October 2020

Reduction of UPOPs emissions by improving waste management practices at landfills

Source Separation and Collection Pilot Study Concept

Saint Lucia

Resources & Waste Advisory Group SCE

Reference number: BCRC#5558_2019_002

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PROJECT NO.	CLIENT.
BCRC# 5558_2019_002	BCRC - Caribbean

VERSION	DATE OF ISSUE	DESCRIPTION	PREPARED	CHECKED	APPROVED
Final	October 07th 2020	Source Separation Pilot – SLU	BM	DG	BM

Contents

List of Acronyms

BAT	Best Available Techniques
BCRC-Caribbean	Basel Convention Regional Centre for Training and Technology Transfer for the Caribbean
BEP	Best Environmental Practices
BM	Brian McCarthy (Team Leader)
CAPEX	Capital Expenditure
CAS	Civic Amenity Sites
DG	Diana Gheorghiu (Deputy Team Leader)
DGM	Deputy General Manager (SLSWMA)
EPR	Extended Producer Responsibility
EU	European Union
FAO	Food and Agriculture Organisation
GHG	Green House Gas
GM	General Manager (SLSWMA)
GoSL	Government of Saint Lucia
M&E	Monitoring and Evaluation
NPC	National Project Coordinator
SLU	Saint Lucia
SLUSWMA	Saint Lucia Solid Waste Management Authority
OLM	Operations and Landfill Manager (SLSWMA)
OPEX	Operational Expenditure
POPs	Persistent Organic Pollutants
PPP	Public Private Partnership
PSP	Private Sector Participation/Private Service Provider
PWC	Project Working Committee
RWA	Resources and Waste Advisory
TPA	Tonnes per annum
ULABs	Used Lead Acid Batteries
UPOPs	Unintentionally produced Persistent Organic Pollutants
WEEE	Waste Electrical and Electronic Equipment

1 Background and Introduction

The BCRC-Caribbean is currently executing a regional project entitled "GEF 5558: Development and Implementation of a Sustainable Management Mechanism for POPs in Eight (8) Caribbean Countries". Component 2 of this project aims to strengthen the capacity of five (5) of the eight (8) Caribbean countries to improve waste management practices at their landfills to reduce site contamination by POPs and Unintentional POPs (UPOPs) emissions. Under this component, RWA Group has been engaged to support "Output 2.1 Improved waste management practices and landfill operations" which targets the reduction of UPOPs emissions in five countries, namely Antigua & Barbuda, Barbados, Saint Lucia, Saint Kitts & Nevis, and Saint Vincent & the Grenadines.

The work on this consultancy project is focused on 4 main components:

- **Component A** - Develop and execute training programs for five (5) countries (Antigua & Barbuda, Barbados, Saint Kitts & Nevis, Saint Lucia, Saint Vincent and the Grenadines.
- **Component B** - Design and improve source separation programs for three (3) countries (Antigua & Barbuda, Barbados and Saint Lucia).
- **Component C** - Assess existing hazardous waste facilities in three (3) countries (Antigua & Barbuda, Barbados and Saint Lucia).
- **Component D** - Recommend and Design upgraded hazardous waste facilities in three (3) countries (Antigua & Barbuda, Barbados and Santa Lucia).

Tasks and Deliverables Covered

This *Source Separation and Collection Pilot Concept Report for Saint Lucia* relates to Component B with the aim to assist develop a municipal solid waste source segregation management system to remove materials that generate UPOPs when landfilled. It builds upon and references specific reports completed under the consultancy project that have contributed to the delivery of the above tasks, these being:

- *SLU Report 1:* ***Baseline Assessment and Training Needs Analysis***. This report details the baseline waste management system and provides an assessment of how the main waste streams and materials are currently managed in Saint Lucia as well as their impact on the landfill and related emissions of POPs/UPOPs to the environment.

- *SLU Report 4*: ***Training Report***. This report presents a summary of the training course delivered to key waste sector stakeholders in Saint Lucia. This engagement included an interactive planning session that assessed the priority waste streams identified in the Baseline Assessment and ranked them in terms of impact on POPs/UPOPs emission potential and potential for improved recovery and treatment.

- *Project Report 2:* ***Source Separation and Collection of Waste - Core Methodology and Principles***. This report presents a reference guide to assessing and prioritising potential waste management interventions and in particular source separation initiatives. It acts as a general aide memoir for assessing and identifying the right purpose/goal for intervening, targeting the right waste material/s to achieve the identified goal, gathering the required data, where to configure the enabling environment, and how to plan and design a targeted source separation that improves waste management.

- *SLU Report 5:* ***Source Separation and Collection of Waste – Methodology for Saint Lucia***. This country specific methodology builds upon the "Source separation and collection of waste core methodology and principles" by assessing the specific waste streams in Saint Lucia and the risk they present to contributing to UPOPs emissions from landfill. The document then works through the methodology and risk assessment to identify Green Waste as the highest priority waste stream to divert from landfill to reduce the potential for landfill fires and associated UPOPs emissions from Deglos Landfill in Saint Lucia.

2 Problem definition

Assessment and identification of waste streams that pose greatest potential of contributing to production and emission of UPOPs from landfill in Saint Lucia are presented in two previous reports, namely “SLU Report 1: Baseline Assessment and Training Needs Analysis” and “SLU Report 5: Source Separation and Collection of Waste – Methodology for Saint Lucia”. These assessments identified “green waste” – for the purpose of this document being loose vegetation collected from tree felling, bush and roadside vegetation clearance, and commercial and domestic garden maintenance[1] – as the waste stream currently entering the landfill that has the greatest adverse impact on enabling efficient and effective landfill operations that would assist mitigate the potential of landfill fires and associated UPOPs emissions.

As detailed in the aforementioned reports, there is currently no existing alternative to landfill for green waste in Saint Lucia. Consequently, this waste stream is being deposited in Deglos Landfill or illegally dumped (Vieux Fort landfill now being closed). As presented in “SLU Report 1”, weighbridge records indicate that between Nov 2018 and Oct 2019 a total of 7 812 tonnes of organic waste (including 873 t Agricultural residues, 1,307 t coconut wastes, 5,632 t Green (see Figure 1)) was disposed of, representing approximately 13% of total waste disposed. A daily average of 14 tonnes of green waste and 7 tonnes of coconut was disposed with a maximum of 57t of green and 18t of coconut in one day in the month of September. These figures are for homogenous loads recorded at Deglos weighbridge. In addition, a waste composition analysis of household waste conducted in 2018 indicates that 53% of municipal (household and Institutional) waste is organic, of which 73% is yard waste, 18% food waste, and 7% agricultural residues suggesting the actual volume of green waste disposed to Deglos is closer to 13,000 tonnes / year, being 23% of total waste disposal, and possibly higher due to the closure of Vieux Fort landfill and transfer of waste to Deglos. It is also noted that a substantial volume of green waste produced in Saint Lucai does not enter landfills and rather is informally dumped or otherwise discarded.

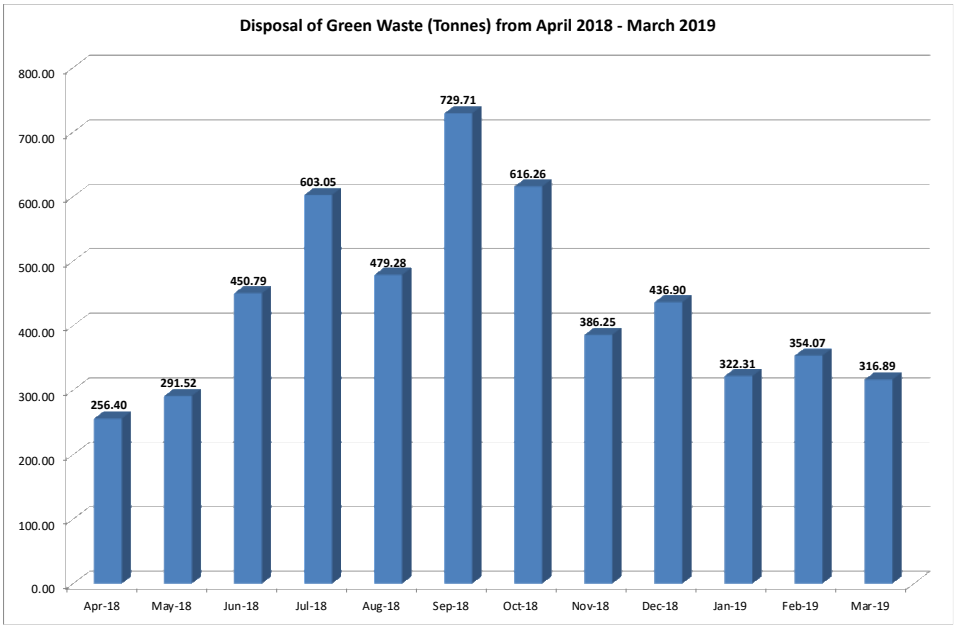

Figure 1: Disposal of green waste at Deglos Landfill between Apr 2018 to Mar 2019

[1] This includes what is termed Leaf and Yard Waste (L&YW) in North America which consists of green grass clippings and thatch, leaves, weeds, brush, and small tree pruning’s.

The key problems with green waste on the landfill can be summarised as follows:

- Low density, high volume nature (particularly tree cuttings) prevents efficient and effective waste mass compaction – green waste has a tendency to "rebound" leaving air pockets in the waste and preventing effective daily cover application which leaves the waste mass susceptible to fire (and consequently UPOPs emissions) and provides breeding ground for disease vectors.
- Provides a fuel source – wood dry organic matter represents a good fuel source to sustain any potential landfill fires, particularly when combined with air pockets as described above.
- Hazard to landfill compactor and other vehicle operations – large items of green waste, particularly tree stumps and branches can become entangled in vehicle tracks/wheels, puncture tyres, rip hose lines, causing vehicle down-time for repair.
- High volumes of large deliveries impact effective tipping face control – green waste requires careful management on site due to all points listed above. Therefore, landfill site staff must take additional time and effort to direct and manage green waste loads detracting from the focus of managing the municipal and other general active waste loads.
- Consumes valuable landfill space – green waste has nutrient value that can be returned to land, it is not toxic or harmful to health or environment if managed correctly and therefore does not require to be landfilled. Once in the landfill green wastes costs more than municipal waste to compact (due to machine passes required) and shortens the lifespan of the landfill site resulting in the need to invest in finding and constructing the next landfill much sooner.
- Contributes to landfill gas and leachate production - The anaerobic decomposition of cellulosic biomass (green, food, paper, etc. wastes) results in methane and other Greenhouse Gas generation which contributes to global warming. This decomposition also contributes to other gas and leachate production in the landfill which can result in the leaching of toxic materials from other wastes such as heavy metals from waste electronic equipment.
- In addition, Saint Lucia are investing in municipal waste pyrolysis units to be located at two or three Kurina Waste Management Facilities in the southern half of the island. These units are designed for dry carbon-based wastes such as plastic and larger, wet green waste and food waste will affect the operational efficiency and temperature curve resulting in additional energy need, time and emissions from the pyrolysis process. Ensure wet waste and green waste do not enter these units is highly advantageous.

For the reasons listed, it is environmentally and economically advisable to divert green waste from the landfill to an alternate waste treatment method. As proposed and detailed in "SLU Report 5: Source Separation and Collection of Waste – Methodology for Saint Lucia", open windrow composting of green waste is recommended as having the greatest potential for success in Saint Lucia within the current enabling environment.

3 Green Waste management plan overview

The proposed plan for green waste management in Saint Lucia was drafted in "ANU Report 5: Source Separation and Collection of Waste – Methodology for Saint Lucia". This document details the development of the proposed concepts and should be referred to along with this document. Additional and complementary information is provided in the following sections to further identify the overall system needs and opportunities for piloting the service.

3.1 Aim and Objectives

The overall aim of the green waste management service is to mitigate, as far as reasonably possible, the problems associated with landfilling green waste as described in the previous section, in particular the occurrence of landfill fires and associated UPOPs emissions.

This will be achieved by diverting parks and gardens waste from landfill to enable improved landfill operations. This will reduce the risk of site fires by establishing the enabling conditions for the sustainable commercial operations of environmentally sound management for green waste to which producers can efficiently divert their material. The production of beneficial materials (compost, mulch, biomass) to be marketed locally to improve land resilience and / or used as landfill cover and remediation material will contribute further to the stated aim.

Food waste is not currently identified as a priority waste to divert from landfill, however, food waste segregation and separate treatment is proposed to be conducted in conjunction with green waste management. This is of particular importance for the Kurina Waste Management Facilities in the southern half of the island where diverting the wet waste fraction shall have substantial benefits on the performance of the pyrolysis units. It is therefore anticipated that a logical progression from establishing the green waste management programme, would be to extend the service to include food waste. Much of the principles, communication and behavioural change campaign, infrastructure and equipment recommended for green waste have potential to be adapted to accept food waste at a later stage.

3.2 Sources of Green waste and current situation

As identified in "SLU Report 5: Source Separation and Collection of Waste – Methodology for Saint Lucia", the main producers of green are:

- LUCELEC (Saint Lucia Electricity Services Ltd.) – green waste arising from tree and bush clearance from around and under power lines and other utility infrastructure throughout the island. This work is conducted by LUCELEC staff and outsourced to contractors.
- Department of Works – green waste arising from activities to clear vegetation from roadsides and public areas as part of the public works initiatives.
- Commercial premises and hotels – resort complexes, hotels, private universities, retail and other commercial premises often have large gardens and / or green areas that require clearance and maintenance, producing substantial volumes of green waste. This work is either conducted inhouse, or by garden services contractors.
- SLSWMA - Public institutions – government owned and operated facilities such as government offices, schools, colleges, and universities, public parks and gardens that produce green waste.
- SLSWMA - Households – Green waste from domestic household gardens.
- Sargassum seaweed clearance from beaches and hurricane debris

As at the beginning of 2020, the majority of green waste produced by all these producers is transported to and disposed in Deglos Landfill along with all other municipal and commercial wastes. Some initiatives have been trialed in the past to divert green waste to a separate disposal area to the side of Deglos, however this has not proven sustainable.

3.3 Proposed Green Waste Management service

NOTE: This section presents a potential long-term green waste management plan for Saint Lucia that requires a full feasibility study prior to full implementation. However, it presents a plan that has been workshopped together with key stakeholders and forms the basis of the pilot trial project which should assist identify if this plan is worth pursuing as well as provide unique data to support decision makers evaluate the entire concept.

To achieve the aims and objectives of this initiative, the SLSWMA have committed to trial a green waste management initiative. This initiative will complement efforts to improve the organisation and management of Deglos Landfill in conjunction with the closure of Vieux Fort landfill and the plans and development of two or three Kurina (pyrolysis) waste management facilities. An illustration of the main concept and waste flow envisaged for this concept, as developed and refined during a workshop between the key stakeholders and the consultants in Saint Lucia during February 2020 and detailed in SLU Report 5, is illustrated in Figure 2.

The initiative is initially targeting the input rather than targeting the output (i.e. the aim being the diversion of green waste from landfill, rather than meeting an established market demand for compost). The focus of the service is therefore identifying the most effective and efficient means to enable the identified waste producers to segregate their green waste from other waste materials for further processing.

As stated in previous reports, it is essential that the SLSWMA work with key stakeholders when establishing public drop-off / transfer locations for green waste at strategic points across the island to ensure sites meet facility licensing and Environmental Impact Assessment criteria.

At the national legislative, or voluntary code level, it is important to establish clear licensing conditions for composting facilities to be able to operate and only license facilities that meet those standards. This prevents legitimate operators that serve the wider societal benefit and invest time and finances into their operation from being undercut and losing business to rogue companies that cut financial corners to the detriment of the environment and society.

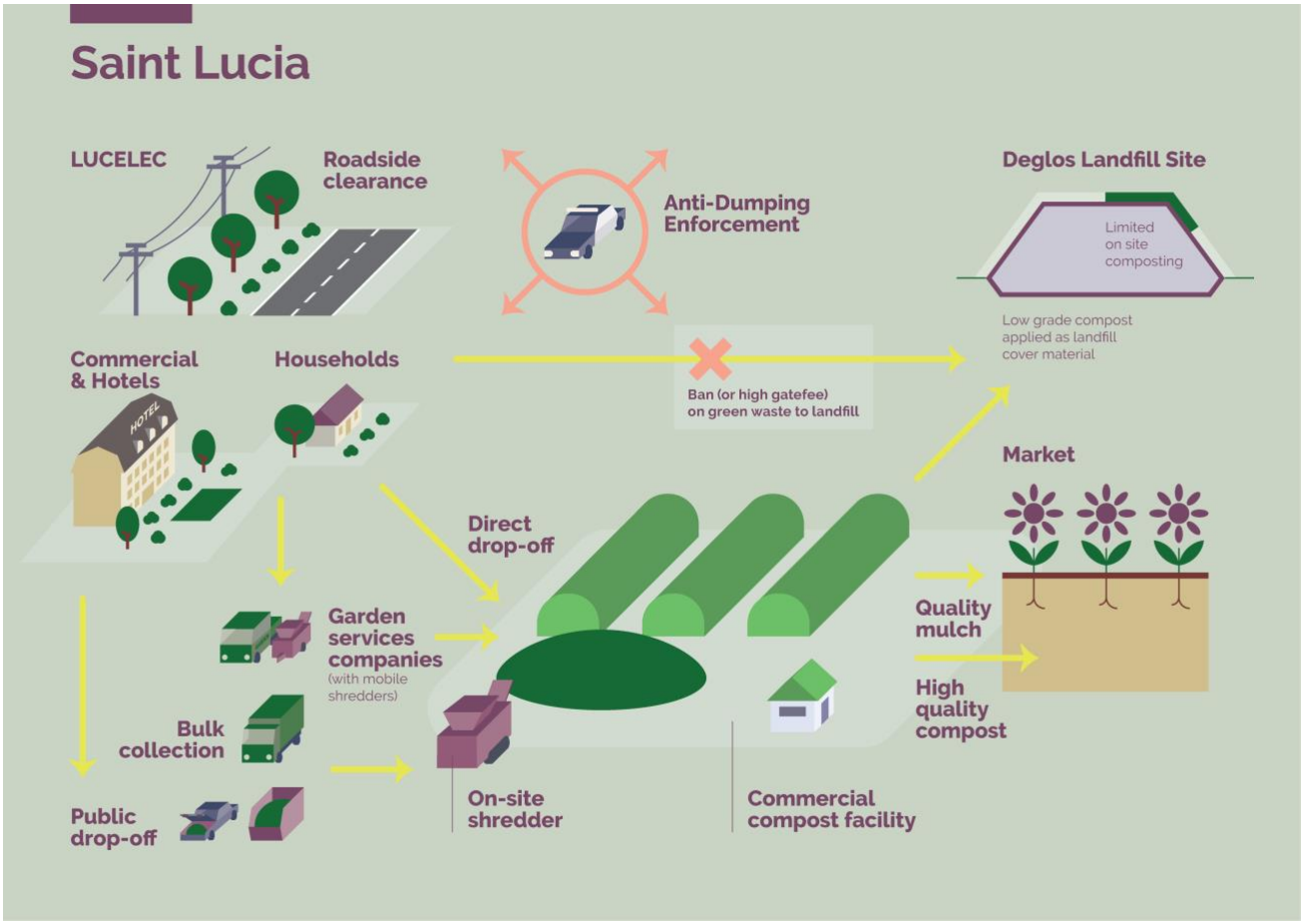

Figure 2: Proposed full scale national green waste management concept for Saint Lucia

The proposed service includes an eventual ban on the landfilling of untreated green waste at Deglos Landfill combined with additional anti-dumping enforcement. Ultimately, the aim is for the SLSWMA to establish and operate public drop-off sites for green waste, either as stand-alone units (mainly in the north) and co-located with the proposed Kurina (pyrolysis) Waste Management Facilities (see Figure 3, initially planned for two to three in the south).

Ideally segregated collection of green waste and food waste should be planned for these facilities in order to divert an estimated 40% of total municipal solid waste from the Kurina units (see Figures 3 and 4). It is recommended that pre-treatment of these two wastes are considered at the Kurina Waste Management Facilities. This would include shredding of green waste where transport distance to composting facility is

significant and initial rapid composting of food waste. This could be achieved through containerized composting unit (Figure 4) to reduce food waste moisture content and activity (and therefore vermin and disease vectors) prior to blending with shredded green waste (co-transported from drop-off to composting facility) and composted in windrow piles at compost facility to ensure further stabilization and reduction of pathogens. Ultimately, the composting facility and operations are envisaged to be outsourced to two private sector partners who shall operate commercial composting facilities and market their own product.

It will take time to permit and establish the drop-off locations and composting facilities. There is also a need for appropriate cover material for Deglos landfill (currently a high clay content cover being used which presents challenges). It is therefore proposed that green waste loads are initially composted on Deglos Landfill site to initiate diversion and create a low-quality compost to use as landfill cover whilst the system operators, infrastructure and equipment are fully established. Where possible, Sargassum seaweed composting should be undertaken as close as possible to the marine environment, however composting this seaweed alone comes with a risk of elevated heavy metals and it is recommended to have a 1:5 mix of Sargassum to green and or food waste to reduce the heavy metal concentrations (to be determined through testing and monitoring).

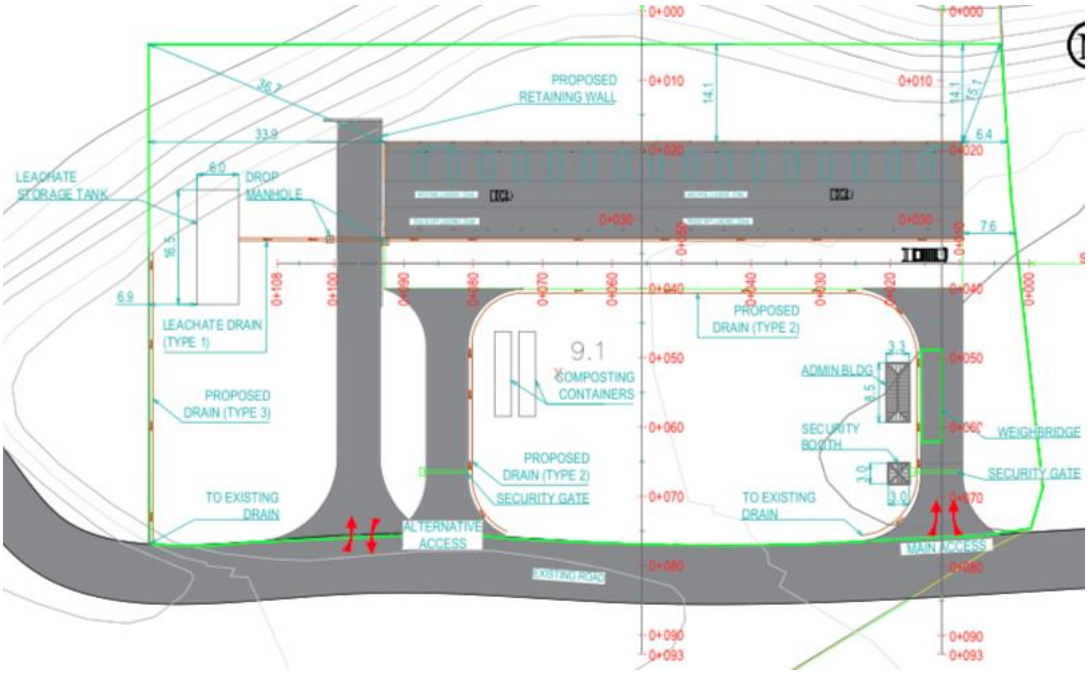

Figure 3: Proposed Kurina Waste Management Facility layout with two composting containers in centre

Figure 4: Example green waste drop-off containers and food waste pre-treatment container potentially suitable for the Kurina Facility

4 Key steps in the green waste service

This chapter reviews the key stages and resource requirements for a green waste management service so as to ensure the service requirements are understood. The subsequent chapter then identifies aspects of the service that will benefit from piloting prior to adjustment and full-scale roll-out.

4.1 Green waste composting process overview

There are many solutions available for producing a marketable output from green waste, however the most commonly practiced is windrow composting. An example process flow for this, covering the service from point of collection to finished product, is depicted in Figure 5. The subsequent Figure 6 illustrates a typical layout of a facility operating this full process, while Figure 7 illustrates a typical drop-off location layout which feeds material into the separate central composting facility. The number sequence in each figure corresponds to the same steps in the process. As introduced in previous reports, it is recommended that the SLSWMA consider all these steps and plan their establishment and operator model prior to initiating collection of separated green waste.

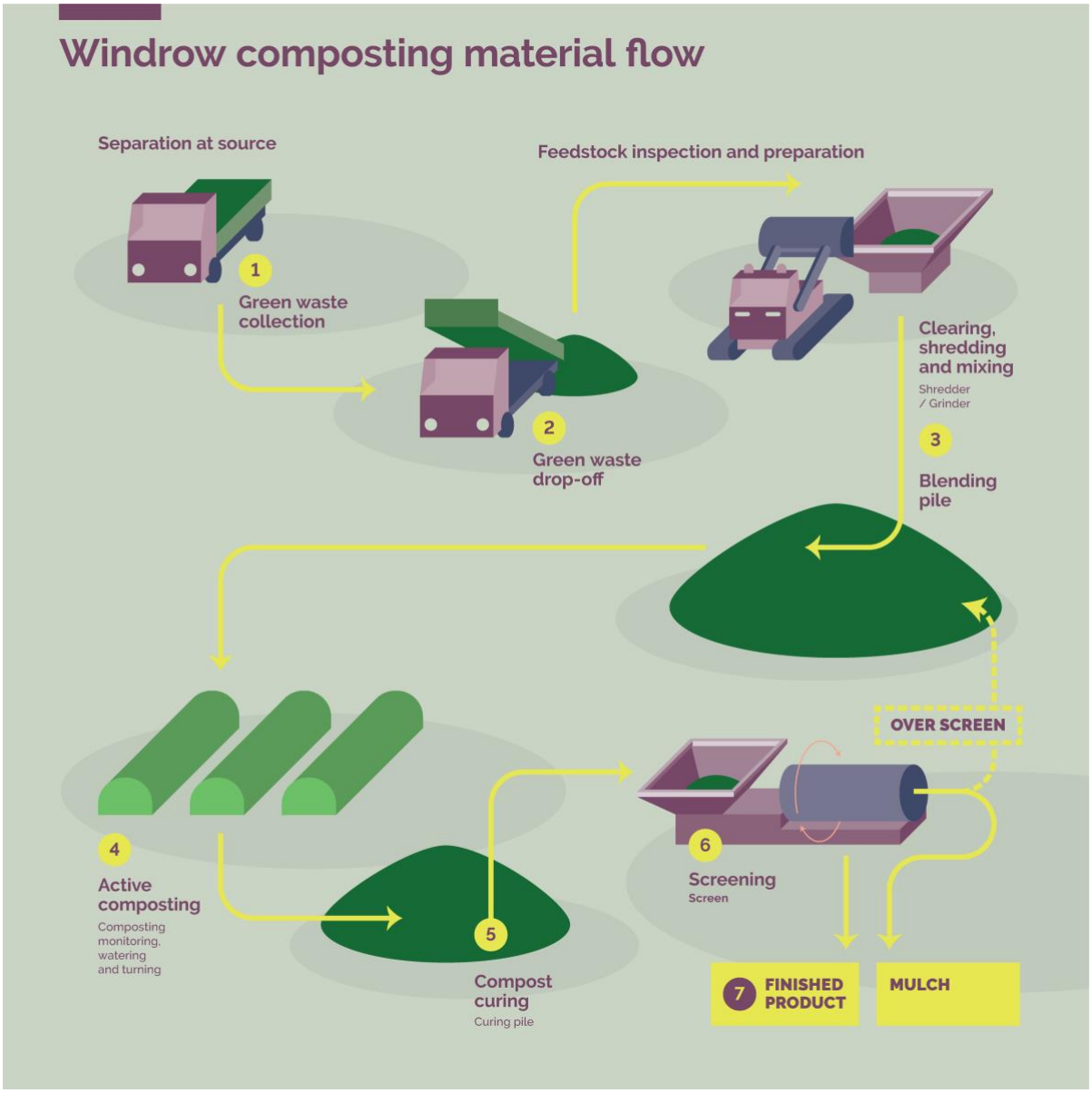

Figure 5: Green waste collection and windrow composting process

Step 1: Separation at source – The separation of green waste from other non-green wastes at point of waste production making subsequent treatment more efficient and effective. This step includes communication and behavioural change campaigns to ensure the right material is collected at the right time and place.

Step 2: Green waste drop-off – Location where source separated homogenous green waste is drop-off by the waste producer / primary collection service provider and made available to the compost facility. Can be located at compost facility or at distributed drop-off points closer to points of green waste production then transferred to composting facility in bulk or following pre-treatment (step 3).

Step 3: Feedstock inspection and preparation – Inspecting dropped-off waste for contaminants, clearing these where possible, shredding / grinding branches and larger items, mixing and blending various materials (nitrogen rich green material with carbon rich brown material) to stimulate good biological activity in composting. A critical component to good composting and achieving good heat and associated pathogen die-off as well as timely decomposition is getting the right Carbon to Nitrogen balance, known as the C:N ratio where 25-30:1 is optimum and 20-40:1 is OK. A list of common materials to compost and their C:N ratio is available at https://www.planetnatural.com/composting-101/making/c-n-ratio/ and a useful calculator to evaluate different mixes is available at: https://www.klickitatcounty.org/DocumentCenter/View/3523/Compost-Calculator Sargassum seaweed would count as a nitrogen rich green waste with a C:N ratio of 19:1. Due to the potential heavy metal content, it is recommended that this material represents a maximum of 15% of the total feedstock.

Rejected / contaminant materials are to be collected in appropriate containers and transferred to appropriate waste treatment (i.e. landfill or recycling if appropriate).

Step 4: Active composting – Creating and maintaining the conditions that promote aerobic microorganisms to thrive and decompose the waste materials. This includes monitoring temperature, moisture and oxygen levels and turning and de/watering piles as required. A summary of optimum composting conditions is presented in Table 2. Many parameters are adjusted through turning the windrow pile. For example, if moisture is low, turn and add water, if too high, turn without adding water. If oxygen is low, turn, if temperature is high or low, turn.

Where the resultant compost material is to be used exclusively as landfill cover, the option exists of utilising septic waste currently being disposed to the landfill by tanker, as a moisture and nutrient addition to the active composting windrows. This will reduce expense and impact of sourcing fresh sweet water for this purpose. When controlled properly, with the composting process meeting the minimum Processes to Further Reduce Pathogens (as detailed in Annex 3) the heat from the composting process will actively kill off faecal coliforms and other pathogens, providing a more appropriate and controlled treatment solution for the septic waste than applying direct to landfill. This must be regulated carefully to ensure minimal aerosol of raw septage and prevent uncontrolled run-off during application.

Table 1: Summary of optimal composting conditions[2]

Parameter	Composting Phase		
	Active composting	Curing	Product Storage
Oxygen concentration	13 to 18%		
Free Air Space	40 to 60%		
Particle size	A mixture of particles between 3 and 50mm		
C:N Ratio	25:1 to 30:1	18:1 to 23:1	15:1 to 20:1
Moisture Content	55 to 65%	45 to 55%	40 to 45%
Temperature	55 to 60°C	Less than 50°C	Ambient
pH	6.5 to 8		

[2] https://www.canada.ca/content/dam/eccc/migration/main/gdd-mw/3e8cf6c7-f214-4ba2-a1a3-163978ee9d6e/13-047-id-458-pdf_accessible_ang_r2-reduced-20size.pdf

Step 5: Compost curing – Following main active decomposition, the resultant compost is left (without turning or aggressive management) to "cure" until microbial activity slows right down, temperature returns to ambient and material is stable and ready to apply to land without damaging crops. This stage includes quality control testing (see Annex 3).

Step 6: Product screening – Following curing the material is sifted / screened with fine particles falling through the screen. The larger items passing over the screen can be returned to step 3 and blended with new waste as a bulking agent / microorganism "seed" if free of contaminants, or further processed into a mulch / soil cover material.

Step 7: Finished product– If quality tests are passed, fines from the screening step can be used / marketed as compost material (may include bagging or bulk sales / use) and larger woody material marketed as a mulch / soil cover material. If quality test is not passed, then the product can still be used as a very beneficial cover material on the landfill site (the relevant government agency may also approve it for use in other applications depending on quality standard achieved, this may include infill or road embankment cover). Other products may also be produced, including firewood or charcoal (see Annex 1).

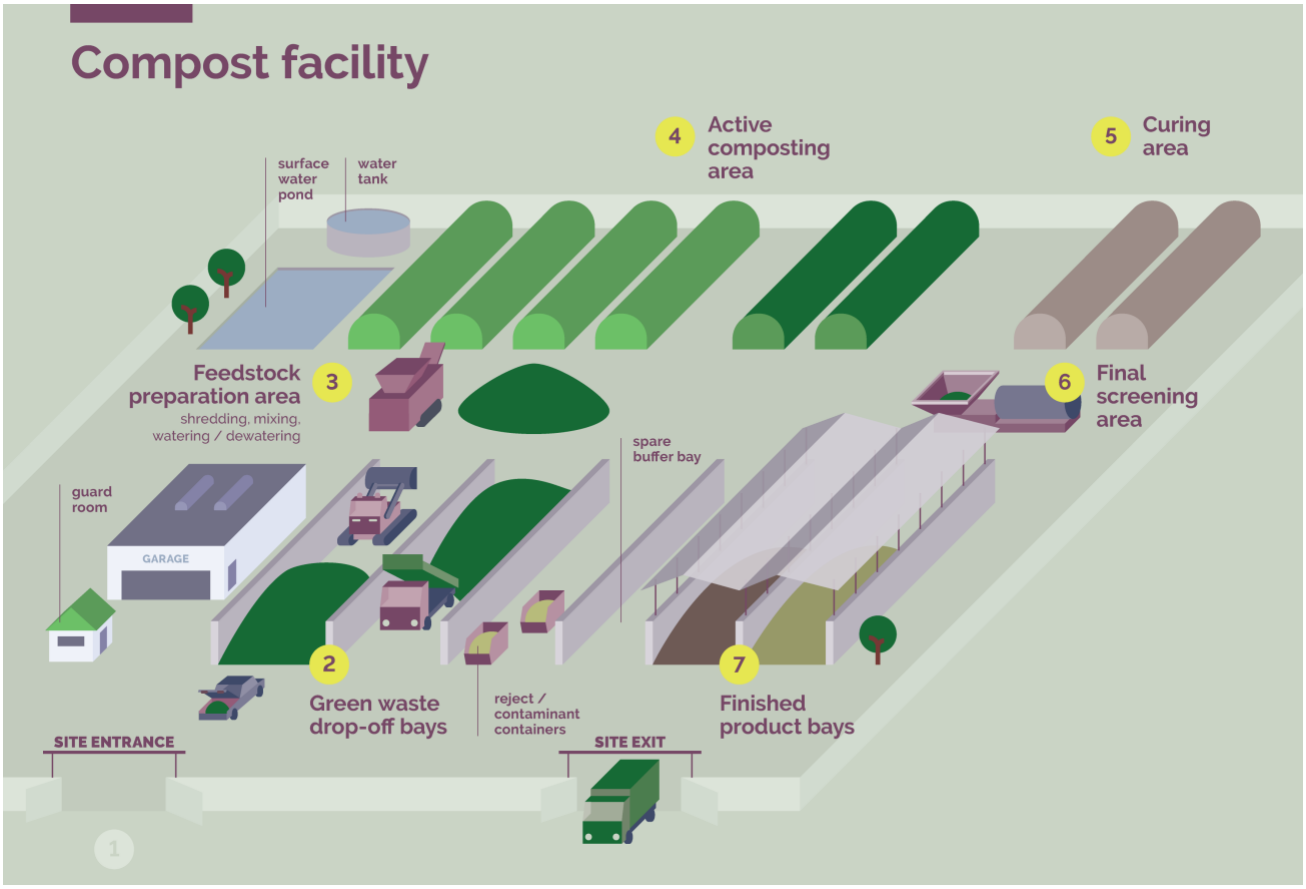

Figure 6: Example green waste drop-off and composting facility

Figure 6 presents a typical layout of a composting facility from drop-off to finished product stockpile. The sizing of such facilities depends on the volume and type of feedstock material arriving at the site per week (maximum and minimum in any one week in the year should be considered) and the speed of decomposition (influenced by local climate conditions and management technique). An estimate of total green waste quantity being produced in Saint Lucia, along with estimated facility size (for a single composting facility) is presented in Annex 5 with a spreadsheet of the calculations attached. This calculates an area of land required for composting the average green waste volumes currently going to Deglos as approximately **4,452m²**. This includes 1,236 m^2 for green waste drop off and material pre-treatment area, 2,996m^2 for active windrow and manoeuvring area, and 220m^2 for product preparation and storage area. Where the distributed green waste drop-off locations plan is

adopted, the land area requirement for each of the proposed sites and associated composting facilities requires to be calculated based on the specific catchment area (and associated green waste / feedstock volume) of each site. This can be achieved using the attached spreadsheet calculator. An additional useful guide is available at:

https://dec.vermont.gov/sites/dec/files/wmp/SolidWaste/Documents/ANR%20Sizing%20Your%20Composting%20Pad.pdf

A typical drop-off facility is illustrated in Figure 7. In this example non-shredded green waste is dropped-off in the "Green waste drop-off bays" while green waste that is pre-shredded (shredded at point of production / collection) is dropped-off in the "shredded feedstock bay". Shredded Feedstock is then transported to the composting facility and fed directly into Step 3.

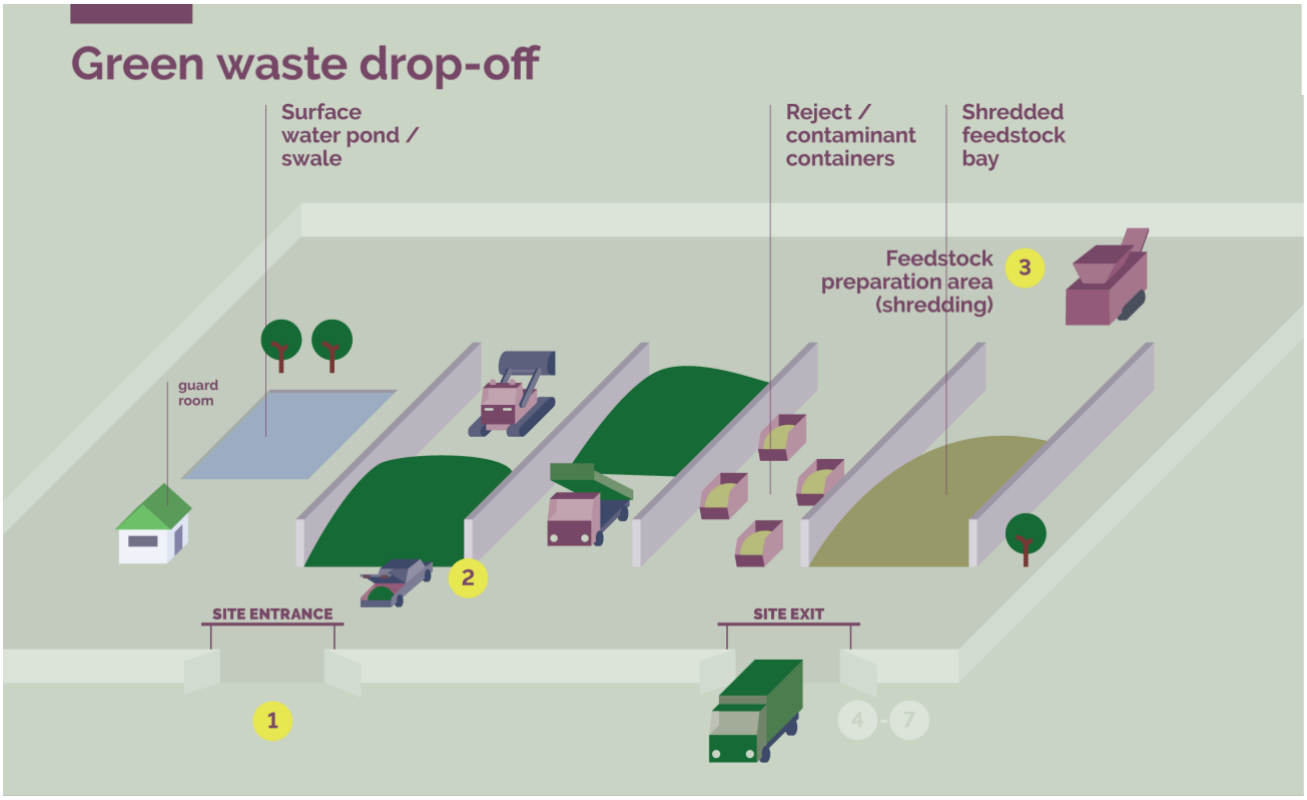

Figure 7: Example green waste drop-off and pre-treatment facility

Without developing the entire system, the risk that collected green waste is just dumped either at the drop-off locations, illegally in the environment, or back in the landfill is high. In such cases the dumped green waste becomes a breeding ground for vermin and disease vectors, become anaerobic and smelly, become uncontrolled dumpsites for all waste materials, all of which are at high risk of ignition and creating large uncontrolled fires. Proper planning and investment in the service is essential from the outset.

Note that both green waste drop-off and composting facilities should be established on dry firm land (preferably a hard standing or lime stabilised soil to prevent leachate infiltration to soil/ground water) with a 1 – 2 % grade across entire site to facilitate positive water flow into the surface water pond / swale. All site roads must be maintained and kept rut free at all times to facilitate access and prevent ponding of water on site.

Further guidance to the composting process can be found in the document "Technical Document on Municipal Solid Waste Organics Processing" produced by the Government of Canada and available from https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/municipal-solid/environment/organics-processing-technical-document-summary.html

4.2 Separation of green waste at source

This section further develops the concepts presented in the "Project Report 2: Source Separation and Collection of Waste – Core Methodology and Principles" and "SLU Report 5: Source Separation and Collection of Waste – Methodology for Saint Lucia". Some aspects are repeated or presented again in a different format to emphasis the importance of these aspects.

Bearing in mind that the objective is to reduce fire risk at landfills by diverting untreated green waste from landfill, and the need for contaminant free material to make good compost, the separation of green waste from other waste materials at point of waste production becomes crucial for the success of the programme. As conditions are similar across the country, it is anticipated that applying a unified approach shall be appropriate in all locations. However, if experience suggests otherwise, then different areas or each Quarter in Saint Lucia should implement the solution which is more viable to their specific conditions depending on the practicality and cost efficiency of delivering the service.

As previously described in the methodology reports, in designing the source separation system, the following aspects are of main importance:

- Separation at source must be implemented in line with the national waste management strategy and other pertinent laws.
- Existing practices, to which SLSWMA, households, commercial entities and other green waste producers are accustomed, must be evaluated and prioritized
- Source separation system must be designed around the identified quantities of priority waste stream and the selected technology
- Costs and benefits of different options for implementing a separation at source system should be compared

Green waste, with its low density, usually necessitates different types of trucks with different capacity than the vehicles used for collection of municipal waste. Table 3 presents the mean bulk density of green waste in various collection type and associated states.

Table 2: Mean bulk material density of green waste in different collection method and state

Collection method / material state	Mean bulk density (kg/m^3)
Uncompacted	150 (ranging 13 to 778)
Compacted	250
Shredded	350
Compost	500 to 800

The largest producers of green waste in Saint Luca have been identified as LUCELEC, the Ministry of Infrastructure undertaking road clearance, SLSWMA and commercial premises (particularly hotel resorts and construction land clearance). With consideration given to these producers and the density characteristics of the collection means, collection of green waste from these producers can be organised in two ways as summarized in Table 4.

Table 3: Collection vehicle options for large/ bulk producers of source segregated green waste.

Collection of green waste by open truck and transporting it to the central facility for chipping and subsequent treatment.

The green waste is collected in bulk (without being compacted or chipped) and transported to the designated drop-off location for chipping and subsequent treatment. Suitable for smaller distances between collection and treatment. Suitable also in cases when there are multiple points of collection (public beautification, road verges, hotels and commercial properties, multiple drop-offs, cemeteries, etc.).

Use mobile chipping equipment to increase the density of the transported material.

In order to reduce the transport cost, mobile chippers are used on spot to increase the density of the transported green waste (to approx. 350 kg/m^3). Chippers vary widely in their capacity and can be procured mobile or stationary (either diesel-engine, or electricity-based). Large capacity chippers are suitable for large de-bushing projects, tree felling (for example under power utility lines) and drop-off centres where significant quantities of green waste are received. Smaller capacity chippers are typically used for concentrated road-verge clearance and smaller public green areas.

These represent the most appropriate solutions for these producers and the fact that the majority of the vehicles available being non-compaction trucks. Table 5 presents comparative costs for these two options based on two different quantities to be collected and transported (assumed distance of 20 km), namely 2,000 tonnes per annum (tpa) and 5,000 tpa. This data has been extrapolated from a detailed study conducted in South Africa by the RWA Group and therefore, although considered accurate, requires further confirmation for the Eastern Caribbean context.

Table 4: Comparative illustrative operation and maintenance costs of two green waste collection options

XCD	Chipping and transport to treatment facility		Direct transport to treatment facility	
	2,000 tpa	*5,000 tpa*	*2,000 tpa*	*5,000 tpa*
Chipping / shredding costs	27,000	63,000	-	-
Transport costs	66,000	160,000	164,000	426,500
Annual costs	**93,000**	**223,000**	**164,000**	**426,500**
Cost per tonne, *(XCD/t)*	**46**	**44**	**82**	**85**

Note: both options use depreciation costs on capital investment in trucks – all data extrapolated from a 2018 study conducted by RWA in South Africa.

The data presented in Table 5 indicates that the expediency of chipping the green material prior to transport increases with the increase of quantities. As expected, costs for direct transport to the composting facility increase progressively with the increase of quantities. Overall, it is clear that, due to the low density of green

waste, prior shredding of the material before hauling is usually economically justified, even over the relatively short distance of 20km.

However, as mentioned, there are additional logistics and factors that require to be taken into consideration when designing the green waste collection system, including:

- Quantities of green waste collected from biggest generation points (major park area, LUCELEC clearance operations, large drop-off centres, etc.)
- Distance between biggest generation points and treatment facility
- Distances between drop-off centres (and opportunities to optimise transport/ share chipping equipment)

Final decision on which type of collection system to utilize should be selected by the waste producer, SLSWMA or other private collectors based on cost estimates, taking all the above factors into account. The pilot source separation of green waste being implemented within this project should contribute to obtaining the data to support this. In addition, as introduced in the source segregation methodology report for Saint Lucia and presented again in Annex 1 of this report which outlines the recommended steps required to realise improved green waste management, two national level initiatives should be considered to encourage improved source segregation and pre-treatment of green waste. These include:

1. The GoSL should consider establishing a small grants programme or improving the system on providing tax relief to assist entrepreneurs (particularly garden services companies) invest in green waste shredders and equipment. This should streamline the existing facility for duty free concessions on goods imported to Saint Lucia which is a cumbersome process requiring a Cabinet memo to be written up for each application and each application to be considered by the Cabinet of Ministers.

2. The Ministry of Infrastructure undertaking roadside clearance and LUCELEC tender and award contracts (minimum 1 year) for bush clearing / treatment services to include condition that material is shredded on site and composted in a licensed facility.

Table 6 presents options for separation at source **collection of green waste from households**.

Table 5: Options for collecting green waste form households

	1. *Public drop-off*. A system established by the waste management authority that enables householders to take their green waste to a local facility to drop-off their waste. Of particular importance is that drop-off centres allow for the waste management system to further develop. Drop-offs can develop in stages and become small recycling centres where various recyclables with market value are collected and stored for subsequent valorisation and hazardous wastes can be segregated and collected for proper treatment.
	2. *Scheduled kerbside collection*. If publicly acceptable, green waste can be collected from households without any investments in containers or establishing additional drop-off centres. Collection can be schedule on a specific day, once a week in the peak seasons and less frequently in low growth season. Suitable for residential areas with significant generation of garden waste and relatively distanced to drop-off centres.

	3. *Individual bins*. This is simply adding an additional bin to the already existing door-to-door system throughout the country. Suitable for collection of variety of green materials, like: • Grass cuttings • Hedge clippings • Annual weeds • Leaves • Small branches (e.g. length: 1 m, diameter: 7 cm) • Small prunings
	*4. Collection of green waste by refuse compactor* The green waste segregated and presented by households (loose as in method 2 above or in bins as in method 3) is collected in a designated compaction truck and transported to the designated treatment location for chipping and subsequent treatment. Suitable for very soft green waste (i.e. grass, leaves and small bushes from domestic gardens) as larger green waste (tree branches) and soil/rock contaminants can cause substantial damage to the compaction plate and hydraulics. Suitable for longer distances between collection and treatment and cases when there are multiple points of collection. Reportedly one (1) of three (3) compactors being donated by the Japanese Government to Saint Lucia was earmarked to collect and transport food waste from households.

Table 7 presents the advantages and disadvantages of possible green waste collection alternatives.

Table 6: Advantages and disadvantages of options for collection of green waste from households

Collection option	Advantages	Disadvantages
Drop-off	- Provides for optimised collection and transport - Lower operating costs for collection compared to other two options - Suitable for oversize materials - Suitable to establish as a civic amenity centre (collection and temporal storage of other separately collected materials, like: dry recyclables; WEEE, bulky waste, hazardous waste etc.)	- Results in lesser collection rates due to potential distance to residents - typically 10 to 25%
Kerbside collection	- Lower investment costs (none apart from investment in collection equipment) compared to other two options - Convenient for households	- Probability for public unacceptability due to appearance - Probability to increase littering and illegal dumping of other wastes

Collection option	Advantages	Disadvantages
	- Suitable for collection of oversize materials - Results in higher capture rates (typically 40 to 65%)	- Not suitable for loose materials such as grass clippings and leaves which should be placed in a reusable container or in a bag - Higher operating costs compared to other two options - necessitates scheduled collection
Individual bins	- Convenient for households - Results in higher capture rates (typically 50 to 75%) - Lower operating costs compared to kerbside option, but higher than the drop-off	- Highest investment costs compared to other two options - Not suitable for oversize materials

In terms of costs, it is clear that collection through public drop-off centres is the lowest cost option because it relies on residents to bring their green waste themselves and no scheduled collection service is needed. Kerbside collection is the lowest investment cost option, but still brings higher operating costs than the option with individual bins. This is due to the time needed to collect the unbundled green waste. It is therefore recommended and planned for the SLSWMA systems to establish drop-off facilities for the green waste at the planned Kurina waste management facilities as well as additional Civic Amenity Sites in the north of the island.

The following Figures 8 to 11 illustrate further examples of green waste drop off points that could be applied in Saint Lucia.

Figure 8: Green waste drop off facility in Bloemfontein, South Africa.

Figure 9: Green waste drop off with container for bags and other foreign objects, also divider wall to separate tree cuttings from smaller grass cutting and pre-shredded material - Eskilstuna landfill in Sweden

Figure 10: Example simple hook loader container as mobile green waste drop-off point = Szombathely, Hungary

Figure 11: Example compost product stockpile for residents to take following compost operations at Eskilstuna Landfill, Sweden

4.3 Communication and Behavioural change

An essential and integral aspect of introducing a Separation at Source campaign for any waste stream, or indeed any waste management initiative involving the waste producers, is to engage the stakeholders. Ensuring waste producers are informed and buy-in to the system and as a result actively participate is the only chance for success. Given the importance of this aspect, a "Communication Strategy and Implementation Plan" and "Communications and Brand Manual" package has been prepared to accompany this report. This package presents a full overview of communication needs in establishing the proposed green waste management service and includes sample communication brand guides. Figure 12 illustrates some of the branding concepts.

Figure 12: Example of branding for communications campaign as presented in separate Communications and Brand Manual document

4.4 Product and Market

The objective of this initiative is the diversion of green waste from landfill to assist in making the management of landfills more efficient and effective and therefore less at risk to fire. The focus is therefore on the diversion of the material rather than the production of a specific product. It is likely that the cost of operating and maintaining green waste collection and production equipment and infrastructure will be higher than the achievable revenue from product sale. The costs will also be higher than the current immediate cost to landfill. However, the full economic cost, when externalities (cost to the environment and society as a whole) are considered, composting will inevitably be the more economical option. It is estimated that the true full cost of landfilling waste at Deglos is currently in the range of 80 to 110 USD/tonne. As the intent in Saint Lucia is to eventually outsource the composting operations to a third-party private service provider, the specific products and markets are not discussed in detail here. However, additional guidance on potential products and markets is provided in Annex 2 and supporting guidance on compost testing and quality control is provided in Annex 3. An accurate calculation of the full cost of landfilling a tonne/m^3 of waste in Saint Lucia is required to be undertaken and the potential to subsidise composting operations accordingly evaluated.

As presented in the recommended steps to implementing green waste management services in Saint Lucia (Annex 1), it is proposed that an initial composting trial is established on Deglos Landfill. This will enable the source segregation of green material to be established first thereby assisting determine the material flow and business case for private composting providers. It will also provide a suitable low-grade compost like output to be made as a cover material for the currently uncovered waste mass. A **Low-grade Compost Like Output** is effectively compost material that does not pass all the quality standard (see Annex 3) and therefore is not beneficial to soil. This might be due to high level of plastic or other contaminant or elevated levels of heavy metal or detrimental chemical. This product can be utilised on the landfill as a beneficial cover material over the active waste cells. It is recommended that this be the target output for the first year of operations until private composting capacity is developed and engaged.

As experience with the composting process and operations improve, marketable products as detailed in Annex 3 can be produced as resources and standards allow.

4.5 Operator Model

Multiple operator models exist throughout the world for municipal-scale composting and include farmers, non-governmental organizations, private companies, and public authorities themselves. Depending on the public authority's capacity and financial situation, the management of organics might be operated by in-house resources, contracted to a private operator (either fully outsourced or through Public Private Partnership, a model for which should be carefully evaluated), partner with an NGO or similar. Each operator model has pro's and con's and the right solution for the specific local conditions is required. A summary of case studies presented in the World Bank Group's 2016 Urban Development Series Knowledge Papers title "Sustainable Financing and Policy Models for Municipal Composting" [3] is presented in Table 8 providing additional insight into the various models operating internationally.

Table 7: Operator Models for Municipal Scale Composting

	Operator Model			
Location	**System**	**Collection**	**Production**	**Distribution**
Austria	Distributed farm-based composting operations	Regional organic waste collected by local authorities and dropped at either a central pre-treatment facility or farm for a fee Farmers sometimes hired by municipality to collect organic waste	Farmers produce compost on-site with municipalities contracting with farmers to collect and co-process municipal organic waste with agricultural waste	Majority of compost is used on-site at farms Remainder sold on- site
Bangladesh	Small- scale pilot facilities	Facility workers collect waste from households	Workers sort and produce compost using low-cost technologies	Partner companies purchase, enrich, and distribute compost through pre-existing agricultural network
	Large scale central composting facility (joint venture)	Clean market feedstock historically picked up for free Company negotiating for free delivery of waste from city	Local NGO and international recycling company partner to produce compost from clean market waste	Fertilizer company purchases and sells compost to farmers through existing distribution network
Brazil	Organic farming cooperative	Cooperative members contribute agricultural waste Non-members can drop off waste for a fee	Farm cooperative produces compost alongside anaerobic digestion	Compost is given for free to member farms Remaining compost is largely sold in bulk to agricultural markets Small bags sold on- site for household use
India	State composting facility	Mixed municipal, household and agricultural, and manure waste dropped off for gate fee	Compost plant produces three grades of compost based on feedstock source	Facility sells both own source compost as well as compost from other producers mainly to farmers Delivery cost included in price

[3] https://www.waste.ccacoalition.org/document/sustainable-financing-and-policy-models-municipal-composting

	Private composting company	Mixed municipal waste dropped off by the city	Firm sorts out recyclables and produces compost from remaining organics	Company sells compost through distributors Compost sold under own name, and in re-branded forms
Sri Lanka	Distributed municipal composting facilities	Door-to-door collection of mixed household municipal waste Source separated biodegradable waste from commercial generators collected and charged if waste is not separated	Facility sorts out recyclables and produces compost from remaining organics	Sold to farmers in eastern Sri Lanka through sales outlets and agents

Note: While operator models are summarized by country, it is important to note that municipal-scale composting and related partnerships are most often led by a city or local government

SLSWMA have indicated the intent to work with local agricultural sector and other key stakeholders to identify potential service providers and composting facility locations, conducting pre-selection of sites that meet composting facility licensing and Environmental Impact Assessment criteria.

As mentioned, the recommended interim solution is to utilize the non-active area of Deglos landfill for initial composting activities. However, in the long-term, it is important to establish clear licensing conditions for composting facilities to be able to operate and ensure that only facilities that meet those standards are licensed. This prevents legitimate operators that serve the wider societal benefit and invest time and finances into their operation from being undercut and losing business to rogue companies that cut financial corners to the detriment of the environment and society.

The establishment and operation of green waste drop-off facilities to collect materials will be operated by SLSWMA directly. Delivery to the drop-off points will be provided by the relevant waste producer or service provider, public or private.

4.6 Equipment

Multiple infrastructure and equipment types, specifications and combinations are available for operating green waste collection, drop-off and composting operations. SLSWMA currently owns much of the essential equipment required to establish and operate the public drop-off facilities, however additional items will be required prior to initiating a functional service.

An overview of the equipment recommended for the drop-off facilities and the initial composting operations on Deglos landfill are provided in Table 9. Equipment recommended for managing a basic but complete composting facility in Saint Lucia and transforming it to marketable compost is provided in Annex 4.

Table 8: Typical equipment required for compost operations

Equipment item	Use	Requirement	Typical cost	Photo
Grapple truck **Hook loader and containers** **Or suitable alternative drop-off collection and transfer system**	Collecting green waste from public drop off points. Grapple truck utilised if loose loads. As previously demonstrated, the transportation of shredded green waste is more economically efficient. Hook loader containers can be placed at any location and can be combined with small shredders to pre-treat tree branches and low-density green waste.	**Highly recommended** Essential to operate decentralised drop-off facilities. SLSWMA do not currently have such equipment on fleet.	Variable, in the region of USD 200,000 including container or crane	 
Front end wheeled bucket loader (Agricultural tractor >75 HP with front-loader also an option for smaller work)	Moving green waste, loading shredder, creating windrows, turning windrows, rolling cover material over windrows, loading screen, moving product. This one machine could manage all composting activities required at Deglos.	**Essential** Available. SLSWMA have equipment located at Deglos that should be able to manage all tasks required. A back-hoe loader or excavator is also adequate.	245,000 USD (Small Agricultural tractor 60,000 USD)	
Water supply and / or storage	>5000 litre water storage capacity with rainwater harvesting equipment installed and connection to water pump Solid tank above ground tank, bladder bags, open surface water pond or reliable mobile tanker supply or well.	**Essential** The microbial processes in composting can have high water demand. Equally rainwater must be drained away from the piles to prevent excess moisture on site. Adequate water collection and storage systems required on all sites for such tasks. It is also possible to utilise site run-off water or tankered liquid waste which currently is being	USD 500 – 10,000	

		disposed of into pits on the landfill. This must be very carefully monitored and controlled for pathogen control, however.		
Water pump (trash pump) and hoses	Self-priming roller pump, minimum 100 litres per minute (or submersible well pump / water tanker pump) with 30-meter head pressure, with 2 x 100 m of hose included	**Essential** Can be achieved through various methods to achieve the requirement to pump /distribute water from well / store / tanker to windrows.	USD 700	
Windrow composting **Temperature Probes**	Robust, heavy duty accurate windrow compost temperature probes (20 pieces) analogue or digital reading, 0°C to 85°C temperature graduating minimum with sealed fogless capsule	**Essential** Required to monitor microbial activity in windrow composting piles and indicates when to actively manage the pile, including when to turn the pile, when to add water, and whether pathogen die off conditions are being achieved.	USD 100 each x 10 = USD1,000	
Chain saw and Log splitter	For cutting up tree branches and other uncontrolled green waste. Log cutter to efficiently and effectively slice wood and branches into 300mm long pieces	**Highly recommended** Helps reduce large materials to a manageable size and shape. Also, useful if firewood production is a viable and marketable product from the green waste materials. Feasibility study required first.	USD 300 – 1,000	
Shredder / Grinder (small mobile for collection, larger hammer mill or tub grinder at compost facility)	Shredding / size reduction of larger green waste items (tree branches etc). Also mixing and blending different materials together as they pass through the shredders to stimulate more rapid decomposition.	**Highly recommended** Shredders and chippers are not essential for all materials, but greatly improve transport efficiency and expediate decomposition times. SLSWMA have two small relatively new shredders, one at Deglos and one in Vieux Fort.	USD 5000 – 250,000	

		These are very small scale and not easily transported. A larger, more mobile shredder is recommended. A larger tub-grinder would also be beneficial.		
Windrow Compost geomembrane / fabric Cover	Geomembrane cover for compost piles - prevent moisture loss (in wet conditions will shed excessive rainfall and reduce the leachate. In dry conditions it will reduce moisture loss. The breathable membrane makes the cover permeable to oxygen, carbon dioxide and water vapour. The cover also assists with reducing odours	**Optional - Recommended** Not essential, but Saint Lucia can experience hot dry periods as well as prolonged heavy rain. Regulating decomposition through keeping rain out and keeping moisture in the piles as required is recommended through purchase and use of windrow cover membranes on all piles. Such membranes work particularly well when used in combination with **air blowers (an additional optional item of equipment**) within the windrow to create positive airflow through the pile reducing the need for turning and expediting decomposition.	USD 500 1,000 / 10m long x 3m wide sheets (depending on quality)	

5 Green Waste Pilot Study

Having established the requirements and plan for the overall green waste management system for Saint Lucia, it is prudent to conduct a pilot study to test the concept before assessing the feasibility of rolling it out to full scale implementation. This section presents the concept and scope of a pilot study that is intended to be implemented to provide additional evidence to support decision makers the options for overall management of green waste.

5.1 Pilot study objective and scope

Overall aim

To contribute to the mitigation of UPOPs emission from landfill through improved efficiency and effectiveness of landfill operations that reduce the occurrence and sustainment of landfill fires.

Specific aim

To assess the effectiveness of a drop-off site and composting approach for diverting green waste from landfill through source segregated collection of homogenous material and its subsequent economically viable and environmentally sound management. The pilot project also aims to assist SLSWMA establish the public drop-off for green waste and provide guidance on establishing interim operations to produce compost like material for use as cover material on Deglos Landfill whilst working to outsource composting operations to a third party.

Objectives

The pilot project has four specific objectives:

1. Assess the effectiveness of source segregated collection drop-off site in diverting green waste from landfill, capturing homogenous green material, and waste producer acceptance of using such sites (including effectiveness of communications strategy and impact of service on open dumping and enforcement resourcing). This shall also assess the quantities of green waste accessible to future private composting service provider.
2. Evaluate the capacity and appropriateness of the proposed operator models for collecting green waste and operating drop-off facilities.
3. Assess the risk associated with green waste management in spreading invasive flora and fauna throughout the country, in particular the Giant African Snail.
4. Monitor the impact green waste diversion has on landfill management and potential fire / UPOPs mitigation (including use of compost product as landfill cover material).

Geographic Location

The pilot study will focus on segregating green waste at a drop-off location as well composting operations at Deglos Landfill site. An alternative is the establishment of one drop-off location separate from Deglos with transfer of green material to Deglos for composting, however this is dependent upon funding and resource availability to conduct transfer.

Waste Producer focus

The pilot project will target the largest waste producers (the so called “low-hanging fruit”) which are:

1. The Ministry of Infrastructure undertaking roadside vegetation clearance teams,
2. LUCELEC bush clearing around public utilities, and
3. larger commercial activities currently delivering green waste to landfill (hotel resorts and land clearance operations).

4. Dependent upon drop-off facility location, households may also be considered.

Only activities of this nature taking place within the catchment area of the selected green waste drop-off facility will be included in the pilot.

Figure 13 provides an illustrative overview of the proposed pilot project scope of service.

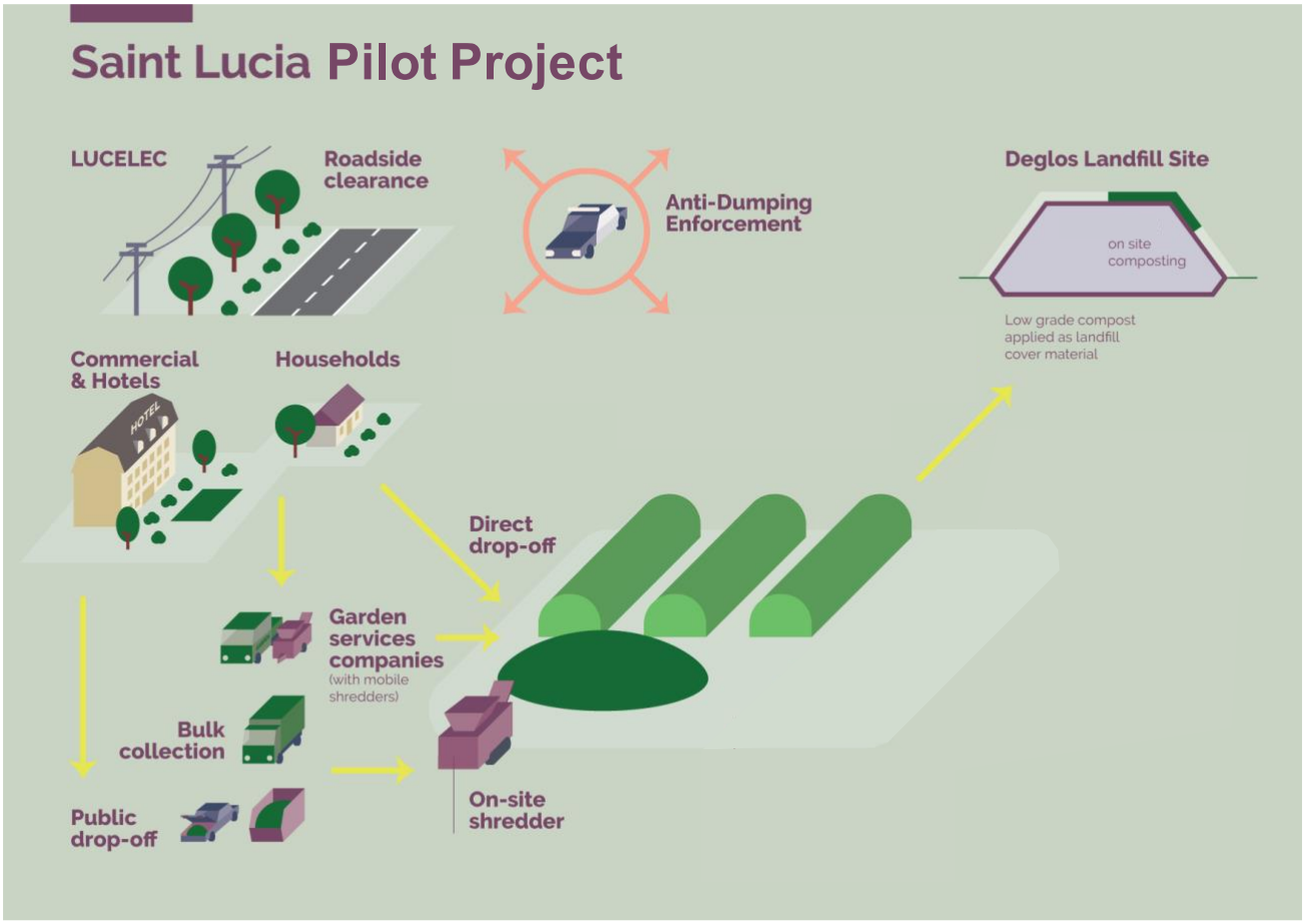

Figure 13: Proposed scope of green waste collection and diversion from landfill pilot project (composting facility is located at the Deglos landfill for the pilot project).

Drop-off and Composting area requirement

As 7,812 tonnes of green and coconut waste per year was delivered to Deglos Landfill site, it is proposed that the pilot project targets up to 50% of this material or 330 tonnes per month / 11 tonnes per day (7-day average) so as not to overwhelm the activities and ease operations into production.

As previously mentioned, and detailed in Annex 5, approximately 4,452m^2 area of land is required for all activities when composting the total average daily green waste currently arriving to Deglos landfill of 22 tonnes/day. This includes a 1,236m^2 waste drop-off / reception area, a 2,996m^2 active windrow area and a 220m^2 product preparation and storage area

When selecting an area for the pilot project, the SLSWMA should consider this ultimate area requirement. However, for the pilot project needs, an area suitable for composting 50% of the current green waste deliveries would still allow for growth and unforeseen variances. At 11 tonnes / day t**he total estimated area required for drop-off and composting activities that captures 50% of the total green waste material currently reported as being disposed to landfill is 2,576m^2.** The calculations for this area are included in Annex 2 (area calculations for 50% and 100% of current green waste volumes disposed to landfill, note that these are all based

on assumptions and estimates of volumes and material pile dimensions as presented in the Annexed calculation tables and the attached spreadsheet). Figures 14 and 15 indicate potential areas on Deglos Landfill that could accommodate this composting area (area shown in Figures is for 100% of receiving material which requires and estimated 4,452m^2) and should be considered for the pilot green waste drop-off and composting operations.

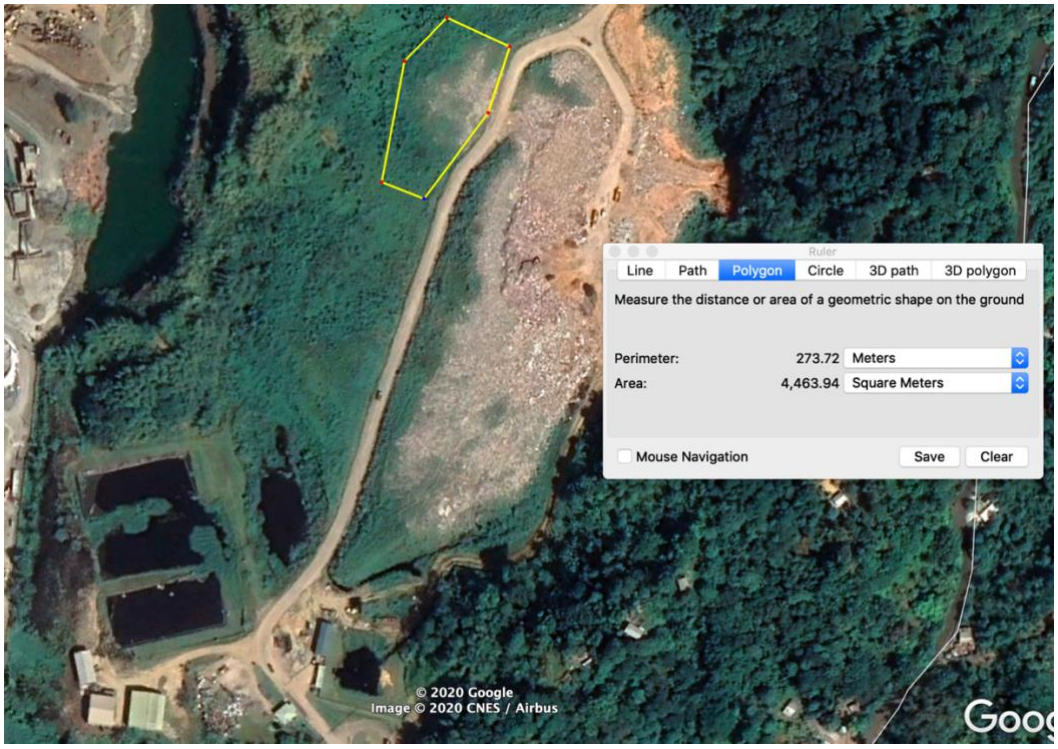

Figure 14: Option A - Potential composting area on top of existing waste mass

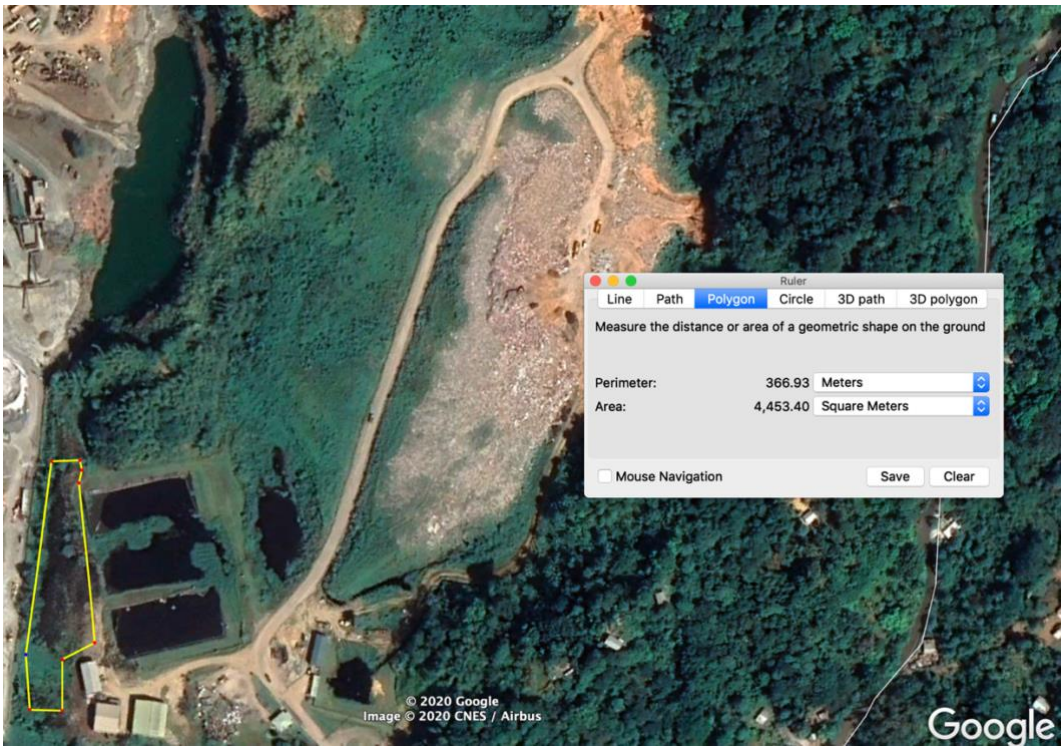

Figure 15: Option B - Potential composting area where whole waste tyre stockpile has been located

5.2 Project stakeholders

The key stakeholders and project partners in this proposed pilot study are listed in Table 10 along with their proposed role and responsibilities.

Table 9: Pilot project partners and their role and responsibilities

Partner	Role / Responsibilities	GM comments
SLSWMA (Operations)	• Responsible for establishing and operating the green waste drop-off, transfer and initial composting operations at Deglos.	• Reallocate staff from tire shredding operations.
	• Refining and delivering communications campaign	• SLSWMA Information & Communications Department
	• Assessing illegal dumping.	• Operations - ZS
	• Working with general management and board of directors to approve investments in green waste management pilot.	• GM and Technical Committee – add to budget
	• Lead entity in undertaking the pilot study and coordinating and completing the Monitoring and Evaluation data collection.	• Operations lead in collaboration with Info & Comms Department
	• Assist in identification and authorisation of green waste drop-off and composting location/s.	• Operations with approval from GM
	• Assess potential government support to service providers in procuring mobile shredders and equipment to facilitate improved green waste diversion from landfill, compost processing, and product sale.	• Duty free concessions procedure in effect; Authority needs to establish an application for each applicant and then dispatched to the Cabinet of Ministers via the Line Ministry.
	• Assess potential for source separation of green waste from households and institutions.	• Operations with Consultants
SLSWMA (Landfill)	• Monitoring incoming green waste before, during and after pilot period.	•
	• Monitoring and assessing changes in efficiency and effectiveness of landfill management and any incidences of fire at the landfill.	• Operations and Landfill Manager (OLM) with staff
	• Assess potential for implementing full ban on green waste material disposal to landfill.	• DGM
	• Divert green waste loads arriving at Deglos to the green waste discharge area.	• Weighbridge Attendants
	• Establish area and operate initial composting operations on non-active area of waste mass.	• OLM
Ministry of Infrastructure and Constituency Councils (roadside clearance)	• Establishing operating practices to ensure homogenous green waste is separated from litter and other wastes (including avoidance of bagging green waste in plastic bags and identifying an alternative practice where required) during road-side clearance activities.	• Re-useable bags
LUCELEC	• Establishing operating practices to ensure homogenous green waste is separated from litter and other wastes (including avoidance of bagging green waste in plastic bags)	• Information and Communications Department, and Admin

	during de-bushing and line clearance activities. • Ensuring green waste delivered to Deglos composting area.	
Ministry of Agriculture	• Collaborate with SLSWMA to provide assistance in composting operations including facility and equipment operation and maintenance as required. • Working with agricultural community to assess composting operator and market opportunities for the sale of various products.	•
Bureau of Standards and Ministry of Agriculture - Analytical Services	• Recommend compost tests and testing standards and conduct tests on interim and final product for trace metals, pathogens and other relevant parameters.	• Bureau of Standards for recommending standards • MoA is the agency that has capacity to conduct analytical tests, albeit limited.
Garden services companies.	• Work with clients / waste producers to ensure green waste is segregated at source and taken to appropriate green waste drop-off. • Work with SLSWMA to assess efficiency and effectiveness of different options for collection including shredding on site and bulk haulage to drop-off facilities.	•
Litter Prevention Wardens	• Monitor and report occurrences of green waste (and other waste) dumping in study area before, during and after pilot study.	• Zonal Supervisor(s)
Saint Lucia GEF 5558 National Project Coordinator and Project Working Committee (PWC)	• Monitor and ensure pilot project is implemented according to concept and take note of findings. • Report findings and integrate outcomes into national green waste management plan.	•
BCRC-Caribbean – GEF 5558 team	• Support the development of the pilot study concept through coordination between PWC/NPC and RWA Group. • Finance and support the procurement of agreed pilot study procurement needs (within the budget limit made available). • Provide support and follow-up on the outcomes of the pilot study with regard to impact on reducing UPOPs emissions from landfill.	•
BCRC-Caribbean – GEF 558 Component 2 consultants - RWA Group	• Developing pilot study concept. • Providing assistance and support for the initial kick-off and start-up of the pilot study.	•

5.3 Pilot project activities

In order to realise the aim and meet the objectives of the pilot study, the SLSWMA and other project stakeholders require to invest in the design and development of the infrastructure, equipment, human and other resources to manage green waste. The following list provides an overview of the items required to be budgeted for to establish the drop-off / compost operations at Deglos. A full finance plan is required once the location and final scope of the pilot has been finalized with SLSWMA.

- Source Segregation Collection Service
    - Targeting the main green waste producers to collect green waste separately and free of contaminants.
    - Marketing (including Behavioral Change) Communications
    - Optional procurement / hire of mobile green waste shredders for road verge clearance teams if deemed appropriate
- Drop-off / Composting facility establishment capital costs:
    - Land identification (see Section 5.1, Figures 14 and 15 as well as Annex 5 for area required for each activity)
    - Land clearance, levelling, sub-base course and hard standing (where installed), and site entrance / exit points with public access road to drop-off areas.
    - Drainage, swales and water storage / sump installation
    - Water pumps and dosing equipment (to apply water to compost piles / windrows)
    - Earth berms or block wall to delineate drop-off and other bays (as illustrated in site layout Figure 6)
    - Establish area for final product (could be roofed or utilise geomembrane cover)
    - Equipment rental
        - Excavator / Wheeled loader (certain machinery is currently available at Deglos landfill, additional machines may be required depending on quantity of materials recovered)
    - Equipment purchases (see Table 12 and Annex 6):
        - Temperature probs and logbooks
        - Chain saws
        - Water pumps
        - Windrow geomembrane cover fabric (if desired)
        - Compost screen (mechanical or static)
        - Reusable bags for green waste collection on roadsides and containers for public drop-off
    - Relevant Personal Protective Equipment (PPE) for all staff and all equipment types.
    - Establish area for rejected materials
    - Site signage
- Composting facility operational and maintenance costs (see operational requirements in Annexes)
    - Equipment (wheeled loader (loading and compost turning), shredder, water pumps, compost screen (if mechanical), skips and rejected waste transfer to landfill).
    - Labour (compost technician, operations manager/supervisor)
    - Sampling and Testing of compost for quality assurance
    - Equipment (wheeled loader (loading and compost turning), shredder, water pumps, compost screen (if mechanical), skips and rejected waste transfer to landfill).
    - Labour (compost technician, operations manager/supervisor)
    - Sampling and Testing of compost for quality assurance

A resourcing plan covering procurement and financing of the above pilot project cost items will be refined as the physical roll-out of the pilot project operations is initiated. The main activities of the pilot project are detailed in Table 11. This should be read and implemented in conjunction with the supporting activities listed and assigned to relevant parties in tables 10 and 13. Estimated activity timeline is reliant upon efficient allocation and approval of land for green waste drop-off and composting.

Table 10: Pilot study activities, accountable stakeholders and timeline

No.	Activity	Responsible Stakeholder	Time frame
1	Confirm pilot study concept and implementation plan - including SLSWMA confirming scale of pilot project –as 7,812 tonnes per year is currently delivered to Cooks Landfill site, it is proposed that the pilot targets up to 50% of this material or 330 tonnes per month.	NPC / PWC	Two weeks from receipt of this concept
2	SLSWMA to identify and confirm the location of one green waste drop-off for the pilot and the compost location on Deglos (or propose alternate)	SLSWMA	ASAP
3	SLSWMA confirm site plans for the identified Green waste drop-off and composting areas, in line with the conceptual recommendations of this report.	SLSWMA	One month following plan approval
4	Prepare drop-off site and composting area with site clearance, site drainage, entrance/exit, drop-off location, and additional layout according to approved plans.	SLSWMA	One week following site use approval
5	Procure additional equipment for composting activities in accordance with afore listed requirements and final green waste management plan.	BCRC-Caribbean	In conjunction with item 4
6	Prepare diversion plan to identify specific waste producers to be targeted for green waste diversion, introduced to the pilot project and directed to drop-off site.	SLSWMA	In conjunction with item 4
7	Record green waste loads entering Deglos landfill and assess operations of landfill compactor and working face in accordance with Monitoring and Evaluation (M&E) framework (Table 13 of this report).	SLSWMA	In conjunction with item 4
8	Attend training (virtual) on communications and behavioural change to be delivered to the SLSWMA by RWA Group	BCRC-Caribbean / SLSWMA	As availability enables
9	Allocate budget and fully develop the recommendations of the communication strategy and implementation plan to communicate the pilot project to target waste generators and service providers in the target catchment area that are participating in the Pilot.	SLSWMA	In conjunction with item 4
10	Pilot project kick-off training to be provided to SLSWMA by RWA Group consultants on implementation and M&E framework.	BCRC-Caribbean / RWA Group	In conjunction with item 5
11	Train zonal supervisors to record data on green waste dumping in catchment area and how to follow the M&E Framework.	Zonal supervisors	In conjunction with item 4
12	Initiate all monitoring and evaluation activities to assess the baseline prior to project start.	Assigned stakeholders	In conjunction with item 4
13	Initiate green waste drop-off, shredding and composting operations using materials collected from road-side clearance and LUCELEC.	SLSWMA	Launch of green waste drop-off.
14	All participating waste producers (business and institutions) within the catchment area should be aware that the facilities exist, why they exist, know where they are and how to use them	SLSWMA	Within one month from launch of green waste drop-off site operations.
15	Continuous implementation of the M&E Framework data collection.	Assigned stakeholders	Throughout project
16	At least 40% of commercial premises in the catchment area should have taken green waste to a facility at least once.	SLSWMA	Within two months from launch of drop-off location
17	Attain a target of 360 tonnes of green waste to have been dropped off at each site with at least half of those who produce green waste in the catchment area having used a site.	SLSWMA	Four-months after the launch of drop-off location.
18	First compost windrows to be finished and begin curing, testing to take place on product to assess product quality in accordance with recommended standards detailed in this report (Annex 3).	Analytical Services / BCRC	Four-months after the launch of drop-off location.

19	Review and assessment of pilot project findings and decision on whether to adjust service, continue pilot for further 6 months, or roll-out full green waste management services country wide.	PWC	Six-months after the launch of drop-off location.

5.4 Budget

This GEF 5558 project being implemented by the BCRC-Caribbean has allocated approximately USD 20,000 to finance aspects of this pilot project. It has been proposed that this budget is utilized to finance the procurement of certain items of composting equipment as detailed in Table 12 below and where possible communications campaign and assistance to establish the drop-off facility where SLSWMA funding falls short, and or testing equipment or tests on the quality of compost product. The items proposed to be procured for the pilot study are listed in Table 12 with additional technical specifications detailed in Annex 6.

Table 11: Recommended equipment procurement for pilot project

#	Item	Number of units	Unit	USD / Unit	Total USD
1	Chain Saw	2	Number	450	900
2	Compost Thermometers	10	Number	50	500
3	Water (trash) pump (self-powered petrol)	1	Number	500	500
4	Water hose (suction pipe)	10	Metre length	5	50
5	Water hose (discharge pipe)	200	Metre length	1	200
6	Water hose spray nozzle and shut-off ball valve	1	Number	50	50
7	Compost Windrow Geomembrane	3000	Metre square	1.80	5,400
	Shipping and duties for item 7	1	Number	1,000	1,000
8	Static compost / soil sifter / screen	1	Number	1,500	1,500
9	Reusable containers / bags for use in roadside clearance operations and / or Public Green Waste Drop-off container (skip bins)	TBD	Number	3,000	6,000
10	Compost testing	2	Two sets	500	1,000
11	Education and behavioural change materials	1	Lump sum		1,900
Total					**20,000**

5.5 Monitoring and Evaluation Plan

Projects are classified as pilots when they involve novel or innovative ideas and techniques about which there is uncertainty as to their effectiveness and the scope of their application. As a consequence, monitoring and evaluation need to be more extensive than for more conventional projects. The Monitoring and Evaluation Framework presented in Table 13 has been developed to assist capture sufficient data to enable evidence-based decision making when planning and allocating resources for wider green waste management services.

Table 12: Monitoring & Evaluation (M&E) Framework

	INDICATOR	DEFINITION How is it calculated?	BASELINE What is the current value?	TARGET What is the target value?	DATA SOURCE How will it be measured?	FREQUENCY How often will it be measured?	RESPONSIBLE Who will measure it?	REPORTING Where will it be reported?
Goal	Efficiency of waste disposal and compaction on Deglos Landfill assist mitigate occurrence of fire.	Ratio of landfill compactor fuel use (litres / hour) per tonne of waste delivered combined with visual assessment of working face waste compaction (photo evidence)	TBD	TBD (reduction on baseline)	Vehicle fuel log, weighbridge data, photographic record of working face	Daily recording of working face, weekly analysis of fuel and weighbridge data.	SLSWMA Operations and Landfill Manager (OLM)	SLSWMA DGM / PWC.
		Number of fires occurring on active landfill site.	TBD	Zero	Visual recordings and reporting in logbook at landfill	Daily	Deglos OLM	SLSWMA DGM / PWC.
Outcomes	Increase in Green Waste diversion from landfill to environmentally sound management.	Quantity (weight) of Green Waste loads recorded as entering Deglos Landfill for disposal.	5,632 per year 2018/19	Reduction on baseline	Deglos Landfill weigh bridge data	Weekly / Monthly reporting	Deglos OLMr	SLSWMA DGM / PWC.
		Number of separate occurrences of open dumping of green waste (and other wastes).	TBD	Reduction on baseline	Reports from Litter Wardens active in pilot green waste drop-off catchment area.	Monthly reporting	Zonal supervisors	SLSWMA DGM / PWC.
	Effectiveness of communication campaign and source segregated drop-off sites	Volume of green waste delivered to drop-off site	Zero	360 tonnes over first 4 months	Weigh bridge data	Daily record keeping reported monthly	Deglos OLM	SLSWMA DGM / PWC.
		Number of green waste producers in target area using drop-off facility	Zero	At least half of those who produce green waste in the catchment area	Gate records of number of distinct different users	Daily record keeping, monthly reporting	Deglos Landfill Manager	SLSWMA DGM / PWC.

				having used a site				
	Impact of green waste management on the spread of invasive fauna.	Incidences (or number) of Giant African Snails in and around drop-off and composting facilities and in final product.	TBD	No increase on baseline	Site assessment and population count	Monthly	Ministry of Agriculture	SLSWMA DGM / PWC.
		Occurrence of pathogens in final product (pathogen destruction also indicates sufficient condition to kill any plant seeds)	TBD	Negligible	Compost testing and quality assurance	Monthly	Ministry of Agriculture – Analytical services	SLSWMA DGM / PWC.
	Capacity and appropriateness of operator models	Volume of processed and unprocessed green waste and compost at point of production, drop-off bay, windrow piles, product pile.	TBD	TBD in line with facility size. Fluid process flow (no excessive stockpiling) and increasing production.	Volume estimate or weight of stockpiles along material flow chain	Monthly	SLSWMA Operations Department	SLSWMA DGM / PWC.
		Marketability of compost produced	N/A	Product quality passes standard and markets identified	Compost testing and quality assurance Market assessment	Monthly testing Market survey	SLSWMA	SLSWMA DGM / PWC.

5.6 Risk Assessment

Risks to successfully implementing the pilot project have been assessed with the main risks and mitigation actions summarised in Table 14.

Table 13: Pilot project risk assessment

Potential Risks	Mitigation action
Covid-19 restriction may affect the international experts' ability to deliver training	RWA Group can engage the project local expert to assist with project coordination and basic training on the ground. Virtual training can be provided on the pilot project concept and plans and additional assistance provided remotely as required.
Spread of Giant African Snail through green waste transfers.	The monitoring of Giant African Snails is included in the project Monitoring and Evaluation Framework. Any increase in snail populations observed will be reported to the Ministry of Agriculture for evaluation and decision to take remedial action. This might be relocation of site location, expedited shredding and site operations to minimise habitat creation, removal and destruction of snails, adjustment of pilot operations, or other.
Public opposition to composting operations due to experiencing nuisance.	Training will have a focus on the importance that all feedstock, composting, and final product material must be managed and stored appropriately. Properly storing the feedstock and finished compost product is an essential step of the composting process. It must be managed and stored in a manner that prevents dust or odours from developing, and prevents contamination of the product from weeds, Giant African Snails, leachate, or other contaminants. For example, large stockpiles of finished compost can become a source of odours if they are saturated with rainfall and can quickly become infested by weeds. Fire prevention and control should also be considered, since green waste and compost can be a fuel source if left to dry out. Both elevated moisture and drying out of compost that result in these nuisances can be mitigated through use of appropriate compost cover fabric which has been recommended for the sites. In addition, the Process to Further Reduce Pathogens has the added advantage of destroying most snail eggs. This is: - Material attains a temperature of 55°C or greater for at least 15 consecutive days during the composting period - During this 15-day period, materials need to be turned at least 5 times

5.7 Next Steps

Saint Lucia GEF 5558 NPC, in consultation with the SLSWMA and the PWC shall confirm this revised green waste management proposal and pilot study concept. Once approved, the activity plan shall be initiated for implementation at the earliest possible opportunity.

Annex 1: Recommended Steps to Implement Green Waste Management Services in Saint Lucia

To establish and implement the example green waste source separation and management service outlined in this report, the following recommended steps represent the key potential system design and implementation activities required to progress up the service delivery growth spiral.

1. Identify the main green waste producers to be approached in the first instance.

   Major producers to be targeted first in Saint Lucia includes LUCELEC's vegetation clearance operations under power lines. Garden services companies that currently dispose homogenous waste loads at Deglos. Hotels and resorts that don't have their own composting facility.

2. Information, Education and Communication campaign

   Sensitize the target waste producer of need and reasons to divert green waste from landfill, the need for segregating green waste and the plans being established to impose a ban of landfilling homogenous vehicle loads of plant materials and imposition of a gate fee for mixed loads containing plant materials mixed with other waste, and the requirement for garden service companies to become licensed by SLSWMA to be green waste haulers and users to only use licensed companies.

3. GoSL should consider establishing a small grants programme or tax relief to assist entrepreneurs (particularly garden services companies) invest in green waste shredders and equipment. Grants to be offered to companies that successfully become licensed by SLSWMA as green waste haulers (optional step).

   Such assistance enables small garden services companies to offer a higher value of service which has wide reaching environmental, social as well as financial benefit to the wider society as illustrated in the Business Model Canvas. The initial financial cost to government of supporting these grants/tax relief must be weighed up and off set against these wider societal benefits.

4. SLSWMA to work with key stakeholders to identify potential service providers and composting facility locations (see Box 2 for land requirement estimations), conducting pre-selection of sites that meet composting facility licensing and Environmental Impact Assessment criteria.

   An interim solution is to utilize the non-active area of Deglos landfill for initial composting activities. However, in the long-term, it is important to establish clear licensing conditions for composting facilities to be able to operate and only license facilities that meet those standards. This prevents legitimate operators that serve the wider societal benefit and invest time and finances into their operation from being undercut and losing business to rogue companies that cut financial corners to the detriment of the environment and society.

5. SLSWMA / LUCELEC Tender and award contracts (minimum 1 year) for bush clearing / treatment services to include condition that material is shredded on site and composted in a licensed facility.

   Government and large agency procurement and contract management systems are important vehicles that enable government to clearly specify goods/services that are beneficial to society without the need for law amendments or grants. Contracts are currently awarded by the GoSL and LUCELEC for vegetation clearance which generate large quantities of material that currently go to landfill which ultimately cost society to manage. In procuring services that mandate licensed contractors and composting of cleared vegetation, this stimulates the commercial sector to invest in composting operations and divert green waste from landfill without requiring additional regulations. Once services are established through these means, the service can be built upon by introducing landfill bans for green waste from other producers as the alternative treatment facility has been established by the service providers.

6. Assist establish compost markets through government procurement of compost.

   Similar to step 5, the establishment of the commercial composting facilities can be assisted without grant financing or additional regulatory control through guaranteed government procurement of compost materials to be used in applications that have wider societal benefit. This is in particular useful in the start-up phase when the operator requires to gain experience to produce good quality compost and mulch. SLSWMA requires substantial volumes of compost material to use as cover material at Deglos and other waste sites requiring rehabilitation. Establishing a guaranteed rate and quantity of compost procurement provides the compost operator with incentive and security to invest in producing the material. Output to be procured can include:

   1. Low grade compost (including ditch and road verge clearance with heavy metal contamination) purchased by SLSWMA for landfill cover (this should be mixed with shredded tyre wastes to provide a robust and resilient cover on the landfilled waste).

   2. Medium grade for mulch, for agriculture and plant nurseries.

   3. Fine grade compost for beautification projects.

7. Ban green waste from going to landfill or place high gate fee on green waste (that subsidizes composting operation / contract).

   Incrementally introduce fees and ban as government and large agency procurement systems assist the establishment of composting facility and facilities gain experience and capacity to accept more clients and materials. Ultimately, without a well enforced ban or fee for landfilling that is more than the cost of composting, the producers will default to the lowest financial cost option, which should not be dumping or landfill.

8. Enforce ban and illegal dumping

   To ensure item 7 has the required impact of stimulating composting facility use, there is a vital need to prevent illegal dumping and heavily punish offenders to ensure green waste producers utilize the composting service.

9. Resorts and Householders see garden services chipping service as cheaper than landfill gate fee / ban and engage service providers. SLSWMA shall require and enforce resorts and households etc. to prove they manage their waste responsibly (i.e. by having contract with licensed garden service provider or evidence of on-site composting facility).

Annex 2: Supporting guidance - Product and Market

As stated in previous reports, in waste management planning, it is advantageous to plan with the end in mind to ensure there is an outlet for the product and that it can be valorised in order to support the recovery of the costs involved in operating the system. In the case of Saint Lucia, the stakeholder engagement identified that it would be up to the market to decide the most viable product, through engagement of private partners to operate commercial green waste treatment. It was the general consensus that compost would be the most likely target product. There is potential for additional products also as listed in this section and a market analysis should be conducted to identify the viability of selling these products on the local market.

Target products:

- **High-grade Compost (soil enhancer) –** produced from any (non-invasive plant) green waste, non-treated wood/lumber, and can include certain paper and cardboard wastes (see full definition below). Material is shredded into fine chips to expedite decomposition, moisture is added and maintained, oxygen levels maintained by regular turning when temperature in pile becomes too low or high. Material is then screened to recover the fine material which are periodically tested to ensure the material meets basic compost standards and can therefore be marketed as a safe soil enhancer.

- **Low-grade Compost Like Output** – effectively compost material as above but that does not pass the quality standard and therefore is not beneficial to soil. This might be due to high level of plastic or other contaminant or elevated levels of heavy metal or detrimental chemical. This product can be utilised on the landfill as a beneficial cover material over the active waste cells.

- **Mulch (soil enhancer)** – Coarsely shredded materials (typically woodchips, shredded bark, leaves, straw or paper) partially composted and used as soil cover to reduce weeds, retain soil moisture and reduce erosion from wind or water. Can include the thicker over-screen from the composting process.

- **Animal bedding material –** shredded wood, including untreated (painted or chemical treated) lumber, has a potential market as animal bedding. This has proven commercially viable in Barbados and is worth considering in Saint Lucia also.

Definition of Compost:

As the main target product, it is important to establish a clear definition of compost. With Saint Lucia having no official definition, the United States Composting Council definition provides a useful guide. They define the term "Compost Product(s)" an item, material or finished article sold in commerce that meets **ALL** of the following criteria:

a) Has been manufactured through the controlled aerobic, biological decomposition of biodegradable materials
b) Has undergone mesophilic and thermophilic temperatures, which significantly reduces the viability of pathogens and weed seeds, and stabilizes the carbon such that it is beneficial to plant growth
c) Is typically used as a soil amendment, but may also contribute plant nutrients
d) Bears little physical resemblance to the raw material from which it originated
e) Is an organic matter source that has the unique ability to improve the chemical, physical, and biological characteristics of soils or growing media
f) The sanitization through the generation of thermophilic heat shall meet the standards of the Processes to Further Reduce Pathogens. For windrow composting this in essence that the:
    - Material attains a temperature of 55°C or greater for at least 15 consecutive days during the composting period
    - During this 15-day period, materials need to be turned at least 5 times

Additional complementary products:

Depending on local market demand, there may be a case for additional complementary products to be produced to enhance the cost recovery potential of the service. These may include the following:

- **Charcoal and Biochar (renewable fuel / soil enhancer) –** Charcoal is pyrolysised wood used as a smokeless fuel in BBQs and other cooking applications. Biochar is a similar product used as a soil amendment that holds moisture and nutrients in soils making it more readily available to plants and made from made from any biomass including green wastes via pyrolysis. The process for making these ranges from an open burn pit in the ground with controlled combustion, through mid-tech Kon-Tiki metal cone kilns, to heavily mechanised pyrolysis machinery. This is conducted a a commercial side venture by the waste management authority in Saint Vincent and is a possible application elsewhere in the region.
- **Firewood (renewable fuel) –** produced from any tree branches greater than 20cm diameter that can be easily recovered from the green waste and wood/lumber waste collected, stripped and cut to 30cm lengths. Requires chainsaw to strip branches, and log saw to cut branches to appropriate length. These items of equipment can also be used to prepare materials for composting or biochar production.

Annex 3: Supporting guidance - Compost Testing and Quality Control

Testing the output material is essential to ensure a marketable product with an assured quality that will not adversely affect plant growth or soil health. If an inferior product is produced and placed on the market resulting in poor plant growth performance or other negative outcome (assumed or proven), the reputation of composting in Saint Lucia will be tainted and it will be incredibly challenging to re-establish a market demand thereafter. Achieving and maintaining high quality standards from day one of marketing the product is essential. As a measure to ensure this is achieved, it is recommended that the product is utilised only as landfill cover during the first year of production with regular quality testing to ensure consistent quality is attainable, prior to general sales for plant growth applications in year two.

Several quality standards and testing methods exist internationally. As Saint Lucia generally align policy and legislation with the European Union but have also utilised laboratory services from North America previously, European, Canadian and the USA compost standards, which are relatively similar (see comparison in Table 15), are introduced here.

EUROPE:

There is no European Union regulation related to compost quality, rather each individual member country has their own standards. However, the European Compost Network (ECN), a member based Non-Governmental Organisation European developed a Quality Assurance Scheme (QAS) for Compost and Digestate' in October 2014, to harmonise the requirements for national certification bodies and quality criteria for recycled materials from organic resources. The aim is to facilitate the free cross-border movement of composts and digestate made out of recycled bio-wastes within the EU. The guidance for the QAS manual and guide provide additional details on operating windrow composting operations and quality testing the compost product and are available at https://www.compostnetwork.info/ecn-qas/ecn-qas-manual/

USA:

The US Composting Council operate a Seal of Testing Assurance (STA) program that certifies compost that has been tested by an accredited laboratory that adheres to the Test Method for the Examination of Composting and Compost (TMECC) [4]. This is a laboratory manual modelled after the American Society for Testing and Materials (ASTM) and provides benchmark methods for compost analysis to enable comparison of analytical results.

STA Certified Compost participants must meet the EPA testing limits for **heavy metals** and **pathogens** in every CTDS (Compost Technical Data Sheet) for every STA Certified Compost product. These test limits are detailed in Table 15.

CANADA:

In Canada, the Fertilizer Act and Regulations set safety standards and labelling requirements for all fertilizer and complementary products (including compost), are similar to those operated by the US Composting Council, but with some slight differences. The Canadian Food Inspection Agency (CFIA) is responsible for the administration and enforcement of the Fertilizer Act, Fertilizer Regulation, and associated Trade Memoranda.

[4] For additional insight into the US Composting Council, the STA Program and the TMECC, see https://www.compostingcouncil.org/page/tmecc

Additional Compost Testing Standards published by the Canadian Council of Ministers of the Environment (CCME) are presented in Table 17 at the end of this Annex.

Table 15 provides a comparison of the compost standards established in Europe, USA and Canada. The Canadian standards also include the maximum concentration limits for heavy metals in the soil that the compost has been applied to.

Table 14: Comparison of European, USA and Canada compost quality parameters and associated limits

Parameter		Maximum acceptable trace element concentrations in products (mg/kg dry weight)			Maximum acceptable cumulative metal additions to soils (kg/ha)
		European Compost Network	USA	Canada	
Organic Matter		≥ 15 %	N/A	> 15%	N/A
Inorganic Pollutants	Arsenic (As)	N/A	**41**	75	15
	Cadmium (Cd)	**1.3**	39	20	4
	Chromium (Cr)	**60**	N/A	N/A	210
	Cobalt (	N/A	N/A	**150**	30
	Copper (Cu)	**300**	1500	N/A	150
	Lead (Pb)	**130**	300	500	100
	Mercury (Hg)	**0.45**	17	5	1
	Molybdenum	N/A	N/A	**20**	4
	Nickel (Ni)	**40**	420	180	36
	Selenium (Se)	N/A	100	**14**	2.8
	Zinc (Zn)	**600**	2800	N/A	N/A
Undesired ingredients and properties	Impurities (content)	Less than or equal to 0.5 % dry matter	N/A	Should not contain sharp objects, such as glass or metal, in a size and shape that can cause injury.	
	Weed Seeds	Less than or equal to 2 seeds per litre	N/A	N/A	N/A
Hygiene / Pathogens (pass either Faecal Coliform and / or Salmonella)	Salmonellae	Absent in 25 g dry matter	< 3 MPN / 4 grams of dry compost	Nondetectable	N/A
	Faecal Coliform (maximum concentrations)	N/A	< 1000 MPN / gram of dry compost	< 1000 MPN per gram of total solids	N/A

Notes:
- Strictest parameter limit is highlighted in bold.
- The ECN state: Copper (Cu) and Zinc (Zn) are also considered as trace elements. Values exceeding 110 mg Cu kg-1 dry matter and 400 mg Zn kg-1 dry matter must be declared.
- Canadian Standards also include definition for: Maturity - Composts must be mature in order to meet the definition of “compost” as set out in the Fertilizer Regulation. It is the manufacturer’s responsibility to demonstrate compost maturity using scientifically valid methods; and Moisture content - Less than 65%
- mg/kg = milligrams per kilogram
- kg/ha = kilograms per hectare

LATIN AMERICAN COUNTRIES:

In addition to the USA, Canada and European standards, several Latin American Countries have compost standards for microbiological limits according to different standards. A selection of these limits is presented in Table 16. Chile has two qualities of compost, grade A for horticulture and grade B for land remediation,

Table 15: Compost microbiological limits in select Latin American Countries

Micro-organism	Tolerance limit			
	Chile NCh 2880/04		Colombia 5167/04	Mexico NTEA-006-SMA-RS-2006
	A	B		
Fecal coliform (dry base)	<1000 NMP/g	<2000 NMP/g	<1000 ufc/g Total enterobacterial	<1000 NMP/g
Salmonella spp	Absent in 25g of product	Absent in 25g of product	Absent in 25g of product	<3 /g en bs
Enteroococus faecalis	-	-	Absent in 25g of product	-
Viable helminth eggs / Ascaris	Absent in 1g	Up to 1 in 1g	ND	<10 / g bs

NMP = Most probably number, ufc = colony formation units, bs = dry base

The standards presented in Table 15 and 16 indicate that compost quality assurance standards for micro-organisms do not vary substantially between the countries and regions presented. Standards for heavy metals do however vary, this is partly due to the differences in application and total concentrations of metals in receiving substrates. It is therefore imperative that the Government of Saint Lucia themselves, or regionally, develop compost standards, that must be met by any compost produced in Saint Lucia to be sold on the market as a soil amendment.

Table 16: Canadian Council of Ministers of the Environment (CCME) Compost Testing Standards

	Category A	Category B	
	Maximum concentration within product (mg/kg dw)	Maximum concentration within product (mg/kg dw)	Maximum cumulative additions to soil (kg/ha)
Trace elements			
Arsenic	13	75	15
Cadmium	3	20	4
Chromium	210	1060	210
Cobalt	34	150	30
Copper	400	757	150
Lead	150	500	100
Mercury	0.8	5	1
Molybdenum	5	20	4
Nickel	62	180	36
Selenium	2	14	2.8
Zinc	700	1850	370
Pathogens[a]			
Compost produced solely from yard waste must meet PFRP criteria[a] ***or*** the following pathogen content limits:			
Salmonella	Less than 3 MPN/4-g (dw)		
Fecal coliform	Less than 1000 MPN/g (dw)		
Compost produced from all other feedstocks must meet PFRP criteria ***and*** the pathogen content limits.			
Foreign matter and sharp foreign matter			
Foreign matter	Less than or equal to 1 piece greater than 25 mm in any dimension per 500 mL	Less than or equal to 2 pieces greater than 25 mm in any dimension per 500 mL	
Sharp foreign matter	None greater than 3 mm in any dimension per 500 mL	Less than or equal to 3 pieces per 500 mL, 12.5-mm maximum dimension	
Maturity/stability			
All compost will be mature and stable at the time of sale and distribution. To be considered mature and stable, it must be cured for a minimum of 21 days, and meet one of the following requirements: • Respiration rate less than or equal to 400 mg O_2/kg VS (or OM) per hour • CO_2 evolution rate less than or equal to 4 mg C-CO_2/kg OM per day • Temperature rise above ambient less than 8°C			
Organic compounds			
Avoid composting feedstocks with high concentrations of persistent bio-accumulating organic contaminants.			

Notes:
[a] To meet PFRP criteria for in-vessel and ASP composting, maintain material at operating conditions of 55°C or greater for 3 consecutive days. For windrow composting, maintain material at a temperature of 55°C or greater for at least 15 consecutive days during the composting period. During the high-temperature period, turn the windrow at least 5 times.

°C—degrees Celsius
ASP—aerated static pile
C-CO_2—carbon-carbon dioxide
dw—dry weight
g—gram
mL—millilitre
mm—millimetre
O_2—oxygen
PFRP—Process to Further Reduce Pathogens
VS—volatile solids

Source: https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/municipal-solid/environment/organics-processing-technical-document-summary.html

Annex 4: Supporting guidance – Composting Equipment

Multiple infrastructure and equipment types, specifications and combinations are available for operating green waste collection, drop-off and composting operations. The SLSWMA currently owns much of the essential equipment required, however additional items will be required prior to initiating a functional service.

An overview of composting equipment required and recommended for managing the green waste in Saint Lucia and transforming it to marketable compost is provided in Table 18.

Table 17: Typical equipment required for compost operations

Equipment item	Use	Requirement	Typical cost	Photo
Grapple truck **Hook loader and containers** **Or suitable alternative drop-off collection and transfer system**	Collecting green waste from public drop off points. Grapple truck utilised if loose loads. As previously demonstrated, the transportation of shredded green waste is more economically efficient. Hook loader containers can be placed at any location and can be combined with small shredders to pre-treat tree branches and low-density green waste.	**Highly recommended** Essential to operate decentralised drop-off facilities. SLSWMA do not currently have such equipment on fleet.	Variable, in the region of USD 200,000 including container or crane	 
Front end wheeled bucket loader (Agricultural tractor >75 HP with front-loader also an option for smaller work)	Moving green waste, loading shredder, creating windrows, turning windrows, rolling cover material over windrows, loading screen, moving product.	**Essential.** Critical equipment able to manage all tasks required. A back-hoe loader or excavator is also adequate.	245,000 USD (Small Agricultural tractor 60,000 USD)	
Water storage	>5000 litre water storage capacity with rainwater harvesting equipment installed and connection to water pump or alternatively a mobile water tanker vehicle to be used. Solid tank above ground tank, bladder bags, or open surface water pond.	**Essential.** The microbial processes in composting can have high water demand. Equally rainwater must be drained away from the piles to prevent excess moisture on site. Adequate water collection and storage systems required on all sites for such tasks.	USD 500 – 10,000	

Water pump (trash pump) and hoses	Self-priming roller pump, minimum 100 litres per minute, 30-meter heads, with 2 x 100 m of hose included	**Essential** Required to pump water from store to windrows.	USD 700	
Windrow composting **Temperature Probes**	Robust, heavy duty accurate windrow compost temperature probes (10 pieces) analogue or digital reading, 0ºC to 85ºC temperature graduating minimum with sealed fogless capsule	**Essential** Required to monitor microbial activity in windrow composting piles and indicates when to actively manage the pile, including when to turn the pile, when to add water, and whether pathogen die off conditions are being achieved.	USD 100 each x 10 = USD1,000	
Chain saw and Log splitter	For cutting up tree branches and other uncontrolled green waste. Log cutter to efficiently and effectively slice wood and branches into 300mm long pieces	**Highly recommended** Helps reduce large materials to a manageable size and shape. Also, useful if firewood production is a viable and marketable product from the green waste materials. Feasibility study required first.	USD 300 – 1,000	
Shredder / Grinder (small mobile for collection, larger hammer mill or tub grinder at compost facility)	Shredding / size reduction of larger green waste items (tree branches etc). Also mixing and blending different materials together as they pass through the shredders to stimulate more rapid decomposition which takes longer the larger the particle sizes.	**Highly recommended** Shredders and chippers are not essential for all materials, but greatly improve transport efficiency and expediate decomposition times. A large, more mobile shredder is recommended. A larger tub-grinder at compost facility would also be beneficial.	USD 5000 – 250,000	

Material Screen / Soil Sifter	Static inclined screen, mechanical vibrating screen or rotating trommel drum screen for compost materials in windrows to screen out any residual poor-quality materials greater than 1cm in diameter.	**Highly recommended** Assists sift contaminants (plastics, stones, etc) and over-sized (not completely decomposed) particles from the finished compost allowing a fine marketable product to be recovered and over-sized particles to be returned to the composting windrows to aid air circulation and microbial populations. A static screen is sufficient for small batch production. Larger daily throughput would require mechanical screen.	USD 5,000 – 150,000	 
Windrow Compost geomembrane / fabric Cover	Geomembrane cover for compost piles - prevent moisture loss (in wet conditions will shed excessive rainfall and reduce the leachate. In dry conditions it will reduce moisture loss. The breathable membrane makes the cover permeable to oxygen, carbon dioxide and water vapour. The cover also assists with reducing odours	**Optional - Recommended** Saint Lucia can experience hot dry periods as well as prolonged heavy rain. Regulating decomposition through keeping rain out and keeping moisture in the piles as required is recommended through purchase and use of windrow cover membranes on all piles. Such membranes work particularly well when used in combination with **air blowers (an additional optional item of equipment**) within the windrow to create positive airflow through the pile reducing the need for turning and expediting decomposition.	USD 500 1,000 / 10m long x 3m wide sheets (depending on quality)	

Windrow Compost **Fabric roller** attachment for tractor front loader	Provides easier and more efficient application and removal of windrow covers, helps prolong life of fabric.	**Optional** Not essential, but worth investing in when purchasing windrow turner and fabric to prolong life of membrane and assist in ease of turning piles.	USD 2,500 +	
Compost heap turner	Self-propelled or tractor pulled PTO driven compost turner with water store and dosing equipment are available. Minimum size should produce 3-metre-wide by 1.3-metre-tall windrows.	**Optional** The creation and turning of windrow pilers can be achieved with excavator, loader or even (with greater effort) manually, however none of these are as effective as a designated windrow turner. SLSWMA don't currently have such equipment. Possible that a farmer has such equipment on the island or that a farmer or agricultural / vocational training centre may collaborate to invest in such equipment. Not essential equipment to start, but as operations scale up then such equipment should be brought in.	USD 540,000 – 160,000	

Annex 5: Estimated land area required for composting

Estimated composting facility land area required to process 100% of green and coconut waste currently being delivered to Deglos landfill.

A	Uncompacted green waste density	157	kg/m3
B	Shredded green waste density	300	kg/m3
C	Compost density	500	kg/m3
D	Total annual mass disposed	7,812	Tonnes/year
E	Average daily mass disposed	21.4	Tonnes/day
F	Percent of total material to be diverted to composting	100	%
G	Average daily mass to be diverted for composting	21	Tonnes/day
H	Average daily mass to be diverted to compost (Kg/day)	21,403	kg/day
I	Daily green waste average density - Uncompacted volume	136	m3
J	Daily green waste average density - shredded volume	71	m3
K	Height of uncompacted material in storage area	1.5	m
L	Number of days uncompacted material to be stored before shredding / moving to active compost area	7	days
M	**Drop-off Storage area required (I*L/K)**	**636**	**m2**
N	**Shredding and maouvering area for stockpiled fresh waste (minimum area of 600m2 required regardless of quantity)**	**600**	**m2**
O	Estimated composting period	90	days
P	Total active compost volume (H*O/C)	3,852	m3
Q	Windrow width at base	4	m
R	Windrow width at top	1.00	m
S	Windrow height	2	m
T	Windrow length (P/(S*(Q+R/2))	428	m
U	**Active composting area required for trapezoid windrows (T*Q)**	**1,712**	**m2**
V	**Area for fire breaks and manouvering of waterng and turning equipment between and around windrows (75% of windrow area)**	**1284**	**m2**
W	**Area required for finished material screening and storage (7 days at 2.5m high pile)**	**220**	**m2**
X	**Total green waste drop off and material pre-treatment area required (M+N)**	**1,236**	**m2**
Y	**Total active composting area required (U+V)**	**2,996**	**m2**
Z	**Total product preparation and storage area required (W)**	**220**	**m2**
	TOTAL AREA REQUIRED (X+Y+Z)	**4,452**	**m2**
	Fields marked in yellow are variables that can be adjusted based on locally improved data		

Estimated composting facility land area required to process 50% of green and coconut waste currently being delivered to Deglos landfill.

A	Uncompacted green waste density	157	kg/m3
B	Shredded green waste density	300	kg/m3
C	Compost density	500	kg/m3
D	Total annual mass disposed	7,812	Tonnes/year
E	Average daily mass disposed	21.4	Tonnes/day
F	Percent of total material to be diverted to composting	50	%
G	Average daily mass to be diverted for composting	11	Tonnes/day
H	Average daily mass to be diverted to compost (Kg/day)	10,701	kg/day
I	Daily green waste average density - Uncompacted volume	68	m3
J	Daily green waste average density - shredded volume	36	m3
K	Height of uncompacted material in storage area	1.5	m
L	Number of days uncompacted material to be stored before shredding / moving to active compost area	7	days
M	**Drop-off Storage area required (I*L/K)**	**318**	**m2**
N	**Shredding and maouvering area for stockpiled fresh waste (minimum area of 600m2 required regardless of quantity)**	**600**	**m2**
O	Estimated composting period	90	days
P	Total active compost volume (H*O/C)	1,926	m3
Q	Windrow width at base	4	m
R	Windrow width at top	1.00	m
S	Windrow height	2	m
T	Windrow length (P/(S*(Q+R/2))	214	m
U	**Active composting area required for trapezoid windrows (T*Q)**	**856**	**m2**
V	**Area for fire breaks and manouvering of waterng and turning equipment between and around windrows (75% of windrow area)**	**642**	**m2**
W	**Area required for finished material screening and storage (7 days at 2.5m high pile)**	**160**	**m2**
X	**Total green waste drop off and material pre-treatment area required (M+N)**	**918**	**m2**
Y	**Total active composting area required (U+V)**	**1,498**	**m2**
Z	**Total product preparation and storage area required (W)**	**160**	**m2**
	TOTAL AREA REQUIRED (X+Y+Z)	**2,576**	**m2**
	Fields marked in yellow are variables that can be adjusted based on locally improved data		

Estimated composting facility land area required to process 13,000 of green and coconut waste estimated as being the potential maximum green waste delivered to Deglos landfill when including mixed loads.

A	Uncompacted green waste density	157	kg/m3
B	Shredded green waste density	300	kg/m3
C	Compost density	500	kg/m3
D	Total annual mass disposed	13,000	Tonnes/year
E	Average daily mass disposed	35.6	Tonnes/day
F	Percent of total material to be diverted to composting	100	%
G	Average daily mass to be diverted for composting	36	Tonnes/day
H	Average daily mass to be diverted to compost (Kg/day)	35,616	kg/day
I	Daily green waste average density - Uncompacted volume	227	m3
J	Daily green waste average density - shredded volume	119	m3
K	Height of uncompacted material in storage area	1.5	m
L	Number of days uncompacted material to be stored before shredding / moving to active compost area	7	days
M	**Drop-off Storage area required (I*L/K)**	**1059**	**m2**
N	**Shredding and maouvering area for stockpiled fresh waste (minimum area of 600m2 required regardless of quantity)**	**600**	**m2**
O	Estimated composting period	90	days
P	Total active compost volume (H*O/C)	6,411	m3
Q	Windrow width at base	4	m
R	Windrow width at top	1.00	m
S	Windrow height	2	m
T	Windrow length (P/(S*(Q+R/2))	712	m
U	**Active composting area required for trapezoid windrows (T*Q)**	**2,849**	**m2**
V	**Area for fire breaks and manouvering of waterng and turning equipment between and around windrows (75% of windrow area)**	**2137**	**m2**
W	**Area required for finished material screening and storage (7 days at 2.5m high pile)**	**299**	**m2**
X	**Total green waste drop off and material pre-treatment area required (M+N)**	**1,659**	**m2**
Y	**Total active composting area required (U+V)**	**4,986**	**m2**
Z	**Total product preparation and storage area required (W)**	**299**	**m2**
	TOTAL AREA REQUIRED (X+Y+Z)	**6,944**	**m2**
	Fields marked in yellow are variables that can be adjusted based on locally improved data		

Annex 6. Pilot project equipment technical specifications

List of all potential equipment and materials for compost pilot project

#	Item	Number of units	Unit
1	Chain Saw	2	Number
2	Compost Thermometers	10	Number
3	Water (trash) pump (self-powered petrol)	1	Number
4	Water hose (suction pipe)	10	Metre length
5	Water hose (discharge pipe)	200	Metre length
6	Water hose spray nozzle and shut-off ball valve	1	Number
7	Compost Windrow Geomembrane	3000	Metre square
	Shipping and duties for item 7	1	Number
8	Static compost / soil sifter / screen	1	Number
9	Reusable containers / bags for use in roadside clearance operations and / or Public Green Waste Drop-off container (skip bins)	TBD	Number
10	Compost testing	2	Two sets
11	Education and behavioural change materials	1	Lump sum

Technical specifications of all potential equipment and materials listed for compost pilot project

Item	**Chain saw**
Description	Petrol powered Chain saw For cutting up tree branches and other uncontrolled green waste.
Technical specifications	• Automatic chain oiling • 40cm to 50cm cutting bar, • Quick start petrol engine • Minimum 35cc engine displacement, • Minimum 2 kW output. • To be supplied with spare chain, chain oil and chain sharpener • To include supply of two sets of personal protective equipment (PPE) face shield, ear defenders, and helmet.
Example	• https://www.stihlusa.com/products/chain-saws/professional-saws/ms261cm/

Item	**Compost thermometers**
Description	Thermometer with 100cm probe to enable accurate temperature readings to be taken from the centre of composting piles.
Technical specifications	• Analogue temperature probe with large Easy-to-Read dial and guard • Robust 100cm long and >50mm diameter Stainless Steel Stem • Hermetically Sealed Dial • Unbreakable Plastic Crystal Lens • Pointed Tip • Accurate to +1% of scale • °F and °C Dual Scales Available running from 0 to 200°F and -10 to 90°C
Example	• https://reotempcompost.com/heavy-duty-compost-thermometer-with-probe-guard-bundle/

Item	**Water Pump / Trash Pump**
Description	Self-powered water pump capable of sucking water from storage pond, river or container and pumping it through hose attachments to spray nozzle for applying water to windrow compost piles.

Technical specifications	• 208 cc, 6.3 hp 4-stroke petrol engine • EURO 5 Compliant • RPM: 3600 • output flow: 1300 l/min • output head (lift height): 28 m • suction head: 8 m • Rated max. pressure: 2.8 bar (40.6 psi) • Outlet size: 3" BSP • Pump to be capable of pumping solids in suspension up to 28 mm dia. • Max Weight: 50 kg
Example	https://www.machinemart.co.uk/p/clarke-pf75a-petrol-powered-3-full-trash-water/

Item	Water hose (suction pipe)
Description	3 inch diameter suction hose to be fully compatible with supplied trash pump to enable suction of water from reservoir, river, pond or shallow well.
Technical specifications	• 10 metre length • 3" Rigid PVC Suction Hose with spiral reinforcement • Smooth inside for delivery and suction of liquids. • Wall Thickness 5mm with 1270g/m and a Bending Radius of 300mm. • Working pressure at 20°C: 5.5 bar, • Vacuum: 10 m. • Operating temperature range -10° to 60°C • Free of toxic softener. • Hose connections with camlock to be fully compatible with supplied trash pump (as detailed above) • 3" Round Hole Strainer for inlet point
Example	• https://www.firehosedirect.com/green-3-x-15-camlock-suction-hose

Item	Water hose (discharge pipe)
Description	2 times 100m long 3 inch diameter discharge pipe to be fully compatible with supplied trash pump.
Technical specifications	• 3" diameter discharge with integrated Camlock fittings (type C and E) • 150 PSI working pressure • Flat PVC pipe with two spiral plies and longitudinal synthetic cords reinforcement • To be rated for agricultural, quarry, irrigation, mining, construction and industrial applications.
	• https://www.firehosedirect.com/Red-3-0-x-50-Lightweight-DIscharge-Hose

Item	Water hose spray nozzle and shut-off ball valve
Description	Spray nozzle with integrated shut off ball valve that connects to and integrates with above detailed discharge pipe.
Technical specifications	• Spray nozzle attachment for above detailed discharge pipe to facilitate water spray application to compost piles that does not substantially restrict water flow whilst preventing washing away compost from piles. • To include integrated shut-off valve

Item	Compost Windrow Geomembrane / fleece
Description	UV stable breathable membrane cover to apply over compost windrows and keep moisture within the pile and prevent rain ingress to pile causing saturation.
Technical specifications	• 3,000metres squared (4 to 5 metre width 50m lengths) • Polypropylene (non-woven) • Thickness to be greater than or equal to 1.8mm • Weight to be greater than or equal to 200 g/m^2 • Air Permeability to be in the range of 200 to 400 cfm • Resistant to static puncture by 2000 N

	• Water Shedding to be 99% or better[2] • Finish treatment to ensure thermal stabilization
Example	• https://www.cvcompost.com/ccovers.php

Item	Static compost / soil sifter / screen
Description	Screen for sifting compost materials from windrows to screen out any residual poor-quality materials greater than 1cm in diameter.
Technical specifications	• 1 cm diameter holes in screen to sift out particles larger than 1cm in diameter. • Artisan made locally as per example photo • Robust 5mm steel grid with 1cm perforations. • Angled at between 35 and 40º to facilitate material sliding over grid at correct velocity • Construction from steel I beams fully prime and final coat painted to prevent corrosion. • Cross bar to be installed to enable wheeled loader to bang bucket without damaging grip structure. • To be transportable by machine around sit as required.
Example	

Item	Roadside clearance reusable containers and / or Green Waste Public Drop Off / Civic Amenity Site Container
Description	Robust reusable sack for collection of green waste and other segregated waste materials during manual roadside clearance operations in Saint Lucia. To be made to withstand multiple (minimum 100) loadings and unloads. Skip container for the bulk collection of publicly dropped off green waste at specified green waste drop-off sites. To be compatible with existing SLSWMA engaged collection vehicles and facilitate ease of entry and transfer of green waste from private cars/trailers to containers.
Technical specifications	TBD based on available lifting equipment and capacity based on locations • Reusable green waste sack for roadside clearance. • 110 litre capacity • Robust woven material with durable stitching • Double stitched carry handles on both sides and one at base • Stiff and robust plastic ring around upper opening to hold bag open during filling • Container for public drop off of green waste

	• Minimum 8m^3
Example	 

Annex 7. Bibliography and online reference resources

Compost Quality Standards

1. European Compost Network – Quality Assurance Scheme for compost and digestate manual

   https://www.compostnetwork.info/ecn-qas/ecn-qas-manual/

2. US Composting Council - STA Program and the TMECC

   https://www.compostingcouncil.org/page/tmecc

3. Canadian Council of Ministers for the Environment - Guidelines for Compost Quality

   https://www.ccme.ca/files/Resources/waste/organics/compostgdlns_1340_e.pdf

Composting methods and general guidance:

4. Government of Canada - Municipal solid waste organics processing: technical document

   https://www.canada.ca/content/dam/eccc/migration/main/gdd-mw/3e8cf6c7-f214-4ba2-a1a3-163978ee9d6e/13-047-id-458-pdf_accessible_ang_r2-reduced-20size.pdf

5. Vermont Agency of natural resources – Department of Environmental Conservation: Turned Windrow Composting - Site Identification and Design Considerations

   https://dec.vermont.gov/sites/dec/files/wmp/SolidWaste/Documents/ANR%20Site%20Identification%20and%20Design.pdf

6. Vermont Agency of natural resources – Department of Environmental Conservation: Turned Windrow Composting – Sizing your composting pad

   https://dec.vermont.gov/sites/dec/files/wmp/SolidWaste/Documents/ANR%20Sizing%20Your%20Composting%20Pad.pdf

7. FARMER´S COMPOST HANDBOOK Experiences in Latin America

   http://www.fao.org/3/a-i3388e.pdf

8. FAO Composting methods – Chap 3 on LARGE-SCALE COMPOSTING- Windrow composting

   http://www.fao.org/3/a-y5104e.pdf

9. Waste management opportunities for rural communities Composting as an effective waste management strategy for farm households and others

   http://www.fao.org/3/k1455e/k1455e.pdf

10. Soils Bulletin on composting in the tropics and subtropics:

    http://www.fao.org/3/s8930e/s8930e.pdf

Carbon to Nitrogen Ratio Guidelines

11. Common materials to compost and their C:N ratio

    https://www.planetnatural.com/composting-101/making/c-n-ratio/ and

12. Useful calculator to evaluate the C:N ratio of different mixes of materials:

    https://www.klickitatcounty.org/DocumentCenter/View/3523/Compost-Calculator

Sargassum Seaweed Management:

13. See Caribbean references:

    http://www.cardi.org/wp-content/uploads/downloads/2015/11/Sargassum-Seaweed-and-its-use-in-crop-and-livestock-production-CARDI-Policy-Brief.pdf

14. A research project in the French West Indies for repurposing Sargassum seaweed

    https://phys.org/news/2018-10-french-west-indies-repurposing-sargassum.html

15.

    http://compostingnews.com/2018/06/21/high-quality-compost-made-from-sargassum/

16. Composting as an Alternative Management Strategy for Sargassum Drifts on Coastlines

    https://www.researchgate.net/publication/323407341_Composting_as_an_Alternative_Management_Strategy_for_Sargassum_Drifts_on_Coastlines

17. CASE STUDY WITH STATS

    https://newenergyevents.com/bec/wp-content/uploads/sites/29/2018/11/BEC_Showcase_St.-Lucia.pdf

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