Africompost programme, ERA Cameroun; Côte d'Ivoire: Africompost programme, ORGAP

On average, in those projects, 0.15 FTE is needed per ton of organic waste treated. However, in the Africompost study, it was suggested that human resources were lacking for commercialisation.

On average, 0.2 FTE is needed per ton collected per month for traditional composting and 0.3 FTE for vermicomposting (the process is more complex and slower and requires more staff).

The majority of staff is dedicated to production. The following breakdown is suggested: 10% for collection, 70% for production and 20% for marketing.

8.1.1.2 Technical resources

Collection

8 m^3 truck
Prices ~ USD 60,000 - 90,000

- A truck for transporting waste from the waste generation site to the production site. Organic Matters uses an 8 m^3 truck which makes three trips per day.

  Note: If the quantity of organic waste collected is low, vehicles with a small capacity such as a tricycle can be used.

Such a truck can collect an average of 0.96 tons per trip (using a waste density of 120 kg/m^3 and a filling of 8 m^3).

One truck is sufficient for collecting up to 200 tons per month. Above 200 tons, a second truck is needed.

Production and marketing

8 m^3 truck for deliveries

Building and infrastructure with enough space (organic waste storage, production process and compost bag storage)

840 m^2 (335 m^2 for the facilities)
Building costs ~ US $8.50/$m^2$

The following investments are needed:

- **An 8 m^3 truck for** delivering compost bags to farmers (same truck as those used for collection)

Considering a compost density of 1,250 kg/m^3, an 8 m^3 truck can transport 10 tons per trip.

- **Buildings and infrastructure (production site)**, which must meet the following requirements:
  - **Reasonable distance** from the collection areas and from the customers (mainly farmers, for reducing the transport costs).
  - **Sufficient waste absorption capacity:** Solid waste collected from various areas reaches the plant site at a variable rate depending upon the distance of collection point. Storage has to be provided to absorb the fluctuations in the waste input to the plant. The value of the storage capacity depends on the schedule of incoming trucks, the number of shifts, and the number of days the plant and solid waste collection system operate.
  - **Presence of covered areas** to protect the compost from humidity and wind (especially during the rainy season).
  - **Sufficient space for** turning the feedstock.

The production site is divided into different zones:

- Waste unloading and sorting area;
- Composting pad;
- Maturation area;

- Screening and bagging area;
- Compost storage area;
- Demo site;
- Caretaker's office; and
- Sanitary facilities for the workers.

These zones must be arranged to ensure efficient workflow of the composting process. The organisation of these areas depends on the characteristics of the plot (for example, the office site can be on the production site or outside). Since local conditions strongly influence final composting plant design, the descriptions provided should be used merely as guidelines and recommendations. The final setup of the site is strongly dependent on the local conditions.

Local construction experts should be consulted, and the usage of materials adapted to the local context – but always related to the key functions of each component.

TABLE 18: Required space for composting plant processing 3 to 5 tons of waste per day

Type	Required Area Windrow Composting	Roof
Sorting area	40 m²	yes
Storage of rejects	30 m²	yes
(Storage of recyclables)	10 m²	yes
Composting pad	400 m²	yes
Maturation area	150 m²	yes
Screening and bagging area	35 m²	yes
Compost storage area	25 m²	yes
Sub-total composting area	**690 m²**	
Office	16 m²	yes
(Sanitary facilities)	10 m²	yes
Tool shed	10 m²	yes
Water supply point	4 m²	no
Vehicles parking area	30 m²	no
Green buffer zone (trees/bushes)	50 m²	no
Total area	**810 m²**	

Source: "Decentralised Composting for Cities of Low- and Middle-Income Countries, table 6.2"

TABLE 19: Benchmark of space needed for manual composting activities

Source	Decentralised Composting for Cities of Low- and Middle-Income Countries (cf. above)	Africompost	Cité-Soleil site (Haiti)
Waste treated per year	1,100 to 1,800 T	10,000	400 to 600 T
Total area	810 m²	10,000 m² (3/4 for compost production and 1/4 for demo site and office)	500 m²

At least 1 m² is needed per ton of organic waste treated per year.

8.1.2 MECHANICAL COMPOSTING

Mechanical composting is relevant and profitable, as more than 10,000 tons of compost are treated every year (830 tons per month).

8.1.2.1 Human resources

The process requires less staff than the manual process, mainly because the windrow is turned mechanically.

TABLE 20: Full-time equivalent employee needs for a plant processing 10,000 tons of organic waste per year

	FTE needs
Collection	6
Reception	1
Sorting	6
Fermentation	2
Maturation	0.5
Communication/Marketing	8
Direction	3
Total	**26**

(Assess mainly based on the study led by CEPREFADE[6]).

[6] Study led by CEFREPADE in 2012 : « Compostage des déchets ménagers dans les pays en développement : modalités de mise en place et de suivi d'installations décentralisées pérennes » (household solid waste in developing countries : Implementation and monitoring of decentralised and sustainable facilities)

To produce 10,000 tons of waste per year (830 tons per month), 26 ETP are needed.

8.1.2.2 Technical resources

Collection

20 m^3 truck
Purchase prices ~ USD 110,000 - 160,000

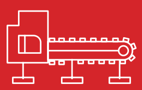
The following investments are needed:

- **A truck** for transporting waste from the waste generation site to the production site.

A 20 m^3 truck can collect an average of 2.5 tons per trip (using a waste density of 120 kg/m^3 and a filling of 20 m^3).

To collect 10,000 to 15,000 tons per year (800 to 1,500 tons per month), 2-3 trucks are needed (one of the trucks is used in case of failure). Above 15,000 tons, a third truck is needed.

Production and marketing

				
Building and infrastructure with enough space	Mechanical composting plant with the combination of a conveyor belt (facultative), shredder, screening plant, and turned windrow equipment	20 m^3 truck for bag deliveries	20 m^3 hookloader for bulk compost deliveries	Truck loader
Building costs ~ US $8.50/m^2	**Prices ~ US $200,000 - 240,000**	**Purchase prices ~ US $110,000 - 160,000**	**Purchase prices ~ US $10,000 - 160,000**	**Purchase prices ~ US $110,000 - 140,000**

The same material resources are needed as in manual composting:

- **Building and infrastructure** on the production site
- **Trucks for delivering** compost to clients:
  - 20m^3 trucks for bag deliveries

Considering a compost density of 1,250 kg/m^3, a 20 m^3 truck can transport 25 tons per trip.

  - Hookloader for bulk compost (there are high quantities of compost produced) and loader

Considering a compost density of 1,250 kg/m^3, a 20 m^3 hookloader can transport 25 tons per trip.

  - A truck loader.

For mechanical composting process, a **mechanical composting plant** is implemented. It combines various units that perform specific functions:

- **A slow-moving conveyor belt (US $15,000 to 20,000)** where the non-decomposable material (plastics, glass, metals) is manually removed by labourers.
- **A shredder (US $45,000 to 50,000)** for shredding green waste such as leaves and branches.
- **A screening plant (US $35,000 to 45,000);**
- **Turned windrow equipment (US $110,000 to 125,000):** Long piles of feedstock (windrows) of about 2 to 3 m high and 3 to 6 m or more wide are constructed, with a roughly triangular cross section. These are constructed on an area known as a composting "pad." These windrows are arranged in rows and are allowed to degrade. The process is accelerated by turning the feedstock, using a front loader or specialised machinery.

Using turned windrow equipment is relevant for 25,000/30,000 tons treated per year. It can be used from 10,000/15,000 tons treated per year but is less profitable.

8.1.3 GREEN COAL

8.1.3.1 Human resources

Collection

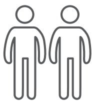

Markets' staff

SME's staff

As with collecting organic waste for composting, collectors are needed in marketplaces (to gather all the organic waste and load it into the trucks). SME employees deal with charging waste and transporting it to the production site.

Such a system is implemented by Green Gold (green coal producer, Greater Monrovia) which buys the organic waste from marketers. They ask street boys to separate organic waste from inorganic waste at the Duala market (50 LD per day, amount depending on the quantity or organic waste provided).

Production


SME's staff

The majority of the staff is needed for production. Women can be hired for production, notably for the mixing of cassava sap, wood dust and dry organic waste, and for the use of the green coal plant.

Marketing

Staff is needed for selling the products on marketplaces.

Green Gold employs 6 people full-time, for a treatment of 5 m^3 of organic waste per day (21 tons per month, considering a density of organic waste of 120 kg/m^3).

TABLE 21: Benchmark of the staff needed in different structures

Structure	Country	Green coal production capacity (T/month)	Staff	FTE/ton
SGFE	Cambodia	20	17	0.85
Samson	Uganda	0.5	2	4
Masupa	Uganda	0.6	3	5
Kyebando Tusobola Youth Initiative Africa (KTYI)	Uganda	0.5	2	4
Centre de valorisation des Déchets Biodégradables (CVDB)	Senegal	12	10	1
Briketi	Uganda	60	29	0.5

Structure	Country	Green coal production capacity (T/month)	Staff	FTE/ton
BRADES (Bureau de recherche-action de développement solidaire)	Senegal	6	5	0.8
Bioterre	Senegal	10	10	1.0
Appropriate Energy Saving Technologies (AEST) LTD	Uganda	25	15	0.6
Green Gold	Liberia	4	6	1.5
Average				**1.91**

On average, 1.91 FTE/ton produced is needed.

The majority of staff is needed for production. The following breakdown is suggested: 20% for collection, 60% for production and 20% for marketing.

8.1.3.2 Technical resources

Collection

8 m^3 truck
Prices ~ USD 60,000 - 90,000

- **A truck** for transporting waste from the waste generation site to the production site.

In the first instance, if the quantity of organic waste collected is low, vehicles with a smaller capacity can be used (tricycles).

A ten-ton truck can collect an average of 1 ton per trip (using an organic waste density of 120 kg/m^3 and a filling of 8 m^3).

One truck is sufficient for collecting up to 200 tons per month. Above 200 tons, a second truck is needed.

FIGURE 30: tricycle used for collection by Green Gold

Production and marketing

Vehicles	Buildings	Equipment
Vehicles for transporting green coal to marketplaces (tricycles or cars) Same truck than for collection	Building and infrastructures with different areas: waste drying area, production process area, green coal drying area,) **200 m^2/T of green coal produced** **Building costs ~ 8.50 USD / m^2**	Green coal production equipment **Purchase prices ~ 60,000 - 100,000 USD**

The following investments are needed:

- **Vehicles for** transporting green coal bags to the points of sale (mainly marketplaces): tricycles, cars or trucks
- **Buildings and infrastructures (production site),** which must meet the following requirements:
  - **Reasonable distance** from the collection areas and from the points of sale (marketplaces), to reduce the transport costs
  - **Presence of covered areas** to accelerate the drying process and protect the green coal produced from humidity, especially during the rainy season
  - **Sufficient space**
  - **Access to a water point**

The production site is divided into different zones for carrying out the various activities for producing green coal:

- Waste unloading and sorting area
- Waste carbonisation area
- Mix preparation area (cooking pots for mixing dust, burnt organic waste and binder, for example cassava sap
- Green coal production area, with a green coal production plant which is the combination of a shredder, a conveyor belt and a mold
- Green coal drying area
- Bagging area
- Green coal storage area
- Caretaker's office
- Sanitary facilities for the workers

Regarding the equipment used for producing green coal, the technology used depends on the production capacity, the financing, and the raw materials used.

TABLE 22: Presentation of the types of equipment needed for the process

Projects	Organic waste drying	Carboni-sation	Binder addition and mixing	Molding	Drying
Type of equipment	Open air	Manual in barrels	Manual in barrels or motorised	Motorised: shredder, conveyor belt and molds	Open air or in a dryer

FIGURE 31: Green coal production plant (Green Gold)

From left to right: shredder, conveyor belt and mold

FIGURE 32: Example of equipment *(Source: Agence Micro Projets)*

From left to right: production site (AEST – Uganda), Drying area for a production of 2 tons/day (Briketi – Uganda)

TABLE 23: Comparison of the site of different production sites

Structure	Country	Surface (m^2)	Green coal production capacity (T/month)	m^2/T of green coal produced
SGFE	Cambodia		20	0
Samson	Uganda		0.5	0
Masupa	Uganda		0.6	0
Kyebando Tusobola Youth Initiative Africa (KTYI)	Uganda		0.5	0
Centre de valorisation des Déchets Biodégradables (CVDB)	Senegal	4800	12	400
Briketi	Uganda	20000	60	333
BRADES (Bureau de recherche-action de développement solidaire)	Senegal		6	0
Bioterre	Senegal		10	0
Appropriate Energy Saving Technologies (AEST) LTD	Uganda	2500	25	100
Green Gold	Liberia	400	4	100
Average				**233**

On average the production site should have a size of 200 m^2 per ton of green coal produced.

8.1.4 CONSTRUCTION MATERIALS PRODUCTION

As mentioned previously, in this process, plastic waste is sorted and melted in order to integrate them in the production process of building elements such as roofing tiles, interlocking tiles, bricks, and blockworks.

The SMEs developing such activities are often small artisanal, family-run businesses.

8.1.4.1 Human resources

Staff is needed at the different steps of the process.

Collection

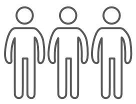
Scavengers / Community

SME's staff

Collectors can be either employees of the SME or individuals/CBEs paid in function of the quantity of waste collected. Such a system is used by Cepwamar (plastic recycler in Greater Monrovia): the collectors are part of the community and collect waste from the households.

Duraplast (industry in Greater Monrovia which recycles plastic for producing plastic bags) buys plastic from individuals who bring their plastic waste to them (except plastic bottles).

Production



SME's staff

Employees are needed for the production process: melting the plastic, mixing with sand, pouring the mix into molds.

Marketing

SME's staff

Employees are needed for selling the products and for communicating/ finding new clients.

TABLE 24: Benchmark of staff needs in different structures

Structure	Country	Production - Tiles and bricks (m^2 per month)	Staff	FTE/m^2 produced
Madacompost (Plasteco)	Madagascar	400	11	0.03
Zelij Invent (Paveco)	Maroc	833	30	0.04
Nelplast	Ghana		74	
Cascade fonderie	Burkina Faso		19	
CEPWAMAR	Liberia	20	10	0.50
Sodiaplast	Guinea		180	
Average				**0.05**

On average, 0.55 FTE per m^2 produced are required. The majority of the staff is needed for production. The following is suggested: 20% for collection, 60% for production and 20% for marketing.

8.1.4.2 Technical resources

Collection

If the collection of materials relies on collectors (CBEs or individuals) paid for collecting and bringing plastic waste to the production site, no collection equipment is needed. If the collection is carried out directly by the recycler, a truck may be purchased (same truck as the one used for deliveries).

Production

Vehicles for delivering the products	Building and infrastructures with different areas: (waste storage, production process and bags storage)	Equipment for melting and mixing the raw materials
Prices ~ USD 60,000 - 90,000 (8 m³ truck)	**Building costs ~ 8.50 USD / m²**	Included in operational costs

The recycling facilities are generally not mechanised, and the production process is done without smoke treatment. The equipment needed for production is simple:

- Covered and dry shelter for protecting the waste resources and the product
- Cooking pots for melting plastic waste
- Containers for mixing sand and melted plastic
- Molds for producing tiles or bricks

Raw material added in the process is mainly sand.

Marketing

- **An office site** for sales, with a sufficient capacity for stocking the bricks/tiles.

FIGURE 33: Pictures from Cepwamara production site (Greater Monrovia)

From left to right: waste resources stock/cooking pot/molds/interlocking tiles produced

TABLE 25: Required space

Structure	Country	Surface (m²)	Production - Tiles and bricks (m² per month)	m²/m² produced
Madacompost (Plasteco)	Madagascar	100	400	4

On average, the surface of the facilities is 4 m² per m² produced.

8.1.5 PLASTIC PALLETS/HDPE GRANULATES

Technology for secondary raw plastic material consists of a plant for crushing, washing and melting plastic into rounded small chips. Green Cities is currently studying a project for grinding HDPE, LDPE, PET and PVC. The process is not yet operational, but sorted and washed plastics are stored awaiting the purchase of an adapted equipment.

8.1.5.1 Human resources

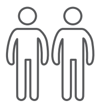
Staff is needed at the different steps of the process.

Collection

Refer to human resources for collection presented for construction materials (roofing and interlocking tiles and bricks)

Green Cities (plastic recycler in Greater Monrovia) collects plastic with its own truck (employees of the SME) and also pay CBEs for collecting plastic.

Production



SME's staff

Employees are needed for the production process. Washing can be done manually. Plastic crushing requires a specialised plant (and few employees).

Marketing

SME's staff

Employees are needed for selling the products and for communicating/ finding new clients. **The majority of staff is needed for production. The following breakdown is suggested: 20% is for collection, 50% for production and 30% for marketing.**

8.1.5.2 Technical resources

Collection

Refer to material resources for collection presented previously (construction materials: roofing and interlocking tiles and bricks).

Production and marketing

Vehicles for deliveries

Prices ~ 60,000 - 90,000 USD (8 m^3 truck)

Building and infrastructures with different areas: (waste storage, production process and bags storage)

Building costs ~ 8.50 USD / m^2

Plastic pellets making machine

Purchase prices ~ 15,000 - 30,000 USD

- **Equipment** for crushing plastic
- **Trucks** for deliveries
- **An office site** for sales, with a sufficient capacity for stocking the HDPE granulate bags.

On average, the surface of the facilities is the same than tile and brick production sites for the same quantity of waste processed.

8.1.6 OTHER PRODUCTS (PLASTIC ITEMS) PP, PEHD, PET

In this process, plastic waste is recycled for manufacturing kitchen articles, bins, buckets and basins, garden and urban furniture.

8.1.6.1 Human resources

Collection

Refer to human resources for collection presented for construction materials (roofing and interlocking tiles and bricks).

Production and marketing

More FTE are needed than for tile and brick production or pellets/granulates production.

8.1.6.2 Technical resources

Collection

Refer to material resources for collection presented for construction materials (roofing and interlocking tiles and bricks).

Production and marketing

Vehicles for deliveries	Building and infrastructures	Platic molding machine
Prices ~ 60,000 - 90,000 USD (8 m^3 truck)	**Building costs ~ 8.50 USD / m^2**	**Prices ~ 10,000 - 30,000 USD**

8.2 Statistics

MCC & PCC STATISTICS

2018	Jan	Feb	Mar	Apr	May	
Waste collected by CBEs at MCC Skip locations Only	**596**	**1056**	**1080**	**1192**	**1290**	
Waste collected by SMEs to Fiamah Transfer Station	17,36	18,93	51,92	21,34	180,33	
Waste collected by SMEs to Stockton Transfer Station	141,33	88,33	113,01	119,55	123,39	
Waste transiting at Fiamah TS	4959,13	1656,01	7431,34	4838,74	4985,75	
Waste transiting at Stockton Creek TS	2227,29	1724,67	5673,95	2669,52	2746,76	
Waste disposed at Whein Town Landfill by SMEs/Private	634,16	536,31	814,82	645,53	532,37	
Waste collected by MCC to Whein Town	7886,28	4033,64	15363,86	8275,37	8550,34	
Waste deposited to Whein Town landfill By PCC	2448,16	1001,00	2511,23	5310,30	3190,93	

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	2100	**2160**	**2384**	**2384**	**2901**	**2901**	**2890**	**22934,00**
	180,76	76,89	30,87	15,64	28,65	13,43	36,01	**672,13**
	69,04	115,01	82,17	66,72	98,47	148,26	166,54	**1331,82**
	1188,13	1418,84	7355,64	3752,97	4088,04	3274,30	3761,10	**48709,99**
	907,24	1274,68	5099,09	2331,00	1569,12	1226,05	1963,67	**29413,04**
	276,34	504,17	566,45	837,08	871,09	731,98	637,06	**7587,36**
	2776,53	4281,10	12807,91	6473,56	6168,70	4799,26	6648,80	**88065,35**
	2744,98	2182,86	2984,21	1492,33	3928,06	1081,71	2322,07	**31197,84**

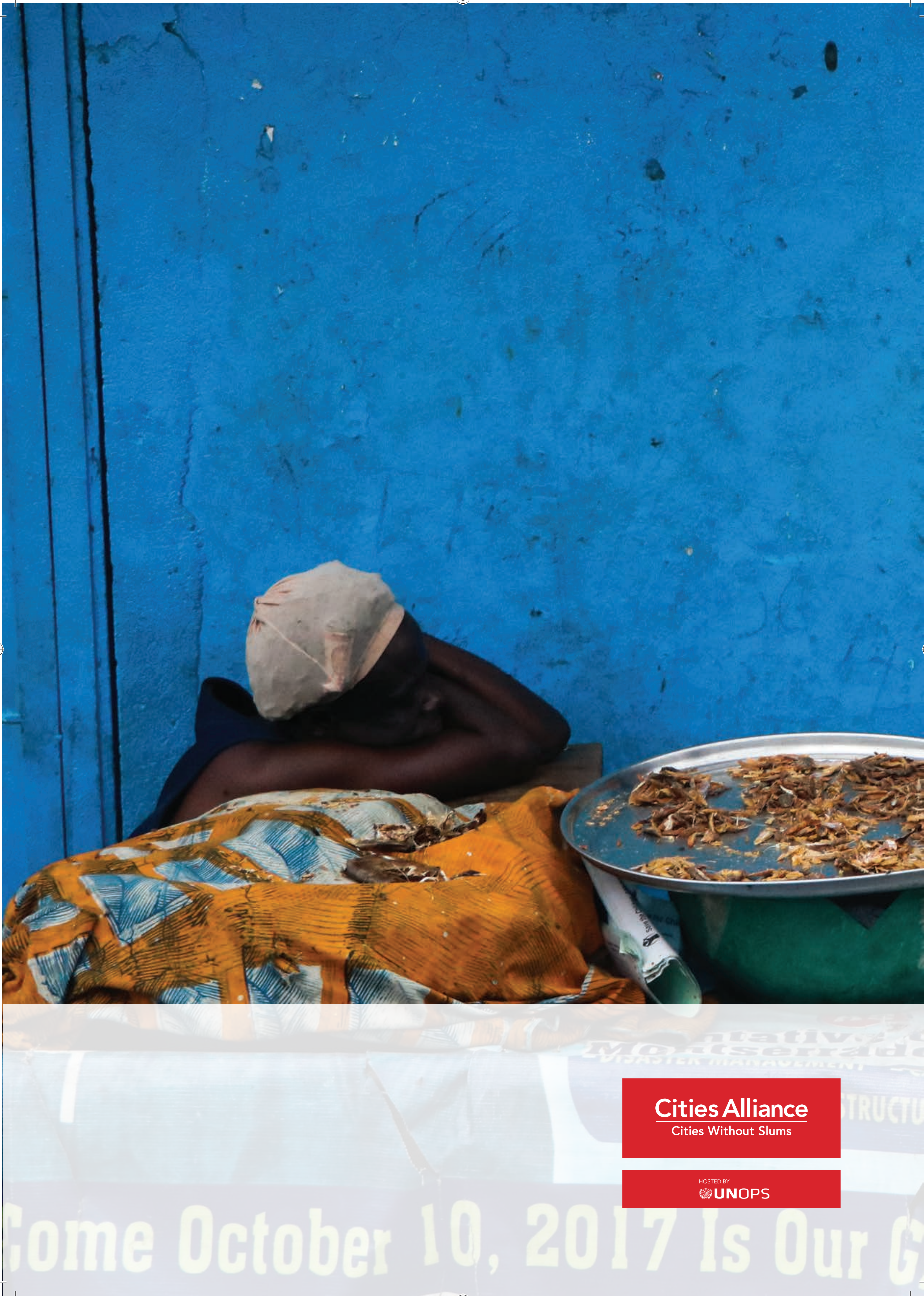
8.3 References of issues addressed

Prioritisation of composting/recycling activities to develop is carried out within a two-step methodology:

- Identification of waste flow to prioritise (Ranking "Waste Flows");
- Identification of value chain to focus on (Ranking "Value Chains").

For each step, a ranking of all waste flows/value chains is based on a multi-criteria analysis taking into consideration the issues raised in the ToR. The following table gives the criteria considered to address each issue.

Issues		Ranking	Criteria
i)	Positive/potential growth trend of the municipal solid waste value chain and unmet market demand	Waste Flows	5-Demand
ii)	Scope for expanding productions and value-addition through processing or product improvement of municipal solid waste	Value Chains	5-Sustainability
iii)	Low entry barriers for small-scale and poor entrepreneurs (low start-up cost, not requiring major capital investment, using low-tech skills)	Value Chains	1-Ease of implementation
iv)	Covering locations where poor population live	Value Chains	4-Social aspects
v)	Significance for the rural economy	Waste Flows	5-Demand
vi)	The conditions of market access	Waste Flows Value Chains	4-Actors and 5-Demand 2-Adequacy to the demand
vii)	Power of market participants (e.g. monopolies)	Waste Flows Value Chains	4-Existing actors 2-Adequacy to the demand
viii)	Tax and tariff regimes (e.g. customs tariffs on inputs)	No data	
ix)	Possible new products (not already existing in Liberia) with a market potential in Liberia	Waste Flows	5-Demand
x)	The competitors and performance	Waste Flows Value Chains	4-Existing actors 2-Adequacy to the demand
xi)	Policy and regulatory impediments, administrative requirements	Value Chains	5-Sustainability



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