Feasibility Study on Waste Management Concepts for Mahé Island, Seychelles

TECHNISCHE UNIVERSITÄT DARMSTADT

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Table of Contents

1. .....Introduction 2
2. .....General Information 3
3. .....Waste Handling 8
3.1. Legal framework 8
3.2. Administrational organisation and authorities 10
3.3. Waste Classification, Collection, Treatment, Disposal and Charging System 12
3.4. Key observations 17
4. .....Determination of key factors and barriers limiting current waste management 19
4.1. Methodology 19
4.1.1. Social Study 19
4.1.2. Stakeholder Interviews 20
4.2. Results 21
4.2.1. Internal Strengths and Weaknesses 23
4.2.2. External Opportunities and Threats 25
5. .....Waste Generation 28
5.1. Waste amounts 28
5.2. Extrapolated forecast on waste amount 31
5.3. Comparison of extrapolated forecast 32
6. .....Monitoring on Mahé 33
6.1. Methodology of Monitoring on the landfill Providence 2 33
6.2. Results of monitoring and verification of the most important classes 33
7. .....Determination of waste composition on Mahé 38
7.1. Methodology of Waste Sorting 38
7.2. Results of sorting and determination of the most important fractions 41
8. .....Potential waste treatment 47
8.1. Anaerobic Digestion 47
8.2. Composting 51
8.3. Incineration 53
8.4. Comparison of potential waste treatment technologies 57
9. .....Recommendation for waste management 59
10. ...Conclusion /Outlook 61
11. ...Literaturverzeichnis 62
12. ...Appendix (A1-AX) 63

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1. Introduction

Among several issues faced by Small Island Developing States (SIDS), rapidly increasing waste generation is becoming one of the major problems. The Republic of Seychelles is one example which is consequently faced with a serious issue of managing its waste in a sustainable manner. Land scarcity, lack of economic resources and expertise in the field of waste management considerably reduce the waste management potentials in this island.

For any waste management concept the complexities of the waste problem must be considered by integrating various processes and measures into an intelligent and comprehensive plan. This includes the consideration of special circumstances of the area which is why there is no patent solution for such a system and waste management concept. It is therefore necessary to develop a system specifically adapted to each area in order to optimise it and to meet any necessary requirements.

In order to draft such a waste management concept for the main island - Mahé - the Technical University of Darmstadt (TUDa), Germany, Jager Biotech GmbH, Germany, and the Ministry of Environment, Energy and Climate Change of the Republic of Seychelles, cooperated in this project "Feasibility Study on Waste Management Concepts for Mahé, Seychelles". It is a subsequent project of the "Waste Sorting Project in Mahe Island - Sechelles" of June 2016.

For this paper data was collected from January 9, 2017 to April 4, 2017. The collection of necessary data is divided into five work packages. These are:

- Collection of technological data (waste and energy structure)
- Collection of socio-economic data (population and urban structure)
- Collection of political data (institutional structure and legal framework)
- Collection of social data (culture and social psychology)
- Summerisation of the results from the data analysis and development of mass- and energy balances for the current waste management
- Creation of mass- and energy balances for the waste management, using the best available technology

Hence, this report introduces with general information on the Republic of Seychelles and especially on the island of Mahé in Chapter **Error! Reference source not found.**. This includes basic information on geography, population and economic context Chapter **Error! Reference source not found.**.

With the beginning of Chapter **Error! Reference source not found.**, this report illustrates collected data on waste handling which features its current legal framework, administrational organisation, waste classification and waste collection, transportation and disposal system. Following this, a SWOT-analysis in Chapter 4 depicts key factors and barriers limiting the current waste management.

The subsequent chapters allow a first look upon potential waste disposal concepts. Therefore Chapter 5 provides basic data such as waste amounts and an estimate of future waste generation, Chapter 6 verifies the most important classes to be considered as top planning priority for a waste disposal concept, while Chapter 7 determines the waste composition of waste generated on Mahé, and finally Chapter 8 illustrates potential waste treatments for specific waste types by considering mass- and energy balances.

The reports closes with recommendations in Chapter 10 and an outlook in Chapter 11.

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2. General Information

For waste management concepts, not only waste data is relevant. General information to describe the current situation is needed as well. This includes parameters in the socio-economic structure which correlate with relevant waste data in order to subsequently interpret the existing waste data in an appropriate manner. Hence, this chapter allows an indication of the structures of Mahé Island.

The Republic of Seychelles is an archipelago nation of 115 islands located northeast of Madagascar in the Indian Ocean. It is a home to approximately 94,700 inhabitants[1] with Mahé as the biggest and most populated island. Victoria is the capital city which is located on Mahé.

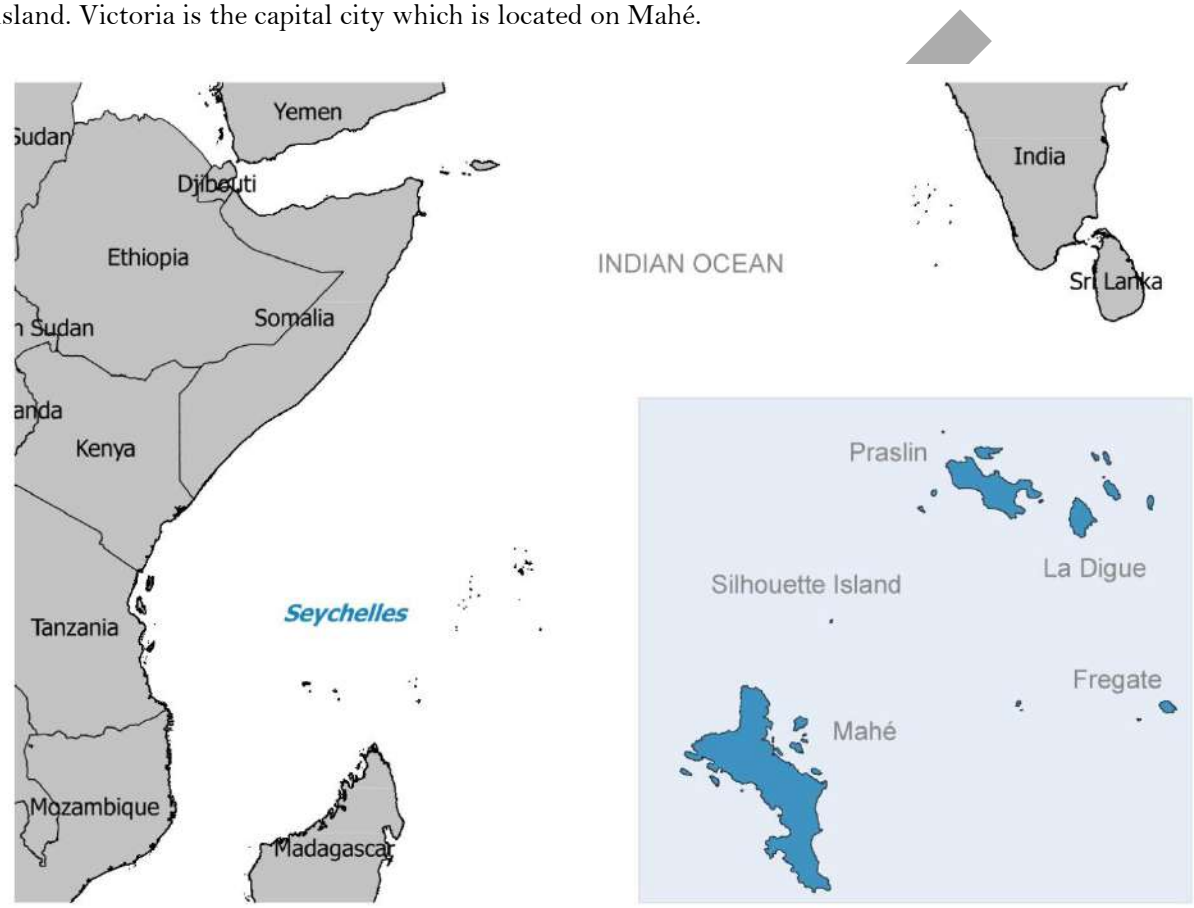

Figure 1:Geographical location of Seychelles and Inner Islands (Tu, 2017)

The area of Mahé covers 154.7 km² with a length of 28 km and a width of 8 km. Mahé is divided into 22 administrative districts which are summarized in four regions:

Table 1:Geographical areas of Mahé (NBS, 2012a)

Region	Districts included
Central	Bel Air, English River, Les Mamelles, Mont Buxton, Mont Fleuri, Plaisance, Roche Caiman, Saint Louis
East & South	Anse Aux Pins, Anse Royal, Au Cap, Cascade, Pointe Larue, Takamaka
West	Anse Boileau, Baie Lazare, Grand Anse Mahe, Port Glaud
North	Anse Etoile, Beau Vallon, Belombe, Glacis

[1] Population projection on the basis of census in 2010 (NBS, 2014a)

The map below demonstrates the geographical location of each individual district. As apparent, most of inhabitated and used land is near the coastline. It includes agricultural land, residential domains, commercial & industrial areas, amongst others. It is the central section which is largely uninhabited due to the mountainous terrain and which is protected as a reserve. Thus, uninhabited land is indicated by areas of Morne Seychelles National Park, Marine Reserves and Forest Reserves.

The map illustrates main roads on Mahé as well. The road network in Seychelles and Mahé includes primary, secondary, feeder and estate roads.

The primary road network connects the main economic centers and also the different districts of Mahé. The secondary and feeder roads provide connectivity to the primary road network and also give motorable access to smaller rural communities including housing estates.

Connectivity within the island of Mahé is satisfactory, with a ring road around most sections of the island (except for a small section at the north-west tip between Bel Ombre and Cap Ternay).

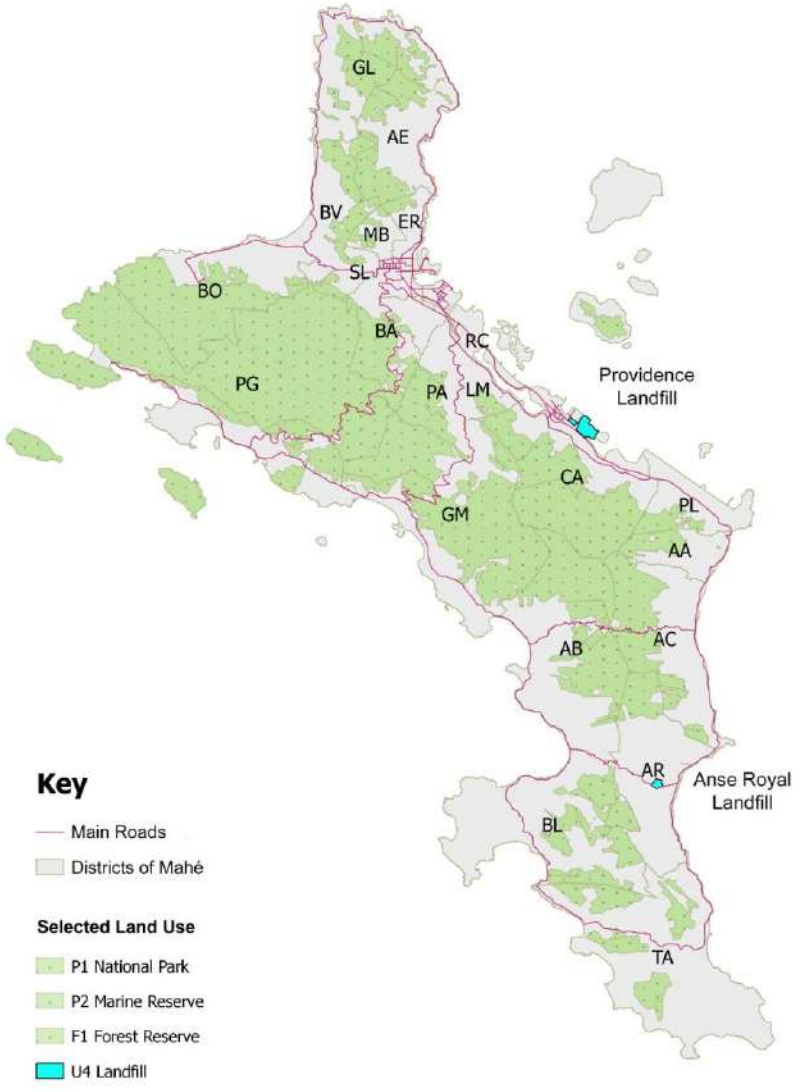

Figure 2: Overview Mahé (Tu, 2017)

Population and housing structure

Waste generation is directly linked to the population representing the most proportion as waste producers. Thus, it is not irrelevant to have the development of the population examined considering estimations about future trends in waste generation.

Projections conclude 81,800 inhabitants[2] for 2016 on Mahé which accounts 86% of the whole population in the Republic. That makes an overall average of 529 persons per km² living on Mahé. In that way, Mahé seems to be highly populated compared to the nominal population density of Seychelles which is around 200 persons per km². (NBS, 2012a)

[2] Population projection is based on census in 2010

There is a growth in the population assumed. Current projections predict an increase to 108,034 by 2045 and decrease to 102,290 by 2080 for the whole Republic. (NBS, 2014a)
There is a general trend of increase in migration but the balance between immigrants and emigrants is similar so that migration influx doesn't need any special attention when interpreting waste data.

The table below illustrates the distribution of inhabitants specific to each district on Mahé with a historical quality referring to census data of the years 1987, 1994, 2002 and the latest 2010.
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Table 2: Population distribution per district in Mahé in number of inhabitants (Gopal, T. personal communication, March 15, 2017)

	CENSUS YEARS			
DISCTRICT	**1987**	**1994**	**2002**	**2010**
Anse Aux Pins	4,468	4,992	3,564	3,850
Anse Boileau	3,989	3,873	4,036	4,011
Au Cap			3,215	4,233
Anse Etoile	3,101	4,134	4,394	4,717
Anse Royale	4,297	4,667	3,687	4,168
Bel Air	2,622	2,660	2,919	2,857
Baie Lazare	2,374	2,734	2,984	3,608
Belombre	1,967	2,280	3,622	3,708
Beau Vallon	3,693	4,103	3,816	4,120
Cascade	2,539	2,928	3,448	4,267
English River	2,770	3,048	3,612	4,196
Glacis	2,342	2,568	3,592	3,833
Grand Anse Mahe	1,997	2,291	2,594	3,106
Les Mamelles			2,391	2,667
Mont Buxton	3,375	3,568	3,110	3,089
Mont Fleuri	5,278	4,840	3,598	3,419
Plaisance	6,287	6,773	3,414	3,781
Port Glaud	1,542	1,777	2,184	2,572
Pointe Larue	2,459	2,559	2,717	3,071
Roche Caiman			2,673	3,232
St Louis	3,993	4,018	3,277	3,209
Takamaka	2,090	2,321	2,609	2,825
TOTAL	61,183	66,134	71,456	78,539

As apparent from the data, there is a general trend of increase in the vital statistics in each district as well.

It can be observed that the most densely populated districts are Saint Louis, Mont Buxton and English River in the Central Region and Anse Aux Pins in the East Region.

In general, apart from the two most densely populated districts of Anse Aux Pins and Pointe Larue in the Eastern part of Mahé, the population is more concentrated in areas closer to the town of Victoria and its suburbs.

Thus, a tendency of people's preference to live near town is obvious. This trend can be observed in the housing and household characteristics as well (NBS, 2012a).

Table 3: Households by type of dwelling in Mahé in 2002 and 2010 in number of households (NBS, 2012a)

Type of dwelling	No. of HH	2010 [%]	2002 [%]
Building used wholly as one housing unit	18,148	73.3	81.0
Building containing more than one housing	5,484	22.1	16.3

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unit (e.g. block of flats)			
Partly residential/ Multi-purpose	535	2.2	2.1
Institution	137	0.6	0.4
Homeless	7	0.0	0.0
Not stated	460	1.9	0.1
TOTAL	24,770	100.0	100.0

Nearly three quarters of households were based in single housing units in 2010 compared to 81 % in 2002. That is how, data from past censuses show accordingly an increasing representation of households in shared buildings (multiple units which include flats and semi-detached houses). This phenomenon is inevitable as space for dwelling construction becomes scarce whereas business and other are built. (NBS, 2012a)

Multi-purpose type refers to dwellings that are used for both domestic and commercial purposes. These may either be single or multiple units, although it is common to find blocks with the top floor used for accommodation and ground floor for commercial purposes. The institutional population includes such accommodation as convents, hospitals, prisons, barracks, hotels and orphanages.

Economic context

As waste generation is often times linked to average income due to purchasing power, the following figure explain the development over the time for data available. This data is explaining the situation of the whole Republic.

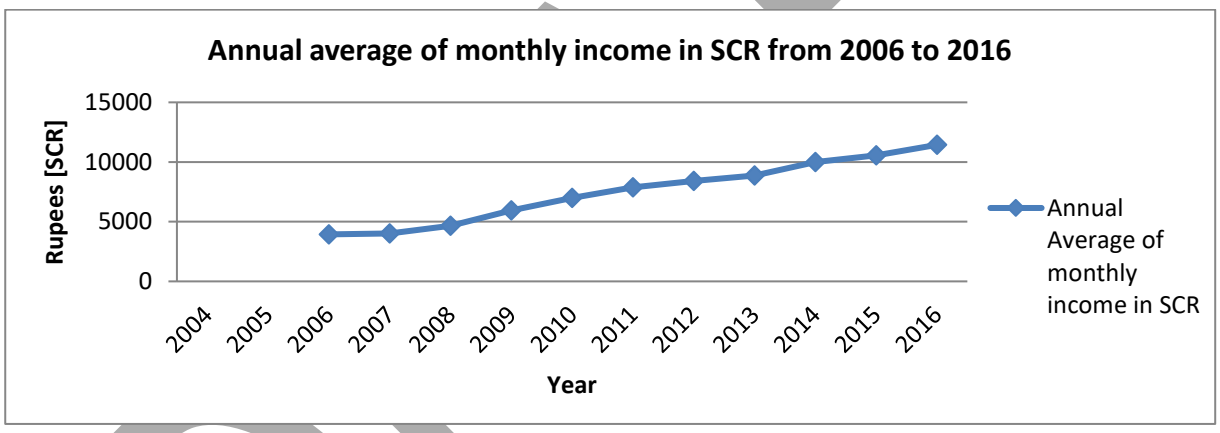

Figure 3: Annual average of monthly income in the Republic of Seychelles from 2006 to 2016 (NBS, 2009; NBS, 2010a; NBS, 2015a; NBS, 2017a)

To have a further insight in the data above, there is a purpose of gaining a notion of important industries as well. As there is no data for Mahé available, average employment numbers in the Republic of Seychelles enriches in any case because most of the businesses are located on Mahé.

With no regards of any specific year, the top five industries remain identical over the years from 2010 to 2015. These are (in order of importance):

- *Accommodation and food service activities (I),*
- *Construction (F),*
- *Public Administration and defence; compulsory social security (O),*
- *Manufacturing (C),*
- *Wholesale and retail trade; repair of motor vehicles and motorcycles (G)*

Accommodation and food service activities (I) comprise of resort and hotel establishments, guest houses, self-catering apartments, restaurants and water sports activities among others that are offered to tourists.

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Manufacturing (C) covers mainly processing and preserving of sea food, manufacturing of tobacco products, liquors, soft drinks, paints and varnishes, provision of electric power and water supply.

Wholesale and retail trade; repair of motor vehicles and motorcycles (G) includes any type of wholesale and retail sale of goods and the rendering of services incidental to the sale of these goods. Wholesaling and retailing are the final steps in the distribution of goods. Goods bought and sold are also referred to as merchandise, e.g. take-away restaurants, snack shops and super markets.
Comparing the top five industries is to GDP (real) by industrial activity there is a slight difference indicating that *Real estate activities (L)* and *Accomodation and food service activities (I)* contribute in a growing manner most of all to the national real GDP including the following industries:

- *Transportation and storage (H)*
- *Public Administration and defence; compulsory social security (O),*
- *Manufacturing (C),*
- *Wholesale and retail trade; repair of motor vehicles and motorcycles (G),*
- *Construction (F)*

The importance of *Accommodation and food service activities* reflect the Republic's significant dependency on tourism. It accounts approximately one fifth to a quarter to the annual GDP. The following figure complements the relevant data for analysis' on waste generation trends considering the development of GDP over eleven years.

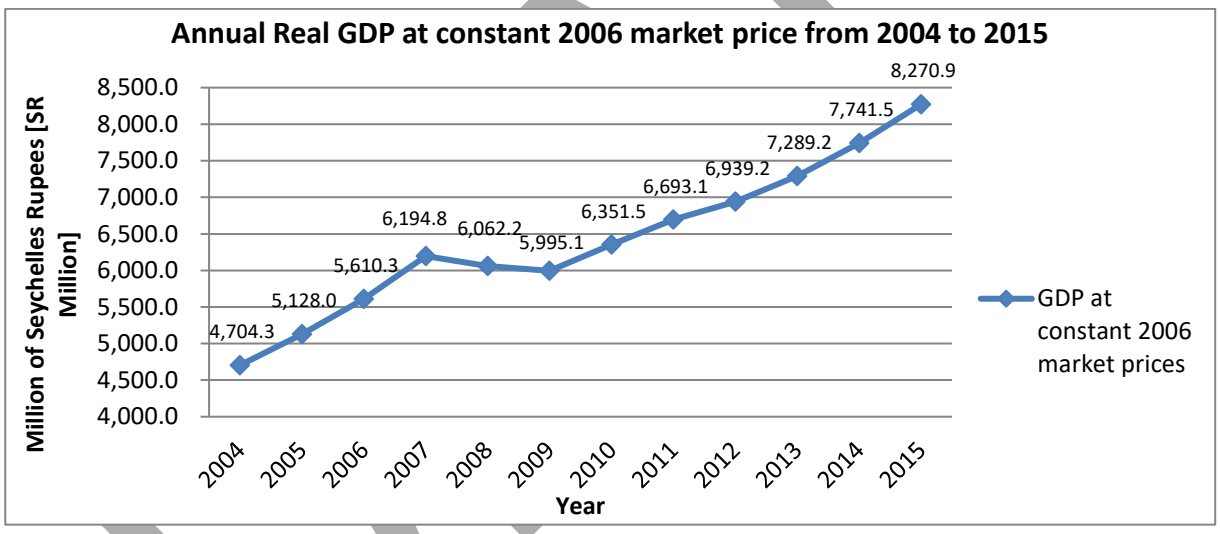

Figure 4: Annual Real GDP (constant 2006 market price) by Production Account in SR Million (NBS, 2015b; NBS, 2016)

As mentioned above, visitor arrivals are a relevant force for the assessment of waste generation and waste amounts. Thus, the following graphic depicts the development in the tourism sector considering visitor arrivals over the years from 2000 to 2016. The lines differentiate the growth for the Republic and Mahé specifically.

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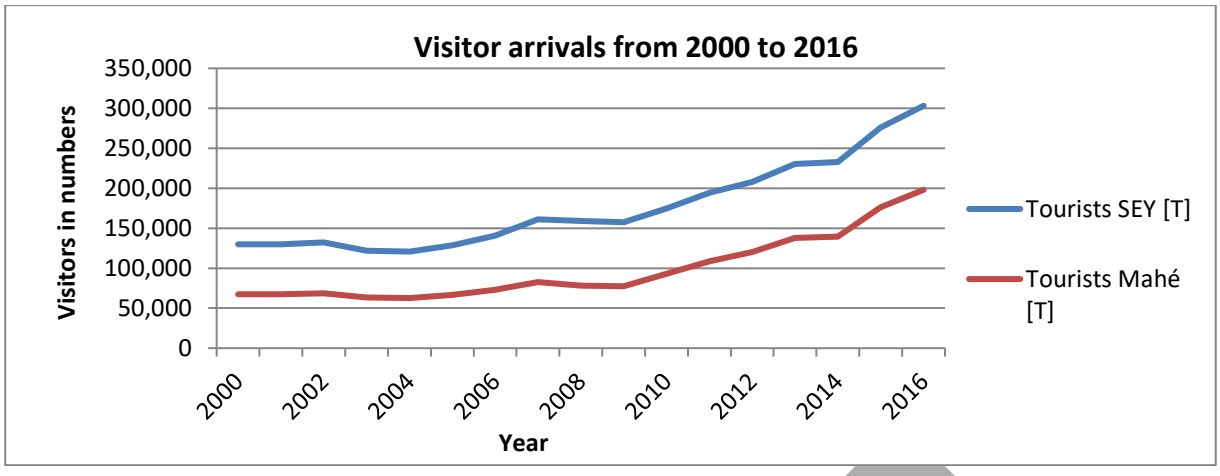

Figure 5: Visitor arrivals in the Republic of Seychelles and Mahé specifically from year 2000 to 2016 (NBS, 2008; NBS, 2010b; NBS, 2012b; NBS, 2014b; NBS, 2015c; NBS, 2017b; NBS, 2017c)

3. Waste Handling

This chapter has an explanatory quality on waste handling in order to understand the current waste management system on Mahé. Therefore, it is necessary to have a look at the legal and administrational framework on which waste management is based on. This is enhanced by a look at existing waste streams and waste handling schemes which encompass waste collection, treatment and disposal. It concludes with key observations as a basis for Chapter 3.4.

3.1. Legal framework

There are two relevant subject-matters to be examined:

1) international influence and its national translation including own national legislation and
2) existing instruments on regulating waste streams (governmental instruments, economic instruments, instruments of businesses)

It needs to be understood that instruments refer here to acts, statutory instruments, policies and strategies as well. The difference is that instruments are means to a regulatory end, i.e. national legislation of axiomatic quality.

As the Republic is a member state of the UN, the United Nations Environment Programme (UNEP) is therefore a guidance in terms of global environmental protection. Additionally, *Specialized Agencies* of the UN such as the *International Maritime Organisation (IMO)* implemented conventions as well. Considering this for waste management the following conventions are ratified by Seychelles:

- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
- Stockholm Convention on Persistent Organic Pollutants
- Nairobi Convention on Removal of Wrecks
- International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto and by the Protocol of 1997 (MARPOL)
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (LC), 1972 (and the 1996 London Protocol)

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The following table allows an understanding of the existing regulatory framework relevant for waste management which includes the integration of the above mentioned international conventions the Republic of Seychelles has partied to. The regulatory framework encompasses acts and statutory instruments which are of axiomatic character and quality.

Having a look at the table, three acts and two regulations altogether govern environmental concerns such as air, water and soil protection. There is no axiomatic regulatory on waste and waste as a resource. Only, the *Environment Protection Act 2016* (hereafter EPA 2016) refers to waste and especially hazardous waste and substances in eleven sections. By virtue of ss. 19, 20, 32-36 and 38-41 of the *EPA 2016* these include regulations upon authorisation for discharging matter in ground or watercourses, responsible agencies for waste management, the designation of waste disposal sites, regulations on importation of hazardous substances, littering and dumping among others.

Table 4: Legal framework of the Republic of Seychelles concerning waste management (Tu, 2017)

Environmental protection	Environment Protection Act (2016) Environment Protection (Impact Assessment) Regulation (1996)
Air pollution	Environment Protection (Standards) Regulation (1995)
Water pollution and pollution control	Environment Protection (Standards) Regulation (1995) Dumping at Sea Act 1974 (Overseas Territories) Order 1975 (1975) Public Utilities Corporation Act (1986)
Soil protection	Environment Protection (Standards) Regulation (1995)
Specific to waste and waste management	N/A

Comparing this to instruments within the policy framework, there are evident efforts regulating waste streams in the Republic of Seychelles.

Table 5: Instruments in the policy framework on regulating waste streams(Tu,2017)

Governmental Instruments	Seychelles Sustainable Development Strategy 2012-2020 Solid Waste Management Policy 2014-2018 Environment Protection (Beverage Containers and Labels) Regulations (2013) Environment Protection (Restriction of Plastic Bags) Regulations (2017) Environment Protection (Restriction of Plastic Utensils and Polystyrene Boxes) Regulations (2017) Pesticide Control Act (1996)
Economic instruments	Customs Management Act (2011) and its corresponding statutory instruments Value Added Tax Act (2010) Corporate Social Responsibility Tax Act (2013)
Instruments of businesses	Green Globe Seychelles Sustainable Tourism Label ISO 14001

In that way, there is clear guidance in the *Seychelles Sustainable Development Strategy 2012-2020* (hereafter SSDS). The *Solid Waste Management Policy 2014-2018* (hereafter SWM Policy) is a product derived from the SSDS.

The *SWM Policy* is the first and only regulatory referring to guiding principles in waste management - these incorporate the common and globally accepted understanding of a waste hierarchy and the 3R's. In that way, top priority is waste reduction, followed by re-use, recycling, energy recovery and disposal as last resort. The global common sense in environmental policy of principles such as precautionary principle, extended producer

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responsibility and polluter pays principle are also covered by the *SWM Policy*. The policy names areas for action specifically for:

- Packaging waste
- Bio waste
- Scrap metal
- Construction and Demolition waste (hereafter C&D waste)
- Waste Electronic and Electrical Equipment (hereafter WEEE)
- Waste batteries and accumulators
- Waste oil
- Hazardous waste

The policy acknowledges necessary improvements related to the implementary character of the identified areas of action such as legal and institutional framework, infrastructure, financing, non-governmental participation, capacity building and public awareness.

Additionally, regulations such as restrictions on the usage of PET or paper labels, limitation on plastic bags, utensils and polystyrene boxes importation and prohibition on certain pesticides and other goods are declared in environmental protection regulations and customs management act and its regulations.

The *Customs Management Act 2011* is an economic instrument to prevent certain goods to enter Seychelles such as toxic chemicals banned under the Stockholm Conventions (i.e. DDT, PCB etc.), waste pharmaceuticals, primary forms of plastic like cellular polymers of styrene or vinyl chloride amongst others. Moreover, it adds taxes and levies on certain goods, such as motor vehicles that operate for taxi business, and PET bottles and beverage cans by virtue of *S.I. 69 of 2013*.

Currently, there are also voluntarily applied means of businesses emulating with global sustainability standards that are emerging such as DIN EN ISO 14001 and sustainability labels in the tourism sector.

3.2. Administrational organisation and authorities

The main Ministry responsible for the environment in the Republic of Seychelles is the Ministry of Environment, Energy and Climate Change (hereafter MEECC). By virtue of s. 4(1) of *EPA 2016*, the MEECC is responsible to "administer, implement and enforce the provisions of this Act". In that way the MEECC is divided in two departments. The relevant department for waste is the DOE. In turn, the Department of Environment (DOE) has two divisions where the Waste, Enforcement and Permit Division (hereafter WEPD) has the main points of contacts with waste.

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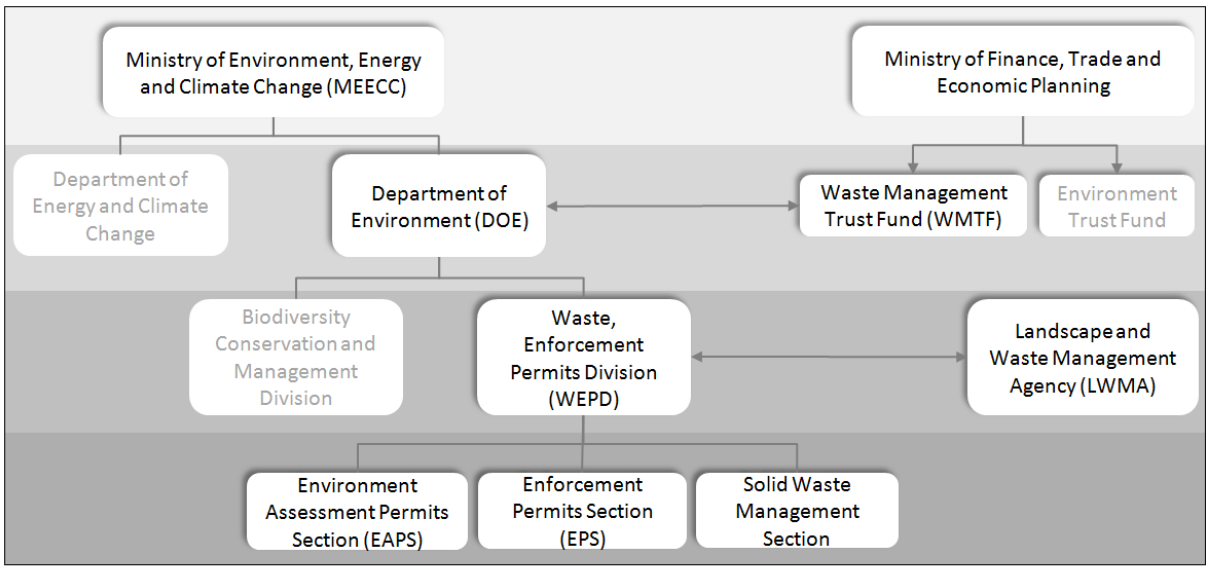

Collaborations with Public Health Authority, Planning Authority among other institutions are not illustrated in this chart.

Figure 6: Overview of administrational organisation in waste management on Mahé (Tu, 2017)

Department of Environment - hereafter DOE:

In accordance with the EPA the main responsibility of the DOE includes the development and enforcement of policies, programmes and guidelines. For the development of the above, the persons in charge are the Minister of MEECC, the Principal Secretary of DOE and the Director General of the WEPD. Enforcement is tasked by the Environmental Assessment Permit Section (hereafter EAPS) and the Enforcement Permit Section (hereafter EPS) within WEPD.

Since April 2017 there is a waste management director in charge of waste especially. Apparently, there was no person in charge allocated wholly for waste management beforehand developing strategies for waste management with necessary enforcing actions.

Environment Assessment Permit Section - hereafter EAPS:

The EAPS within WEPD is wholly responsible for Part IV of the *EPA 2016* by virtue of ss. 43 to 53. Generally speaking, EAPS examines EIAs for environmental authorisation of any applying person that intends to carry out a project or activity (e.g. launch of business in conjunction with making material change of any building or land). The aforementioned examination is construed under specific conditions for different topics. Among conditions for sanitary facilities, drainage, water conservation, noise and emissions, there is a catalogue of seven conditions for waste handling (see following; Rosette, M.-A., personal communication, March 27, 2017):

- Provision of adequate litter bins
- Provision and maintenance of enclosed vermin proof solid waste handling facility
- Liaison with Landscape and Waste Management Agency (for Mahé only) for removal of waste under particular contract conditions (*Solid Waste Service Agreement*)
- Separation of medical from domestic waste that should be collected according to standards applied by Victoria Hospital and transferred to a designated treatment facility
- Provision of storage facilities for waste oil and other garage waste
- Separation of plastics, rubber, glass, synthetic and other inorganic waste, construction and demolition waste at source for appropriate disposal at designated waste disposal site

Currently, no controlling mechanism is existent to monitor if imposed conditions are applied after authorisation.

Enforcement and Permits Section - hereafter EPS:

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The EPS within WEPD is wholly responsible for Part III of the *EPA 2016* by virtue of ss. 14 to 42. Generally speaking, EPS intervenes if any offence regarding environmental pollution occurs. The focus of EPS staff is on either small or large scale offences of illegal dumping in ground and watercourses, littering in town and nuisance. Apparently, no controlling mechanism for air pollution exist. For their patrolling function, EPS relies on cooperation with LWMA, Public Health Authority, the Industrial Estate Authority.

Landscape and Waste Management Agency - hereafter LWMA:

Having an agency such as LWMA is regulated by virtue of s. 9 of the *Environmental Protection Act 2016* and by virtue of the *Environment Protection (Landscape and Waste Management Agency) Regulations 2009*. The latter sets out that the "Agency is responsible for the management of waste and overall landscape development and management of Seychelles." In regards of waste management, LWMA covers different functions. On one hand, its function encompasses advice on strategic means (i.e. waste management plans and laws) in connection with its agency functions without enforcement quality. On the other hand, its functions include operative means of implementing character such as the supervision on waste collection, disposal and disposal site in the means of technical instructions, contracting, charging fees, monitoring/logging data on waste generation).

Waste Management Trust Fund - hereafter WMTF:

The Waste Management Trust Fund is by virtue of *S.I 29 of 2007* an official fund with the main purpose of making funds available for the management of recycling schemes. Currently, there are recycling schemes for PET bottles and beverage cans that are supported by the WMTF. Apparently, LWMA has no administrational function to direct WMTF but it is overseen by seven board members. Among representatives from the Ministry of Education, Seychelles Chamber of Commerce and Industry, from media, legal services and production, the WMTF is supervised by the Principal Secretary of Ministry of Environment, Energy and Climate Change and of Ministry of Finance, Trade and Economic Planning.

The fund raises money mainly from levies that fall under the *Customs Management Act* (2011).

3.3. Waste Classification, Collection, Treatment, Disposal and Charging System

With an understanding of the legal and institutional framework regarding waste management, this sub-chapter is complementary. The figure below demonstrates how waste is actually handled on Mahé.

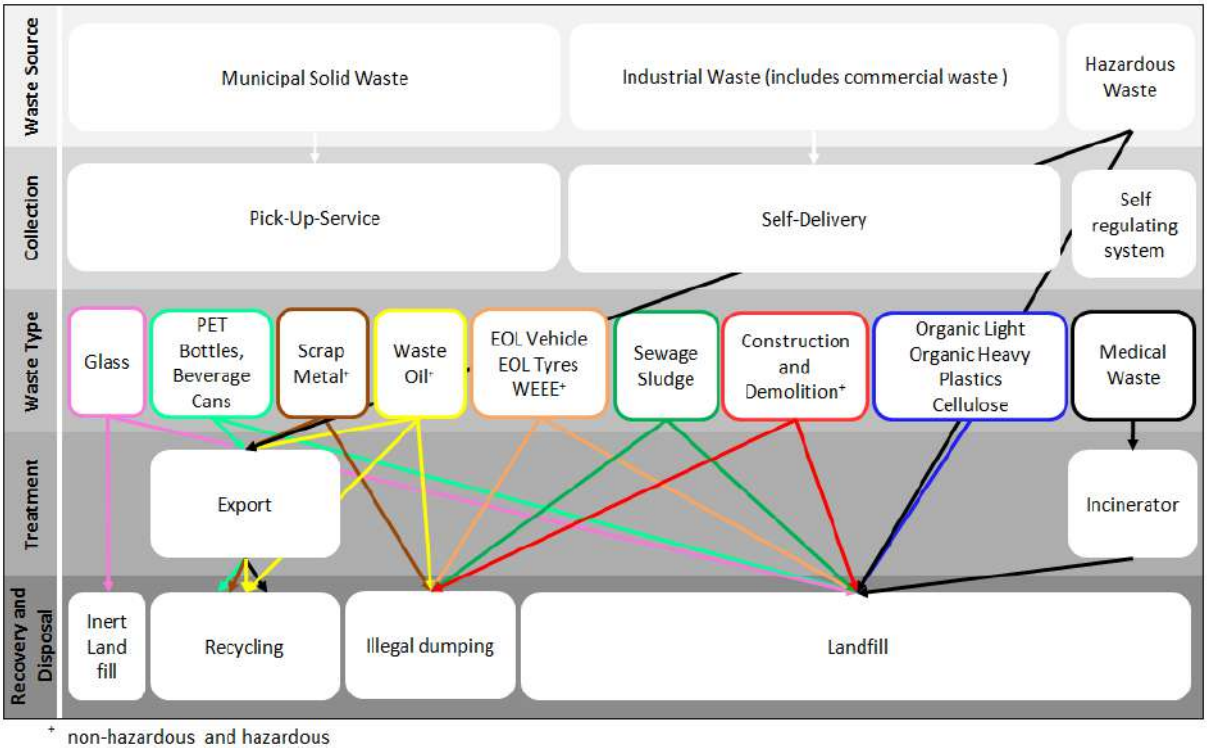

Figure 7: Current Waste Management System in Mahé (Tu, 2017)

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To have a first overview of different waste streams a differentiation of sources is necessary. For that purpose, difference is made between the following in **Error! Reference source not found.**.

Table 6: Waste Sources on Mahé (Tu,2017)

Municipal solid waste	Municipal solid waste has globally no uniform definition. On Mahé it comprises any waste that is placed in receptacles designated by virtue of EPA 2016 s. 34 (1) b, i.a. household waste, commercial waste, bulky waste and landscaping waste. As in any case of municipal solid waste, it covers a wide range of different waste fractions - paper and tissues, plastics, food waste, wood and glass among others are prevalent.
Industrial waste including Commercial Waste	Industrial waste includes commercial waste. Referring to Chapter **Error! Reference source not found.**, that industries are not mainly covered by the processing and manufacturing sector, it is evident that industrial waste is comprised of mainly commercial waste similar to domestic refuse together with packaging waste. For example, Indian Ocean Tuna Ltd. mainly recycles its processing waste, so that packaging waste, food waste and sewage are the remaining (Jobard, 2017).
Hazardous waste	Hazardous waste has different ways of handling. Hazardous waste can be found in the two categories above. Only hospital waste is considered on Mahé specifically due to its infectious character so that apparently, it is the only waste that is going through an incinerator for treatment.

Furthermore, waste management system on Mahé organises waste streams in 12 waste classes. The table below provides a glance at those waste streams.

Table 7: Current waste classification on Mahé (Payet, 2016)

Class 1	**Municipal Solid Waste** Waste collected in communal waste bins (domestic)
Class 2	**Commercial Waste** Waste usually collected from commercial, tourism and industrial establishments
Class 3	**Green Waste** Includes all types of vegetation matter mostly disposed by private trucks
Class 4	**Liquid Waste** Includes mostly sewage sludge and grease trap
Class 5	**Mixed Waste** Includes all types of waste
Class 6	**Metal Waste** Includes scrap metal and WEEE
Class 7	**Putrescent Waste** Includes animal waste from abattoirs
Class 8	**Waste Oil** Includes waste oil originating from hotels, restaurants, garages and boats
Class 9	**Construction Waste** Waste usually originating from construction sites

This classification is not backed up by any legal regulation nor is it officially represented. (Payet, 2017a)

The apparent waste classification is based on a mixed systematic, i.e. there are classes both based on waste source and property (physical, chemical, physiological).

Notably, Class 1 covers also commercial waste. This is because of EIA condition on waste handling for commercial, industrial, or domestic establishments to liaise with LWMA for the removal of their wastes. (see Chapter 3.2)

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	and demolition works
Class 10	**Inert Waste** Includes mostly glass waste and un-powdered asbestos
Class 11	**Hazardous Waste** Mostly car batteries, medicines, expired goods, reagents, waste oil etc.
Class 12	**Others/ Special Waste** Mostly ashes and sawdust

Waste Collection

On Mahé there is a differentiation between pick-up-service and self-delivery-system for the main waste streams. Pick-Up-service is offered for municipal solid waste and the latter needs to be delivered by own responsibility. Only hospital waste is attributed with a self-regulating system.

Redeem Centres are not illustrated in **Error! Reference source not found.** but they are facilitating recycling PET bottles and aluminum cans abroad. Redeem Centres are understood as a self-delivering system as waste producers have to bring their PET bottles and beverage cans to either of the four existing Redeem Centres on Mahé if they want to have this waste recycled.

Obviously, waste pick-up is only governmentally organised for Class 1. This has started in year 1997. For this, communal bin sites with bins of 240 Litres capacity have been allocated. The allocation is ensued district-wise. However, the pick-up of the waste in communal waste bins is organised in ten collection routes (hereafter CR). There is a general north-south, east-west and central divide for CRs so that northern districts, for instance, are organised in one CR.

Moreover, pick-up of waste is coordinated twofold: As any waste is placed at the communal waste bin sites where waste producers not only dump their household waste but small scale construction waste and bulky waste as well, compactors are served daily for household waste and open-trucks are served on a weekly basis for bulky waste.

Waste pick-up-service for Class 1 is related to impediments additionally. Even though commercial premises are in obligation of being in contract with LWMA for waste collection, many shop owners dump their (mainly packaging) waste into the communal waste bins and block bins and bin sites.

Classes 2 to 12 are considered in the self-delivery system without pick-up-service. However, there are private companies who offer waste collecting services, especially for Class 2, 4, 7 and 8. Depending on class, private companies offer skip-services, mobile compactor services and liquid waste pumping services. In any case, it is apparent, that there is an inconsistency to EIA conditions on waste handling (see Chapter 3.2).

Waste treatment and disposal

Especially PET bottles, beverage cans, scrap metal (Class 6), waste oil (Class 8) and hazardous waste (class 11) are exported.
As mentioned before, Redeem Centres receive PET bottles and beverage cans. After collection they are diverted to private recycling companies who prepare the exportation of these.

Within Class 8 and 11 not all waste types are exported - specific procedures are imposed. For both classes a form must be filled in that is diverted to EPS (Standards Section). After assessment, authorisation is either given to be dumped on landfill or to be exported. In Class 8 especially, only hydraulic oil and kitchen oil need authorisation from EPS. Engine oil is recycled within the country. Therefore, LWMA functions as a customer to receive used bunker fuel that is again sold to the private sector.

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As there is currently only exportation implying a subsequent recycling scheme abroad and incineration for medical waste as another treatment method imposed, there are threefold ways of disposing waste in Mahé. Unfortunately, it represents the least desired options in the waste hierarchy that is stated in the SWM Policy. Disposal happens either illegally or on designated disposal sites. Designated disposal sites are comprised of an inert landfill in Anse Royal and one landfill in Providence for all the remaining waste streams (Chapter **Error! Reference source not found.** depicts the geographical location of both.)

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Table 8: Overview on disposal sites (Anse Royal and Providence Landfill)

Anse Royal Landfill	According to interviews Anse Royal Landfill is barely approached, i.e. once every or every two weeks. Anse Royal Landfill receives only inert waste. It seems that this landfill is a sanitary one but neither general data nor technical details were traceable.
Providence Landfill	Providence Landfill has started in year 1995. Landfill management has been given to a private company *STAR Seychelles* under Build-Operate-Transfer contract (BOT) since 1997. The landfill today, is divided in two sections - Landfill No.1 and Landfill No. 2 as being the new landfill with a start of operation in year 2015. Supposedly Class 4, 7, 9 and bulky waste go to Landfill No.1. All the remaining go to Landfill No. 2. There is no technical data on Landfill No. 1 available. Only some trivial data is available for Landfill No. 2. It has a volume capacity of 433,000 m^3 calculated to the level of 30.000 m from bottom of landfill (= 27.000 m from ground level). However, it is additionally known, that only Landfill No. 2 is a sanitary landfill but leachate is discharged into the sea as the installed leachate plant is not operating. Landfill gas is not vented. Furthermore, a sorting plant transformed to a composting plant is placed at Providence Landfill. According to interviews it is unclear when exactly the composting plant operated. The majority stated, that operation of the composting plant stopped approximately 5 years ago. All in all, composting operations had lasted only a few months (3 to 6 months). At landfill any incoming waste is weighed at the weight bridge distinguished in waste classes.

Charging system for waste collection and disposal

The charging system on Mahé for waste collection and disposal have double standards. There is a differentiation between fees imposed by government and fees imposed by landfill operator.

As there is no specific legal framework for waste and waste management, no charging system for waste is actually imposed. Thus, the table below explains quite clearly that, wherever DOE or LWMA do not charge, the landfill operator charges.

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Table 9: Charging system for waste collection and disposal (Payet, 2016; Payet, 2017b; Ladouce, 2017; Croguennec, 2017)

Waste Class	Governmental Fees	Governmental fees in detail	Fees by Landfill Operator
Class 1	No fees	• Waste collection of Class 1 (communal waste bin only) is financed through VAT • Waste collection via contracts with LWMA have different fees depending on frequency and quantity ranging from SCR 251 (weekly, 2 bins) to SCR 8821 (daily, max. 10 bins)	No fees
Class 2	No fees		Fees apply
Class 3	No fees		No fees
Class 4	No fees		Fees apply
Class 5	Fees apply	SCR 100 for first ton of mixed waste and SCR 50/ton of mixed waste thereafter	No fees
Class 6	No fees		No fees
Class 7	No fees		Fees apply
Class 8	Fees apply	*Engine Oil:* SCR 6,50/litre of engine oil *Hydraulic Oil:* N/A+ *Kitchen Oil:* N/A+	No fees
Class 9	No fees		Fees apply
Class 10	Fees apply	SCR 1000 of administration fee in addition SCR 200/ton of glass	No fees
Class 11	No fees		N/A*
Class 12	No fees		N/A*

+ According to interviews those waste types were not considered in the system for applied fees of engine oil. It is assumed that no fees are charged for those waste types.

* According to interviews those wastes coming as these classes are very rarely. Hence, no information on fees were able to deduct out of the interview. It is assumed that no fees are charged for those waste types.

DRAFT

3.4. Key observations

To sum up the chapter, the following table illustrates key observations that are relevant to determine key factors and barriers in the current waste management system in Mahé in Chapter 4.

Table 10: Key observations in current waste management on Mahé

Legal Framework	• Instruments for regulating few waste streams exist • There is no legal regulation for waste existent • Ground and watercourses are protected by standards but there are no regulatory for air pollution
Administrational organisation and authorities	• Applied EIA conditions are not monitored after environmental authorisation • Waste agency exists (LWMA) • LWMA has no authority on all matters for waste management • No governmental body or person in charge with waste-subjected expertise to plan, organise, staff, direct and control on waste matters
Classification	• Current waste classification is based on a mixed systematic • Undefined terms such as municipal solid waste and commercial waste
Collection	• Recycling schemes for PET bottles and beverage cans exist • Waste Collection happens daily • Ambiguous management of commercial waste • No penalties for non-compliance with *Solid Waste Service Agreement Conditions* imposed on commercial, industrial, or domestic establishments
Treatment and Disposal	• Hospital waste is handled separately • Waste amounts are recorded at weight bridge • Waste Oil (Class 8) is under control of government • A formal environmental authorisation process to dispose hazardous waste is allocated • Unused technologies (leachate plant and composting plant) • Landfill leachate is received by sea without treatment

	• Landfill gas emits
Charging System	• Double standards on charging system existent

DRAFT

4. Determination of key factors and barriers limiting current waste management

The basis for the determination of key factors and barriers regarding current waste management is subjected to the previous chapter which described current waste handling. Thus, key findings in Chapter 3.4 give a notion on current challenges and opportunities, whereas this chapter concentrates on a more enhanced impression of current waste management practices.

For the purpose of determining those factors and forces, additionally, a social study and stakeholder interviews have been conducted. The spectrum of these tools allows, thus, a comprehensive understanding within all dimensions that affect waste management. The identification of factors and forces differentiates between internal factors and external forces within the framework of a SWOT-Analysis. The SWOT-Analysis itself combines the results of ascertained factors from the stakeholder interviews and the social study with the key findings of the previous chapter. Those factors then are analysed upon an appropriate categorisation.

Hence, Chapter 4.1 describes first of all the methodology of these tools. Thereupon, Chapter 4.2 illustrates the results in a categorised manner.

Only after identification and categorisation within the framework of a SWOT-Matrix, explicit strategies can be deduced and then drafted for any specific challenge faced.

4.1. Methodology

As described, two additional tools were used to identify internal factors and external forces. This chapter portrays the methodology of the following tools:

- Social Study
- Stakeholder Interviews

4.1.1. Social Study

In order to have a notion about the general public, their behaviour and perception on waste reduction and recycling a social study has been conducted within two weeks including preparation and trial runs.

The social study comprised a questionnaire of eight questions with five additional conditional branching questions depending on the answer of the parent question. Moreover, statistical data has been recorded (gender, age, district affiliation). The questionnaire was designed not to last for more than ten minutes in order to avoid any inconveniences while the interview was conducted. Exceptions, when interviewees wanted to take their time to explain their concerns about any waste relevant topic, were welcomed. The questionnaire and the results can be seen in Appendix 1 and 2.

Three eligible locations have been identified to carry out the study to have a variety of Seychellois interviewees:

- Providence Take-Away Restaurants
- Bazar Labrin in Beau Vallon
- Bus Terminal in Victoria

The social study was conducted with the support of EPS staff for translation and breaking cultural boundaries. In total 105 Seychellois women and men demonstrated their cooperation so that the results can be integrated in the SWOT-Analysis.

It is noted, that the study might be limited. This is explained by the interviewing circumstances, so that the number of respondents do not represent the real situation regarding population distribution and demographic characteristic (i.e. gender, age, district affiliation) to have representative data set. In other words, the social

DRAFT

study did not interview for instance, 52% males and 48% females according to the census in 2010, but 33% males and 67% female. Neither do numbers of interviewees correspond to the real percental demographic situation so that 16% and not 20% of age group '> 50' were interviewed. Therefore, it might be more appropriate to conclude the results from the study as a notion of generic quality on motivation and willingness in waste reduction and recycling of Seychellois people only. However and more importantly though, on a percentage basis the data set of the social study is actually similar to the collected data on (municipal solid) waste generation depending on region (i.e. Class 1). To sum it up, the social study depicts, motivation, willingness and knowledge of Mahe's hot spots of waste generation concerning waste reduction and recycling. Unfortunately, the study does not seem to cover the behavioural characteristics of Seychellois living in the rural areas.

4.1.2. Stakeholder Interviews

For an integrated waste management concept all stakeholders must be considered not only to ensure feasibility but also to make use of synergy. Only by understanding who has a stake in an initiative, and through understanding the nature of their claims and inter-relationships with each other, appropriate stakeholders can be effectively involved in environmental decision-making. (Reed et al., 2009)

The following table explains the methods in order to identify and interview the stakeholders.

Table 11: Methods of identifying and interviewing stakeholders in waste management on Mahé

Method	Description
Semi-structured interviews	Semi-structured interviews are conversations in which a set of questions and a good idea of what topics will be covered - but the conversation is free to vary, and is likely to change substantially between participants. They contrast with structured interviews in which there is a predetermined list of questions that are covered in the same order for each person. There is also contrast with unstructured interviews, in which the area of investigation is delineated, but there is no assumed order to the questions, and very little predetermined boundaries as to the topics that should be covered.
Snow-ball sampling	Snowball sampling is an approach for locating information-rich key informants. Using this approach, a few potential respondents are contacted and asked whether they know of anybody with the characteristics that are looked for in the research. In that way, individuals from initial stakeholder categories are interviewed, identifying new stakeholder categories and contacts. Sample may be biased by the social networks of the first individual in the snow-ball sample, though.

Like most stakeholder identifications, the determination of relevant stakeholders in the waste sector in Mahé, was an iterative process, during which additional stakeholders are added as the analysis continues. Semi-structured interviews and snow-ball sampling as methods has been used to identify and interview stakeholders. However, there is a risk that some stakeholders may be accidently omitted and as a consequence not all relevant stakeholders of the phenomenon are identified and considered. That's why, it is not possible to include all stakeholders and a line was drawn at some point. It was not even possible to meet with importers.

Stakeholders have been interviewed during the time from January 10 to March 28, 2017 whenever possible. A certain flexibility in scheduling the meetings was necessary to hold meetings with the relevant stakeholders so that there was no daily schedule. Interviews varied from 45 to 90 minutes of duration due to the chosen method of semi-structured interviews.

DRAFT

As semi-structured interviews allow a framework of themes to conclude new ideas during the interview, the following themes were covered:

- Description of the organisation the interviewee works in
- Scope of work of the interviewee
- Working procedures regarding waste
- Interrelation with other stakeholders
- Gaps/ challenges/ concerns in current waste management within the organisation and in the country
- Ideas how to improve current waste management within the organisation and in the country

The graphic below illustrates stakeholders who has been interviewed.

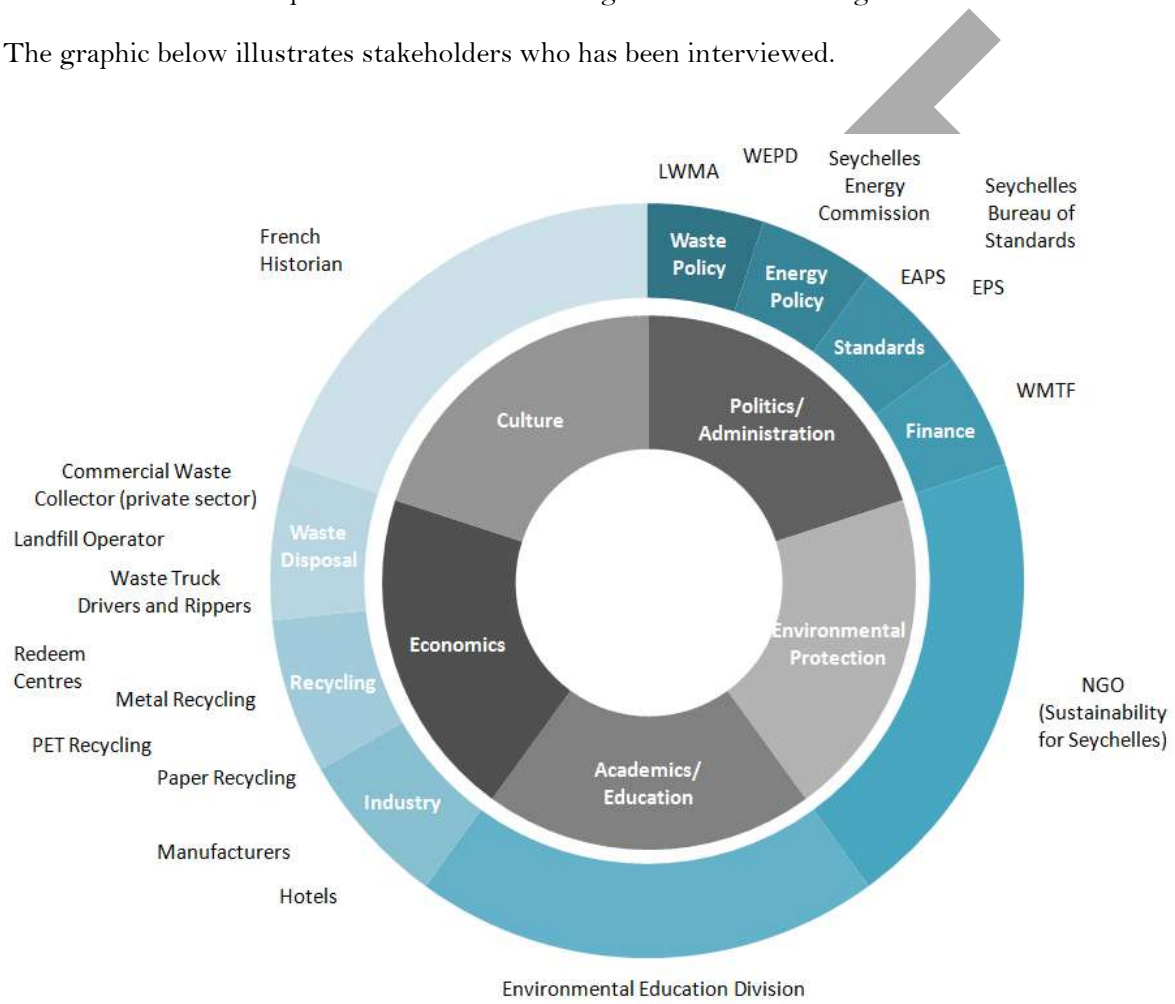

Figure 8: Stakeholder Map of waste sector in Mahé (Tu, 2017)

4.2. Results

Having the aforementioned tools in identifying influencing factors regarding waste management on Mahé, this chapter illustrates the data gathered in four categories: Strengths, Weaknesses, Opportunities, and Threats. This is to depict them in a SWOT-Matrix as seen in **Error! Reference source not found.**. The SWOT matrix includes 17 internal factors (six strengths and eleven weaknesses) and 15 external factors (ten opportunities and five threats).

Table 12: SWOT-Matrix regarding waste management on Mahé

Internal Strengths		External Opportunities	
S1	Regular and daily waste collection	O1	Redeem Centres bear unused capacity
S2	Waste amounts are partly recorded	O2	General public uses public bins
S3	An EPA implementing agency exists	O3	Composting is practiced more or less within households with garden
S4	Hazardous waste has special attention	O4	The majority of the general public is willing to separate waste
S5	Instruments on regulating waste streams exist and new ones are planned	O5	General public is more or less likely to take their bulky waste to a recycling depot
S6	Environmental education schemes exist	O6	NGOs, CBOs and private people engage themselves in independent waste management filling in the existing waste management gaps
		O7	Private sector engages independently and voluntarily in waste avoidance and recycling
		O8	There are technologies existent (leachate plant and composting plant)
		O9	Seychelles Integrated and Comprehensive Sanitation Masterplan's objectives include recycling of water and solids
		O10	Increase use of RE by 15% by 2030 through e.g. waste, biomass and waste heat
Internal Weaknesses		External Threats	
W1	Lack of regulated waste handling procedures/schemes (therefore no control over waste streams)	T1	Waste lacks sensitivity within the general public
W2	Waste policy does not comprehensively cover actual waste situation	T2	It is not safe for businesses to invest in the recycling market
W3	Lack of human resources to enforce and implement EPA	T3	Few recycling initiatives in the country
W4	Lack of monitoring of enforced and implemented EPA procedures	T4	Landfill gas emits and is not vented in a controlled manner and leachate is diverted to the sea
W5	Top-down approach leaves no space for bottom-up approach	T5	The majority of the general public is not willing to pay for the collection of their waste
W6	Lack of pertinent units for planned actions with appropriate authority (rooting in lack of direction)		
W7	Lack of network in waste management		
W8	No appropriate waste charging system		
W9	Waste classification is based on a mixed systematic (therefore waste streams are mixed)		
W10	Waste collection is inappropriately equipped		
W11	Inappropriate conditions for waste collecting staff		

DRAFT

4.2.1. Internal Strengths and Weaknesses

As this is a collection of all stakeholder opinions, results of the social study and of key observations of current waste management practices, there is a better drafting for strategies by categorising these factors influencing waste management. The categorisation supports the understanding of the roots as well. Hence, a casual chain analysis allows to deduce the internal factors into five categories in regards to functions of management according to Koontz and O'Donnell: *Planning*, *Controlling Organising*, *Directing and Staffing*. There is a similarity to the systems approach according to ISO 14001 on the PDCA-model[3] that has led to consider the functions of management according to Koontz and O'Donnell.

The functions of management according to Koontz and O'Donnell must be understood as highly interdependent to each other as opposed to a clear chain of sequence. Therefore the illustration in a table aims for a demonstration of the conceptual context of the functions of management only. In short, internal factors could be categorised in a multiple way, but in this case, *Internal Strengths and Weaknesses* are not categorised in a multiple way, i.e. more than one function. For example, the table below does not allocate internal factors for *Directing* because those findings were considered in the *staffing function.*

The following table illustrates which one of the internal factors belong to which management function.

Table 13: Internal Strengths and Weaknesses influencing waste management on Mahé

Function of Management	Internal Strength	Internal Weakness
Planning	S4, S5, S6	W1, W2, W8, W9
Organising	S1, S3	W6, W10
Staffing	-	W3, W5, W7
Directing	-	-
Controlling	S2	W4, W11

For any successful management scheme, there must be a decision made in advance on "what to do, when to do & how to do". As for the *planning function*, current waste management has three strengths that form at least a base. (S4, S5 and S6).

In detail, the afore mentioned refers on one hand to the existing formal processes for disposal of waste oil and hazardous waste especially (S4). Even medical waste underlies a separate waste disposal scheme with own waste treatment (i.e. incinerator). On the other hand, internal strengths include actions planned such as a levy on imported glassware starting from 2018, levies on electric, electronical equipment in conjunction with an e-waste consortium to finance e-waste recycling, an enhancement of PET bottle recycling to other PET containers and the restrictions on plastic bags, plastic utensils and polystyrene boxes effective from July 2017 (S5). Moreover, the Environmental Education Division currently has started a cooperation with the Ministry of Education in order to raise awareness about sustainable management of waste starting from May 2017 (S6).

In a good way, these actions planned are part of the policy framework specified as instruments to regulate waste streams. This means that the *Solid Waste Management Policy 2014-2018* acknowledges the existing problems in waste management by stating policy aims and guiding principles such as waste hierarchy amongst others. But according to stakeholders the policy has its weaknesses as well (W2). Even though the policy describes areas for action, the strategic quality is not well imposed in the policy timeframe as strategic goals are designed for over five years. The policy seems to be too ambitious without defining strategies "SMART"-ly and without merging the actual situation in order to reach the goal within a timeframe of 4 years only having additionally in mind that Seychelles is a young country without proper transition from Marxism to capitalism and globalisation.

Moreover, there is no list of priorities of actions to be taken. In a way, this originates in the lack of an axiomatic legal framework as already observed in Chapter 3.4. The existing *Environmental Protection Act 2016*

[3] PDCA-model: The basis for the approach in ISO 14001 underlying an environmental management system is founded on the concept of Plan-Do-Check-Act.

DRAFT

dedicates only eleven sections to waste and especially to hazardous waste out of 29 sections addressing prevention, control and abatement of environmental pollution. However, those, in short, state what should not be done - i.e. they prohibit merely pollution (either waste or any of hazardous substance) and obligate land owners to keep their land free from waste for one thing. For the other, especially by virtue of Section 32 (1) b of the *EPA 2016*, "[t]he Minister shall make regulations to control the introduction, production, possession, handling, storage, transportations, segregation, processing and disposal of waste and hazardous waste". Hence, waste regulation could be enforced but firstly there is no other regulations enforced and secondly the sections do not exactly imply "what to do, how to do and when to do".

This phenomena can be observed exemplary in waste collection: Double standards regarding charging commercial establishments for waste collection exist because private and governmental bodies are in competition with each other (W8). There is no *weakness* in competition as such, but there is no framework (and rules) on "what to do, how to do and when to do" for private waste collectors to make business in the waste sector resulting in a (financial and environmental) loss for the Government. In that way, commercial waste is not tackled in an appropriate manner and priority as well.

Another evident is, that the current waste classification is based on a mixed systematic which does not support recycling schemes efficiently (W9). This originates in non-existent defined termini such as municipal solid waste or commercial waste that are used for the current waste classification from Classes 1 to 12. Without definition of termini - a "what do to" cannot be specified.

Any specifications on "how to" handle hazardous waste are missing as well. This is evident as there is no control over hazardous waste even though a formal procedure is imposed on this waste stream (W1). Hazardous waste seem to be handled insufficient or slack according to stakeholders as they didn't know how to proceed and who to turn to concerning the disposal on their hazardous waste from laboratories.

Apart from planning the desired conditions it is important to organise a goal-driven framework to pursue the ambitions stated for example in a legal framework. Here it is about establishing units and entrusting them to certain authority to carry out planned actions. Tasks are coordinated and therefore communication systems between responsible parties are established.

In this matter, it is noteworthy to say that operating waste collection is thoroughly organised (S1). Additionally, to that, clearly the DOE has the enforcing role considering the *Environmental Protection Act* and the *Solid Waste Management Policy 2014-2018* whereas LWMA occupies the role of an implementing instance in waste management (S3). In practical matters though by looking at W1, W6, and W10, only LWMA seem to have the expertise and capacity to strategise and draft enforcement plans. But they have no appropriate authority in order to follow up on any strategies. The organising structure is even more so weakened exemplary in the seemingly formal regulated waste stream of PET bottles and beverage cans. The implied lack of defined entrusted authorities seems to limit LWMA in their implementing function as it seems that there is an overlap of responsibilities of governmental bodies. As DOE administers the WMTF which deals with the financial framework of PET bottle and beverage can levy - LWMA as an implementing unit cannot overview waste amounts on the named how it should be by virtue of Section 4 (m) of *S.I. 29 of 2009*. All in all, there is not one single institutional body governing all waste streams.

At DOE or at LWMA another unit is missed to tender appropriately for example for waste collection as well. As waste collection is contracted to the private sector, it seems that no institutional body has agreed on appropriate terms and conditions in the contract, so that collection equipment is not maintained for efficient operation causing dreadful working conditions for collecting staff.

All in all, the *internal weakness* in the *organising function* is intensified very much so through both a lack of a proper communication system to discuss about enforcing strategies between the two parties and a lack of human resources in the DOE to *direct* LWMA to execute any specific plan. Evidently the lack of clear responsibilities, the *organising function* is directly interdependent with the next important functions of management: *Directing and Staffing*.

For every project or organisation qualified staff is needed, in this case, to either enforce or implement legal requirements. Until the end of March 2017 there was no specific position engaged for waste management at

DRAFT

DOE which is why weaknesses from past actions in the *organising function* can be actually placed in here as well. By then only three personnel at DOE have taken care of waste management matters in a substituting quality because their main job focuses on other. In this matter, it is understandable why a mixed understanding of enforcing and implementing exists and why there is no clear *directing* to hand. As there is a waste management director since April 2017 at DOE there are prospects of getting matters in regards of waste management planned, organised, staffed, directed and controlled.

However, like mentioned before, DOE needs more than a waste management director to support pursuing a desired waste management plan for the long run - that is qualified staff in-house instead of relying on consultancies which cannot tackle waste management problems - for example staff which at least considers bottom-up approaches while planning matters instead of going along with top-down approaches only (W5) and for instance to establish a network that coordinate between government, private sector, CBO's and NGO's if stakeholder participation is desired as stated in the *SWM Policy 2014-2018* (W7).

Anyhow, waste management executing entity lacks human resources as well, especially, as for the current state, if LWMA would need capacity on strategising then the agency will need more qualified staff as well for example to implement actions planned. This is evident, as bin sites are currently not adequately allocated: The lack of human resources might be a reason why a separate bin project a few years ago did not work out. All desired separated waste types were not distinguished from another on behalf of their volume as bin quantities for organic waste were allocated for instance equal to receptacles for plastics. The lack of human capacity includes already the existing shortage to control the contractor on landfill management (see next paragraph).

Having said so, the *controlling function* within a successful management scheme considers not only controlling third party performances with desired conditions but also one own's performance with targeted conditions (W4). Interviews with stakeholders and own observations see weaknesses in:

- PET and beverage can levy is not under control of DOE (no accurate data is transmitted to WMTF for the imported preforms of relevant plastics, so that there is a need for a correct mechanism to monitor at point of entry for levied goods)
- Not all commercial establishments are in contract with LWMA for waste collection (there is a lack of monitoring schemes after issuing licenses if termed conditions are applied). Even though commercial site visits exist, contracted conditions are not penalised when non-compliance prevails.
- Not even 50% of cases of illegal pollution are uncovered due to lack of human resources to monitor

However, at least waste amounts are recorded at Providence Landfill (S2) even if there is an assumption that the recorded data is challenged by neglected recording behaviour in specific (minor) classes such as hazardous waste like mentioned before. This originates from lacking human resources and units to control landfill management contractor as the landfill operator imposes inappropriate conditions for waste collecting staff as well (W11).

4.2.2. External Opportunities and Threats

Having a look at the internal factors under the functions of management, it is best to make use of a PEEST analysis for external factors (macro environment level). PEEST analysis is a simple and effective tool used in situation analysis - in this case - to categorise the ascertained key external forces (opportunities and threats) into *political*, *economic*, *ecological*, *social and technological* dimensions that might affect the organisation. Basically, the PEEST analysis will help to determine how these factors will affect the performance and activities of the organisation in the long-term. In this case, the political dimensions are not considered because it is seen as an internal factor (see Chapter 4.2.1) so that EEST analysis can be used as a term.

The table below visualises the categorisation made.

DRAFT

Table 14: External Opportunities and Threats influencing waste management in Mahé

Dimension	External Opportunities	External Threats
Economic	• Redeem Centres bear unused capacity (O1) • Private sector engages independently and voluntarily in waste avoidance and recycling (O7)	• It is not safe for businesses to invest in the recycling market (T2) • Few recycling initiatives in the country (T3)
Ecological		• Landfill gas emits and is not vented in a controlled manner and leachate is diverted to the sea (T4)
Social	• General public uses public bins (O1) • Composting is practiced more or less within households with garden (O3) • The majority of the general public is willing to separate waste (O4) • General public is more or less likely to take their bulky waste to a recycling depot (O5) • NGOs, CBOs and private people engage themselves in independent waste management filling in the existing waste management gaps (O6)	• Waste lacks sensitivity within the general public (T1) • The majority of the general public is not willing to pay for the collection of their waste (T5)
Techno-logical	• There are technologies existent (leachate plant and composting plant) (O8) • The Seychelles Integrated and Comprehensive Sanitation Masterplan's objectives include recycling of water and solids (O9) • Increase use of RE by 15% by 2030 through e.g. waste, biomass and waste heat (O10)	

The external threats in the economic dimension are interdependent to each other. As it is understandably that private businesses struggle with investing in the recycling business it is evident that other stakeholders are concerned about the few recycling initiatives in the country. On the other hand, obviously there are private businesses (i.e. large capacity hotels) who voluntarily and successfully implemented recycling schemes within their establishments. Most of the motivation derives from voluntarily participating in ecological tourism labels such as Green Globe and Seychelles Sustainable Tourism Label. The global phenomena of becoming more sustainable and ecologically friendly has reached the market in Seychelles as well, which seems to bear enormous opportunity. Additionally, as governmental recycling schemes already exist, it cannot be far from expanding the responsibilities of Redeem Centres as relevant stakeholders state, that there is unused capacity that should be made use of to avoid waste going unnecessarily going to landfill. All in all, a first glance makes clear that the *economic forces* concerning waste management imply sufficient opportunities to improve.

On the contrary, there are currently no opportunities that mitigate *ecological threats* imposed by the landfill. Even though there are no tested parameters of the leachate and the landfill gas existent, it is assumed that ecological threatening substances are of matter with time.

The most promising and challenging force is the *social dimension* imposed on waste management. Without any motivation, willingness and knowledge opportunities that are evident cannot take up with imposed threats. Only if proper schemes are introduced, opportunities and threats seem to compensate each other. Therefore, the internationally most acknowledged principles of *Education for Sustainable Development* are comprised of *envisioning, critical thinking, participation, partnerships and systemic thinking* which needs consideration when planning any scheme to tackle the forces in the social dimension.

DRAFT

Last but not least *technological forces* seem to have good prospects as well because there is the possibility to synergise with other sectors and no threats seem to be at hand. However, the technologies cannot be opportunities if we have a look at the internal factors in the previous chapter. As there is currently no capacity to make use of the technology, then any technology cannot improve waste management practices at all.

Hence, at this stage it is reasonable to consider internal factors and external forces at the same time to draft strategies.

DRAFT

5. Waste Generation

The previous chapters illustrate factors influencing the overall waste sector. Thereby, it allows an understanding of its interdependencies and complexity. This chapter focuses now on the actual waste amounts that are generated on Mahé. This includes an illustration of the total MSW amounts going to landfill and waste amounts by existing waste classes going to landfill. Furthermore, this chapter aims to estimate a trend for future waste generation for Mahé by taking into account different factors. The chapter concludes with a verification of the extrapolated projection.

This chapter needs careful attention as data collection on site might not be comprehensively sufficient. For one thing, no differentiation is made between rural and urban areas. On the other hand, Chapter 5.1 does not consider rainfall that might influence masses.

5.1. Waste amounts

For 2016 the total waste amount is at 73,225 tonnes going to Providence Landfill. The following figure illustrates the development of waste amounts throughout year 2016 by months.

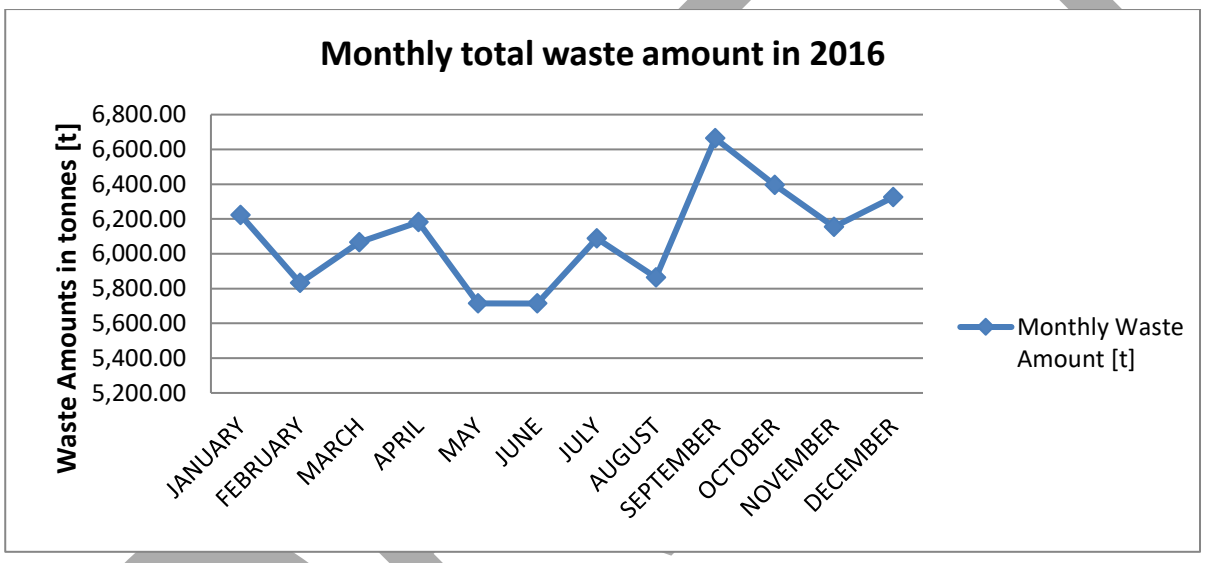

Figure 9: Monthly waste amount throughout year 2016 in tonnes [t] (Ladouce, L., personal communication, January 19, 2017)

For a better comparism with international figures in waste generation the existing data will be approximated and compiled as waste amounts per capita in kg per day as well. Thus, not only population and vital statistics of Mahé are integrated. Visitors arriving in Seychelles are considered as well, who are multiplied by a factor of $\frac{2d}{365d}$ (2 days as average length of stay on Mahé Island) to consider their influence on waste generation on Mahé. The calculations state a yearly waste generation of 877.5 $\frac{kg}{E \cdot a}$ in 2016. (For details of data and data analysis see Appendix 3.) In daily means, Mahé counts for 2.40 $\frac{kg}{E \cdot d}$ in year 2016 which is already increased for high-income countries according to World Bank classification compared to an average of 2.16 $\frac{kg}{E \cdot d}$ (Hoornweg & Bhada-Tata, 2012). Compared to other AIMS SIDS with an average of 1.56 $\frac{kg}{E \cdot d}$ only Maledives produced similar amounts of 2.49 $\frac{kg}{E \cdot d}$ in year 2013 (Mohee et al., 2015).

At this point it is interesting to consider the development of the monthly generated waste in the 12 different classes over the year 2016 (**Error! Reference source not found.**). This is to understand the individual behaviour of each waste class exemplary.

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The comparison is drawn between:

- Waste amounts from January to December 2016
- Visitor arrivals from January to December 2016
- Value of imports from January to December 2016

Waste generated in Class 1 and Class 2 behave moderately stable except for the increase in Class 1 from October onwards. Unfortunately, due to a lack of data no comparison can be made. There is, however, no correlation between waste generation in Class 1/Class 2 and importing goods. Nevertheless, an interdependency can be assumed between Class 2 and slightly increased visitor arrivals in the months of November and December. Thus, apparently there are no seasonal changes due to tourism or the like except partly for Class 4. This is reasonable because liquid waste arriving at landfill is mostly sewage sludge from hotels amongst grease trap and waste water (Dupouy, 2017).

For Class 5 there is a considerable low in February/March and November/December. This line has its similarities with the line chart of imported good throughout 2016. The lows are visible in February/March and December.

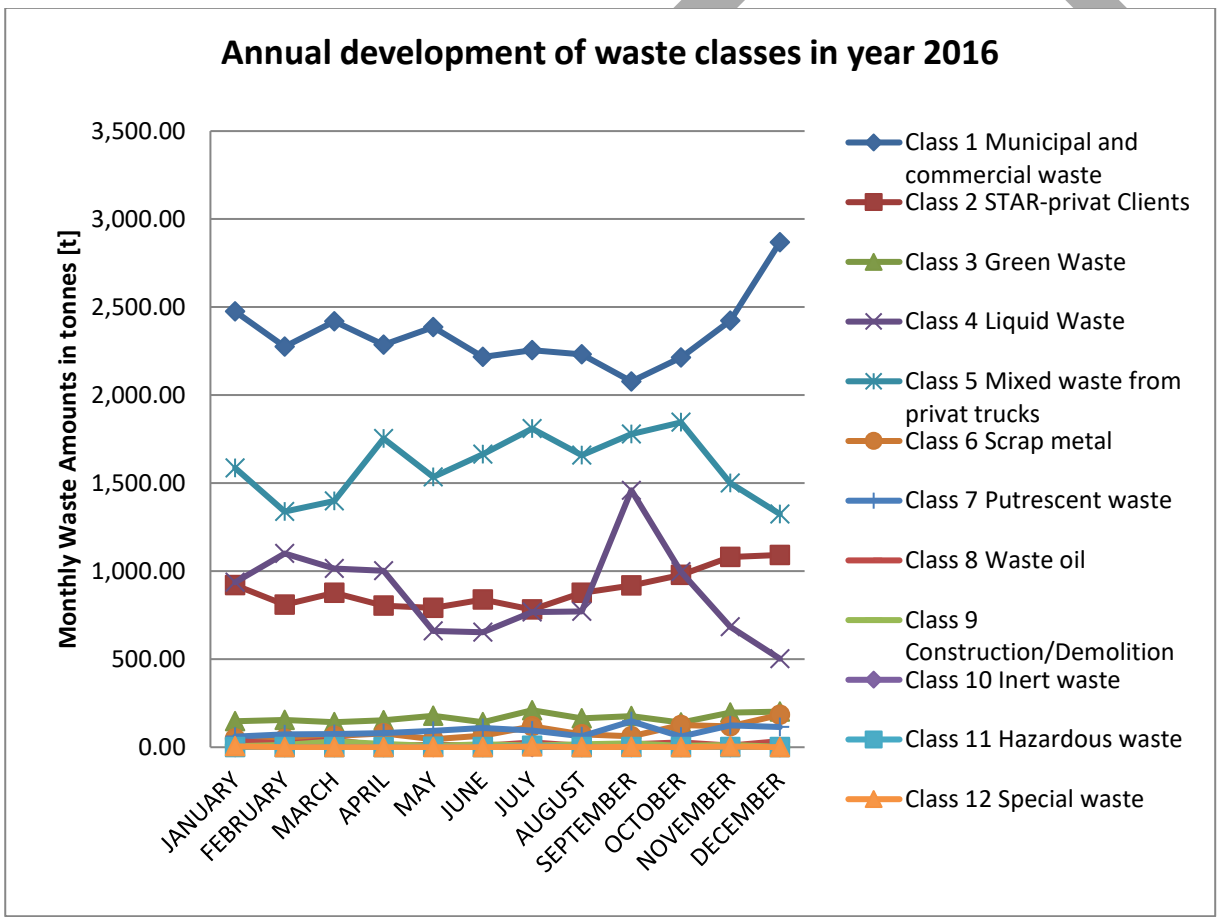

Figure 10: Annual development of waste classes in year 2016 in tonnes [t] (Ladouce, L., personal communication, January 19, 2017)

The remaining classes behave highly fluctuating with no reasonable changes. There is the assumption, however, to be challenged with a neglected recording behaviour in these classes. It is visible, that Class 1, 2, 4, 5 are the biggest contributors to the landfill.

Their ratios are the following:

- Class 1 Municipal Solid Waste (38 %)

- Class 5 Mixed Waste (26 %)
- Class 2 Commercial Waste (15 %)
- Class 4 Liquid Waste (14 %)

This finding is crucial as these classes generate the biggest amounts going to landfill. From there appropriate future waste disposal systems or waste treatment plants can be ascertained after considering their waste composition (Chapter 8).

Having a look at the annual change within the individual waste class, it is additionally interesting to look at the development of the generated waste in the 12 different classes over the years from 1999 to 2016. This might enhance and confirm the notion of the future trend for each waste class and thus the development of municipal solid waste and commercial waste as important waste sources. Several factors influence the waste amount and quality. The comparism considers the following factors:

- Waste amounts from 1999 to 2016
- Changes in population from 1999 until 2016 on Mahé
- Gross Domestic Product (GDP) of the Republic of Seychelles from 2009 until 2014
- Average income of inhabitants from 2012 until 2016
- Visitor Arrivals from 2000 until 2016

The most striking line in the chart below can be attributed to Class 1 as a constant and appalling increase is noted. The increase matches with the development of GDP and average income in Seychelles. This can especially be confirmed with the increased gradient apparent just after the financial crisis in 2008 as growth in municipal solid waste is connoted to consumption. As with growing inhabitants on Mahé, population growth also explains increasing waste generation in Class 1.

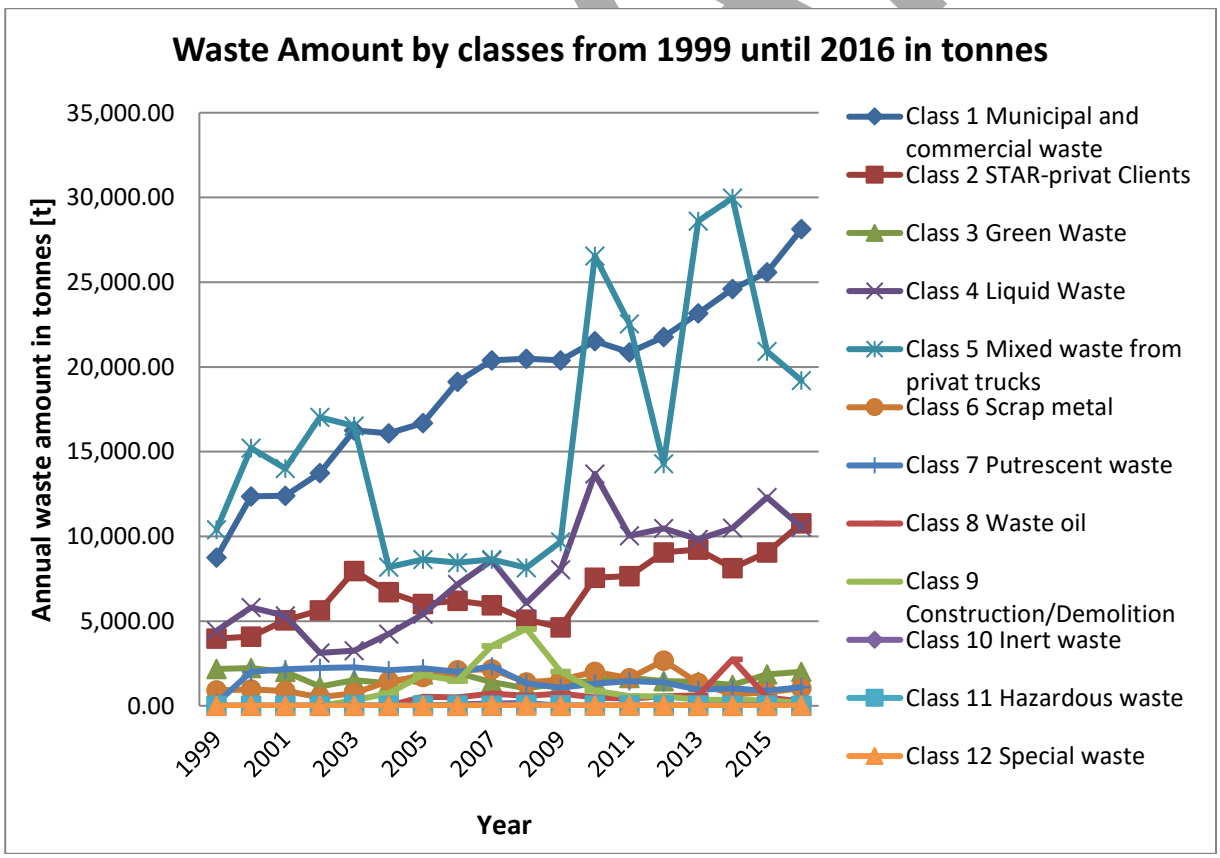

Figure 11: Annual waste amounts by classes from 1999 to 2016 in tonnes [t] (Ladouce, L., personal communication, January 19, 2017)

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Even depending on economic factors Class 2 seems very stable. The phenomenon resulting from the financial support after the crisis in 2008 is yet visible in waste generation of Class 2.

The changes in Class 4 can be explained through a comparison with the progress in population and visitor arrivals together. There is this peak in 2010/2011 in which is visible in the vital statistics. This is reasonable as sewage sludge from PUC is categorised in Class 4 as well.

Out of the four most outstanding waste amounts within all classes, Class 5 seems to be the most fluctuating one. Hence, no obvious conclusiveness can be allocated while studying at the line. For example, it is incomprehensible to have a downfall in year 2012 according to the available data. Nonetheless, the fluctuations are reasonable taking the sources of waste categorised in this class into consideration. What is clearly obvious in this line though, is the common growth from year 2009 onwards.

5.2. Extrapolated forecast on waste amount

Seemingly, several factors influence the waste amount and quality. A proper forecast on waste generation on Mahé considers therefore factors predominantly such as, population development, Gross Domestic Product and average income of inhabitants. A projection in such an extent is not possible in this paper which is why the forecast made here is verified by a comparison with an extrapolation of available data of 2017 recorded at the weighbridge (Chapter 4.2)

In order to approximate a future trend for waste generation Figure 12 depicts already very clearly the growing tonnes that is being dumped on the landfill in Providence.

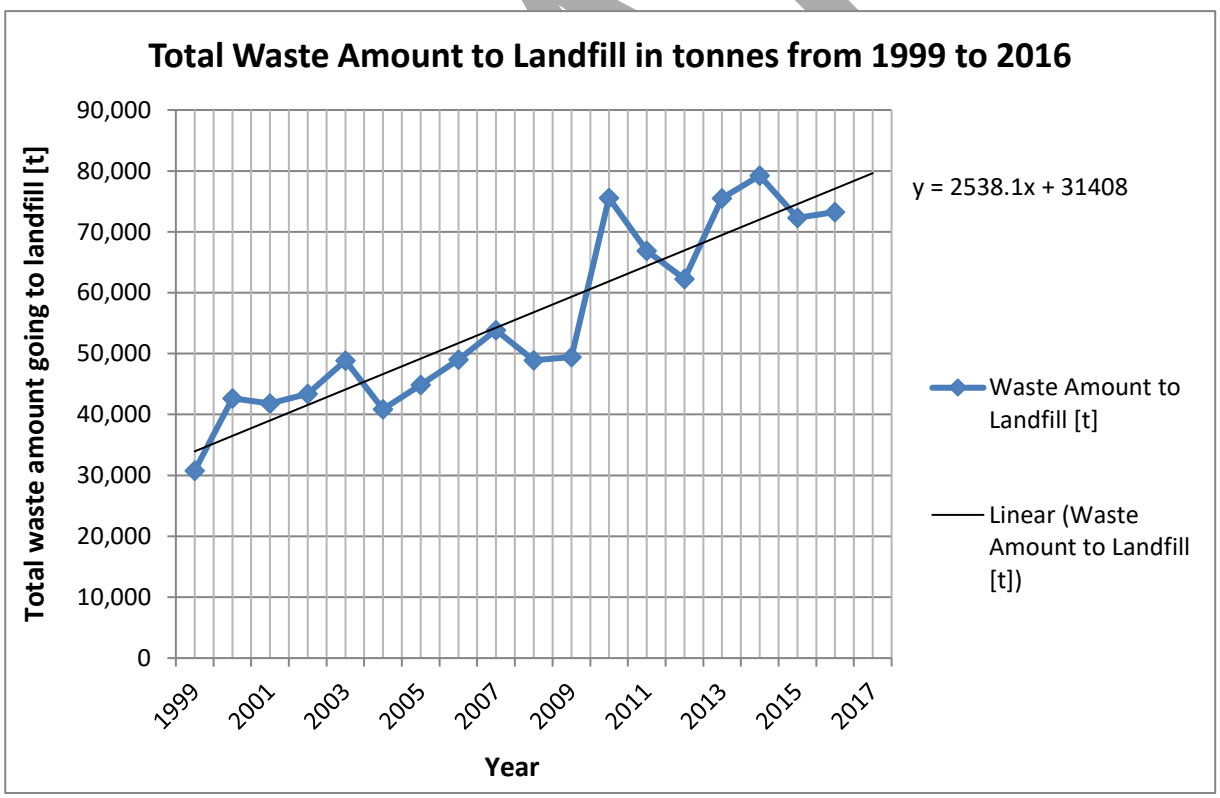

Figure 12: Total waste amount to Providence Landfill from 1999 to 2016 in tonnes [t] (Ladouce, L., personal communication, January 19, 2017)

In this calculation there are 79,630 tonnes of waste on Mahé in year 2017 expected. Thus, Mahé will extend to 112,624 tonnes of waste for year 2030. Looking simultaneously at the designed capacity of 360,000 tonnes (Payet, 2016) of Providence Landfill No. 2 the landfill will reach its full capacity by the second half of year 2019 considering classes 1, 2, 3 and 5 only arriving at Providence Landfill No. 2.

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5.3. Comparison of extrapolated forecast

Those figures seem plausible comparing to projections of available data of 2017 recorded at the weight bridge. For the purpose of verifying the extrapolated forecast on waste amount another extrapolation of available data of year 2017 recorded at the weight bridge is necessary. The considered data contains the amounts of all waste classes in four different time intervals:

- Monitoring at Landfill Providence 1 (16.01.2017-22.01.2017)
- Waste Sorting (23.01.2017-02.02.2017)
- Monitoring Landfill Providence 2 (13.03.2017-19.03.2017
- Collection Route Monitoring (20.03.2017-26.03.2017)

The calculation resulted in 214 $\frac{t}{d}$ considering the average values of the waste amount delivered on landfill . Hence, the total waste amount which will reach the landfill until the end of 2017 via extrapolation is 77,925 $\frac{t}{a}$. In comparison with the projected waste amount in the previous sub-chapter the deviation between both results is approximately at 2.14%. Furthermore, an additional extrapolation of the waste classes 1,2 and 5 was done and compared to the results from the forecast. The average daily waste amount for these classes is at 170$\frac{t}{d}$ which implies a yearly waste amount of 61,750$\frac{t}{a}$. In comparison with the result of 60,727 the forecast the deviation is at 1.68 %.

Due to the slight deviation of both results, the chosen sorting weeks can be reasonably concluded. In reason of the broad spectrum that is covered by available data between 1999 and 2016 this report will subsequently use the results calculated by the extrapolated forecast for further calculations.

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6. Monitoring on Mahé

To get a global overview about the delivery and disposal of waste and to determine the class for the additional waste sorting activity a truck monitoring at Landfill providence 2 on Mahé was conducted.
The followed chapter describes the methodology of the monitoring and the results for verification of the most important classes for an integrated waste treatment concept. The monitoring activity was divided in 3 steps. The first step included the analysis of the recorded vehicles and waste amounts at the weighbridge. The second step an on-site monitoring of the trucks at the landfill Providence 2 and the third step the characterization of the load on the trucks.

6.1. Methodology of Monitoring on the landfill Providence 2

For the technical data collection, a monitoring activity on the current landfill in use Providence No.2 on Mahé was necessary. It starts from the 17th of January for a duration of four days till 20th of January. From the waste sorting activity in June 2016 it was known, that the main waste flow to the landfill is delivered by compactors for waste class 1. The aim of the monitoring was to get an overview which classes as defined in Chapter 3 are also responsible for the increasing waste amounts on the island and to define which classes must be additionally sorted.
For the monitoring, the university developed a sorting protocol (See Appendix XY) to characterize the load and the source of the waste. Additionally, the waste classification and the weight from the weighbridge data was added. To get an overview of the load characterization reduced fraction types where defined as followed:

- Wood
- Green Waste
- Household Waste
- Electro Waste
- Paper, Carton, Cardboard
- Bulky Waste
- Plastics
- Metal
- Glass
- Construction Waste
- Tyres
- Miscellaneous

The aim of the research was to identify the main waste producers and sources to verify the documentation of the trucks at the weighbridge. Furthermore, to get an overview for the homogeneity or inhomogeneity of the delivered classes and to compare with the results from the waste sorting activity in June 2016.

6.2. Results of monitoring and verification of the most important classes

During the monitoring in total 556 vehicles including compactors, open trucks and private pickups with a total load of 892,77 t at the weighbridge office were recorded. The detailed distribution for each class and the total load is shown in Table 15:

Table 15: Monitored trucks in total 17.01.2017-20.01.2017 (Ladouce, L., personal communication, January 20, 2017)

Class	Description	PC	Amount [t]
1	Municipal and commercial waste	91	305.13
2	STAR-private clients / WASTEA	97	196.14

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3	Green waste	106	48.05
4	Liquid waste	21	85.97
5	Mixed waste from private trucks	216	235.35
6	Scrap metal	16	13.19
7	Putrescent waste	6	6.56
8	Waste oil	3	2.38
	Total	**556**	**892.77**

In the time period of monitoring there were no trucks for class 9 to 12 recorded. Considering the total waste amount of the trucks depending on the assigned class is the class 1 with a value of 305.13 t in the recorded time the main waste producer, in second priority class 5 with 235.35 t and in third priority class 2 with 196.14 t. This result is also supported by the analysis of the total waste amount from 1999 to 2016 for each class in chapter 5.1 Figure 11. By identifying these classes, a characterization of the waste in form of an additional waste sorting activity was necessary for an integrated overview of mixed waste producers.
In addition to the analysis of the weighbridge data was an on-site monitoring on the landfill Providence 2 done. The on-site monitoring was done in reason of a better understanding of the load and to identify representative vehicles for the sorting activity. During the monitoring of the classes 1,2,3 and 5 which are dumping on landfill providence 2 were 46 % of the total vehicle amount recorded (See Table 16).

Table 16: Monitored vehicles at landfill Providence 2 (Monitoring 17.01.2017-20.01.2017, Mahé, Seychelles)

Class	Description	PC monitored	PC recorded
1	Municipal and commercial waste	33	91
2	STAR-private clients / WASTEA	44	97
3	Green waste	65	106
5	Mixed waste from private trucks	93	216
	Total [-]	235	510
	Monitored [%]	46	

The sorting of class 1 was done in June 2016. To get a global overview of the waste generated on Mahé it was necessary to analyse the other waste classes. Assuming that class 3 contains only green waste the focus of the investigation of the loads was on class 2 and 5.

ANALYSIS CLASS 2

Class 2 is mainly delivered by two private companies STAR and WASTEA. In total 44 vehicles in class 2 were monitored. 21 vehicles came from industry and commercial, 18 from hotels, 4 from with not defined source and 1 from public. The distribution of the origin for the waste in class 2 can be seen in Figure 13:

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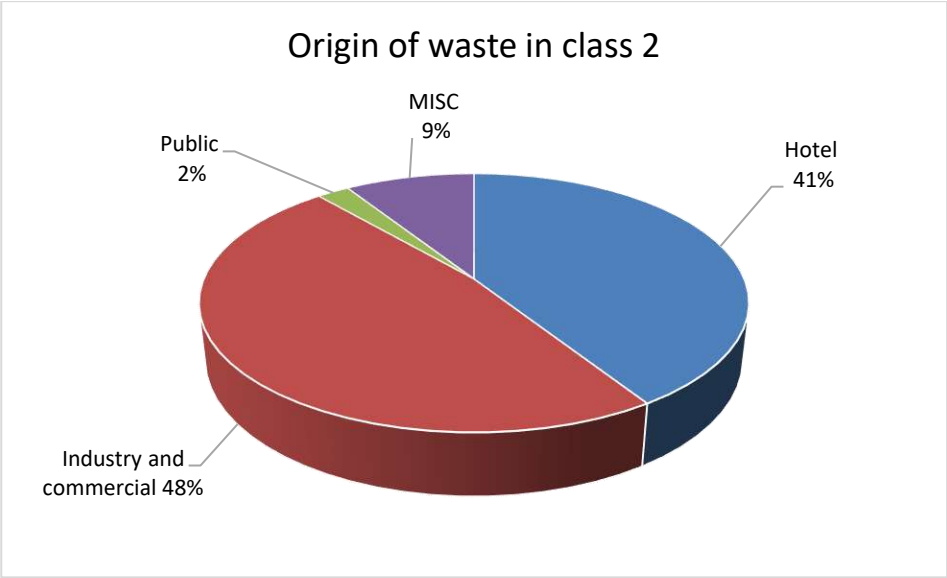

Figure 13: Origin of the waste in class 2 (Monitoring 17.01.2017-20.01.2017, Mahé, Seychelles)

The main waste flow in this class is from the industrial and commercial sector with a value of 48 % followed by the tourism sector (Hotels) with 41 %.
The collection of the waste in this class is covered mainly with an average of 93% by the private contractor WASTEA and 7 % by private STAR contracts (Source: Monitoring 17.01.2017-20.01.2017, Mahé, Seychelles).
According to the defined fraction types an overview of the load for class 2 can be seen in Table 17 :

Table 17: Fraction type frequency in total for Class 2 (Monitoring 17.01.2017-20.01.2017, Mahé, Seychelles)

Fraction type	**Frequency**
Wood	9
Green waste	16
Household like commercial waste	23
Electro waste	0
Paper, Carton, Cardboard	22
Bulky waste	3
Plastics	19
Metal	2
Glass	2
Construction	1
Tyres	2
MISC	0

The most frequently observed fractions during the monitoring are in first priority household like commercial waste (23), second priority paper, carton, cardboard (22) and in third plastics (19) followed by green waste (16). In the second step as result of the monitoring an analysis of the load composition of each vehicle to check for homogeneity/inhomogeneity was done (See Table 18).

Table 18: Quantity of different fractions in vehicles of class 2 (Monitoring 17.01.2017-20.01.2017, Mahé, Seychelles)

Quantity of different fractions	**1**	**2**	**3**	**4**	**5**	**6**
Vehicles	15	10	9	4	3	1

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As seen in Table 18 most of the vehicles in class 2 which are dumping on landfill Providence 2 have one type of fraction loaded. By combining results of the quantity with the frequency of different fraction types (See Table 17 and Table 18) most of the trucks have household like commercial waste, Paper, Carton, Cardboard or Plastics loaded. Thus, the result of the analysis of class 2 concerning the waste sorting activity is the mixed characteristics of waste in this class 2.

ANALYSIS CLASS *5*

Class 5 is mainly delivered to the landfill by the private sector in pickups and open trucks. In total 91 vehicles were monitored. 25 came from construction companies, 23 from cleaning activities and waste services, 15 from import and industry, 14 from shops, 8 from not defined sources and 6 from hotels. The distribution of the origin in this class is presented in Figure 14:

Figure 14: Origin of the waste in class 5 (Monitoring 17.01.2017-20.01.2017, Mahé, Seychelles)

In class 5 is the origin of the waste more heterogeneous then in class 2. The main waste is from the construction sector (27 %), followed by private waste service sector (25 %). In third and fourth priority are the import industry (16 %) and the shop sector (15 %). In this class is the hotel sector with a value of 7 % not as dominant as in class 2. The fraction type frequency is presented in Table 19:

Table 19: Fraction type frequency in total for Class 5 (Monitoring 17.01.2017-20.01.2017, Mahé, Seychelles)

Fraction type	Frequency
Wood	35
Green waste	19
Household like commercial waste	23
Electro waste	2

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Paper, Carton, Cardboard	44
Bulky waste	23
Plastics	43
Metal	9
Glass	2
Construction	14
Tyres	0
MISC	5

The dominant recorded fraction during the monitoring of class 5 were in ranking order paper, carton, cardboard (44), plastics (43), wood (34), household like commercial waste (23) and bulky waste (23).

Table 20: Quantity of different fractions in vehicles of class 5 (Monitoring 17.01.2017-20.01.2017, Mahé, Seychelles)

Quantity of different fractions	**1**	**2**	**3**	**4**	**5**	**6**
Vehicles	16	38	23	11	2	0

By combining the results with the quantity of different fractions per truck (See Table 20) can be seen that most trucks in this class have two different fraction types loaded. The combination possibilities of different fractions in this class are higher than in class 2. A definite allocation is not possible.
The compilation of the waste in the considered classes 2 and 5 are highly heterogenous comparing to class 1 but the commonality of these is the mixed characteristics of household and household like commercial waste.
Based on the results of the monitoring activity is for the development of an integrated sustainable waste management concept the additional waste sorting activity for class 2 and 5 was necessary.

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7. Determination of waste composition on Mahé

For the determination of the waste composition on Mahé the research for the feasibility study was divided in three parts. Part one contained the waste sorting activity of class 1 in June 2016, part two the monitoring of the other waste classes in January 2017 as seen in Chapter 6 and part three the additional waste sorting activity in February and March 2017 based on the results of the monitoring. The determination of the waste composition is the data base for the development of possible waste treatment methods for the main waste flows of Mahé.

7.1. Methodology of Waste Sorting

The waste sorting was done by two qualified students from the Technical University of Darmstadt and University of Applied Sciences under supervision of Dr.- Ing. Jan Kannengiesser (TUD) for the theoretical part and Timo Mrukwia (TUD) for the technical part.
Additionally, for each week the Ministry of Environment, Energy and Climate Change (MEECC) supported the sorting by providing three employees.

Workspace
With the permission of the current contractor STAR who is responsible for the landfill management including collecting, transport and disposal the working space was installed on the premises near the head office.
The Landscape and Waste Management Agency (LWMA) provided the necessary equipment for building up the workplace (See Figure 15).

Figure 15: Waste sorting workplace at the landfill Providence (Brandt, 2017)

For the manual sorting two sorting tables, three vats and 46 bins to separate each specific fraction were provided. The weight of the sorted fractions was recorded through a balance provided by the university.

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Discharge of material
Unlike class 1 which is delivered in compactors the focused waste of class 2 (commercial waste) was mainly delivered by open trucks in skips (See Figure 16 and Figure 17) with total volumes of 2 m^3, 8 m^3, 10 m^3, 14 m^3 and 20m^3 (Dupouy, 2017).

Figure 17: Class 2, Skip with a volume of 10 m^2 (Brandt, 2017)

Figure 16: Class 2, Skip with a volume of 14 m^2 (Brandt, 2017)

The second focused class 5 (Mixed waste) was brought directly to the disposal site by private trucks (Open trucks and pickups) with different volume sizes (See Figure 18).

Figure 18: Class 5, open truck (Brandt, 2017)

The chosen trucks for the waste sorting discharged the material in front of the working place in the prepared area (See Figure 15).

Sample size
For reliable results, it is fundamental to take a representative sample size of the waste. In order to get these data is it usually necessary either to sort the content of the vehicle or discharge the vehicle, mix the pile with an excavator and take 10 % of the total volume for the sorting activity.
In reason of equipment restrictions, the second method was not an option for waste classes 2 and 5. Due to the large volume size of the skips delivering waste class 2 and sorting time restrictions given by the company STAR in these class the sorted amount was reduced partly to a half skip. In this case, it can be assumed the sample size remained representative because:

- The skip can be filled by the customer with waste from each side
- The waste in the skip is moving during the transport. The smaller particles of varied sizes can fall from the top of the pile to the base plate of the skip and remain there until the discharging process
- In case of waste particles of exceptional size (large particles like pallets) the particle was divided in two parts to retain the representative composition

Class 5 was delivered by smaller open trucks and pickups. In these class, the content of the whole vehicle was discharged and sorted.

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Sorting

After the discharging of the material at the waste sorting working space the waste was sorted manually on the sorting tables. Each fraction was collected in a separate bin, weighted and recorded in a sorting protocol (See Appendix XY). The fraction categories and the sub categories were defined as followed.

Main fraction categories

The waste was sorted by the participants according to the sub categories and detailed descriptions presented in Table 21. For better overview the sub categories where summarized in main categories depending on the material.

Table 21: Main fraction categories and sub categories for the waste sorting analysis in January February 2017, Mahé, Seychelles (Source: Sorting Protocol TU-Darmstadt, see Appendix XY)

Category	No.	Sub Category	Detailed description
Cellulose	1	Cellulose Household and Product Packings	Supermarket products, tissues
	2	Cellulose Distribution Packings	Shipping cartons
Plastic	3	Plastic Product Packings	Supermarket products
	4	Plastics	One way bags, one way cups, Styrofoam from take-aways
	5	Plastic/Foils-Industry	Integrated in No.4
Composite	6	Composite Product Packings	Supermarket products
Glass	7	Glass	Bottles
Metal	8	Metal Product Packings	Supermarket cans
	9	Aluminium Product Packings	Supermarket cans, pet food packings
	10	Metals	Aluminium foils
Organic	11	Kitchen Waste	Food, vegetables, fruits
	12	Green Cut	Leaves, coco nuts, trees
Oils and Fats	13	Oils and Fats	Motor oils in canister, kitchen oils and fats in canister
Chemicals	14	Chemicals and Varnishes	Chemicals and varnishes in packings and buckets
Wood	15	Construction Wood	Furniture's made of wood, treated wood
Construction	16	Construction Waste	With concrete connected Materials
Inert	17	Inert	Ceramic dishes, stones, ceramics
Tires and Rubber	18	Tires and Rubber	
Textiles	19	Textiles	Clothes and towels
Electronics	20	Electronic Waste	Cables, tools, toys, entertainment utensils
	21	Batteries	
Unsortable	22	Unsortable Waste	Mostly unsortable, because of the high intensity of kitchen waste inside the bag or a high intensity of mould which is too risky to sort in reason of biological hazard
Sorting Rest	23	Sorting Rest	Mostly materials which are too small to handle with gloves
Disturbance Materials	24	Disturbance Materials	Mostly supermarket liquids inside their package

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7.2. Results of sorting and determination of the most important fractions

By comparing the several waste classes during the monitoring, class 1,2 and 5 had in common to consist mixed municipal solid waste in the form of household waste from the public bin side and household like commercial waste from the industry, shops and hotels. For an integrated concept should be all three classes considered.
The distribution for class 1 is shown in Figure 19.

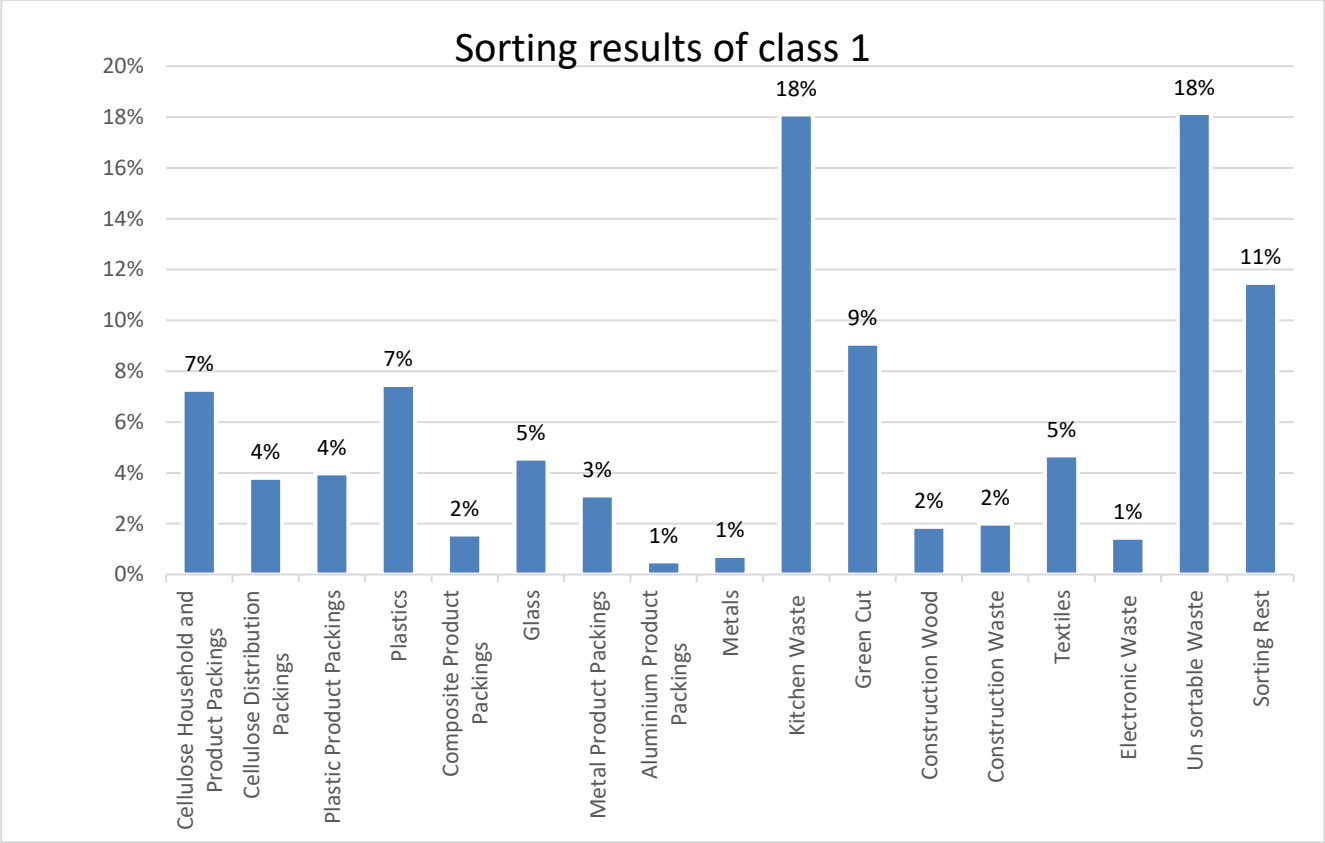

Figure 19: Sorting results for class 1 (Only Compactors) (Sorting results June 2016, see Appendix XY)

Fractions with values less than 1% can be seen in the detailed distribution attached (See Appendix XY). For a better overview in Figure 20 are presented the six dominant clearly identified fractions for class 1.

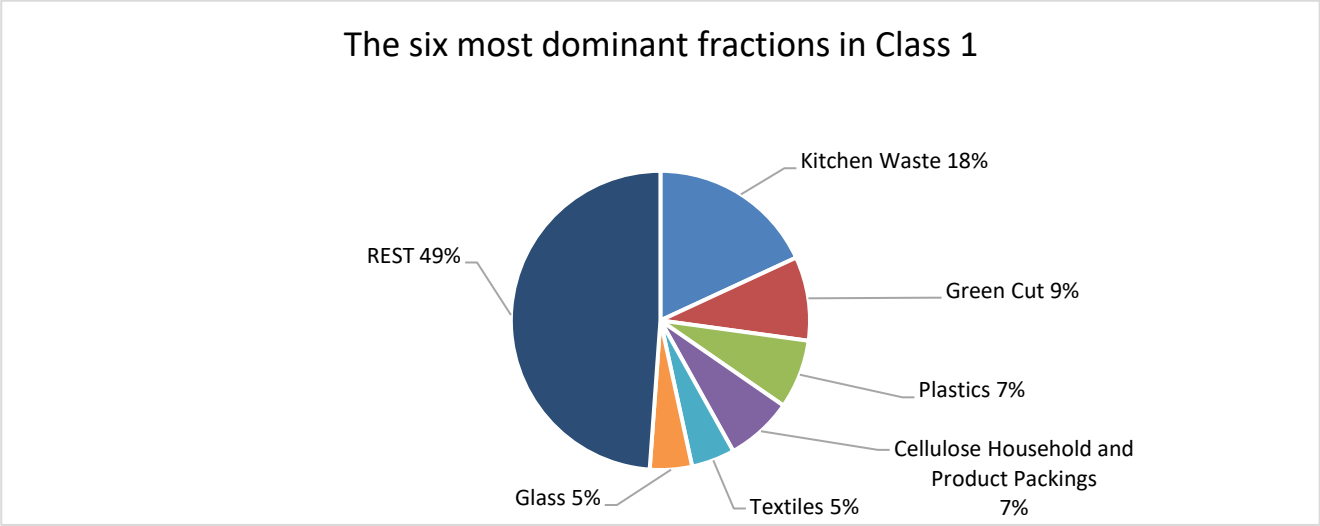

Figure 20: The six most dominant fractions Class 1, Compactors only (Source: Sorting results June 2016, see Appendix XY)

The dominant fraction in the waste of the class 1 is the kitchen waste with a value of 18 %, followed by green cut 9 %, Plastics 7 %, cellulose household and product packings 7 %, textiles and 5%, Glass 5 %.
In REST is with a value of 18 % Unsortable waste and sorting rest (11 %) contained which is not clearly identified during the waste sorting activity 2016. The remaining waste fractions have values less den 4 %.

In followed diagram Figure 21 is the distribution of the waste for class 2 pictured.

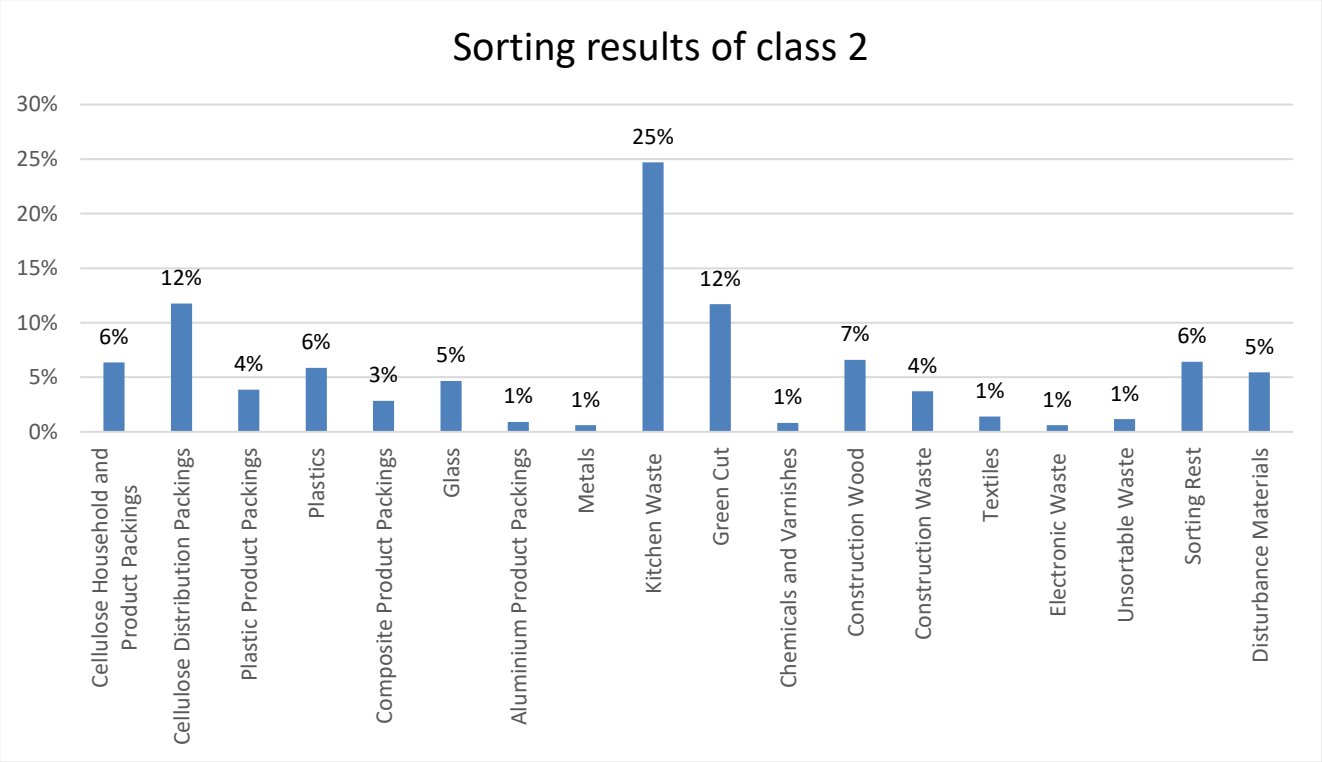

Figure 21: Sorting results for class 2 (Source: Sorting results January/February 2017, Mahé, Seychelles)

The main source for waste of class 2 is referring to the monitoring results in Chapter 6.2, 41 % Hotel and 48 % commercial and industry (Mainly big shops). On this basis, the dominant fractions in this class are kitchen waste 25 %, cellulose distribution packings 12 %, green cut 12 %, construction wood 7 %, cellulose household and product packings 6 % and plastics 6 %. Fractions with values less than 1 % can be seen in the detailed distribution attached (See Appendix XY).

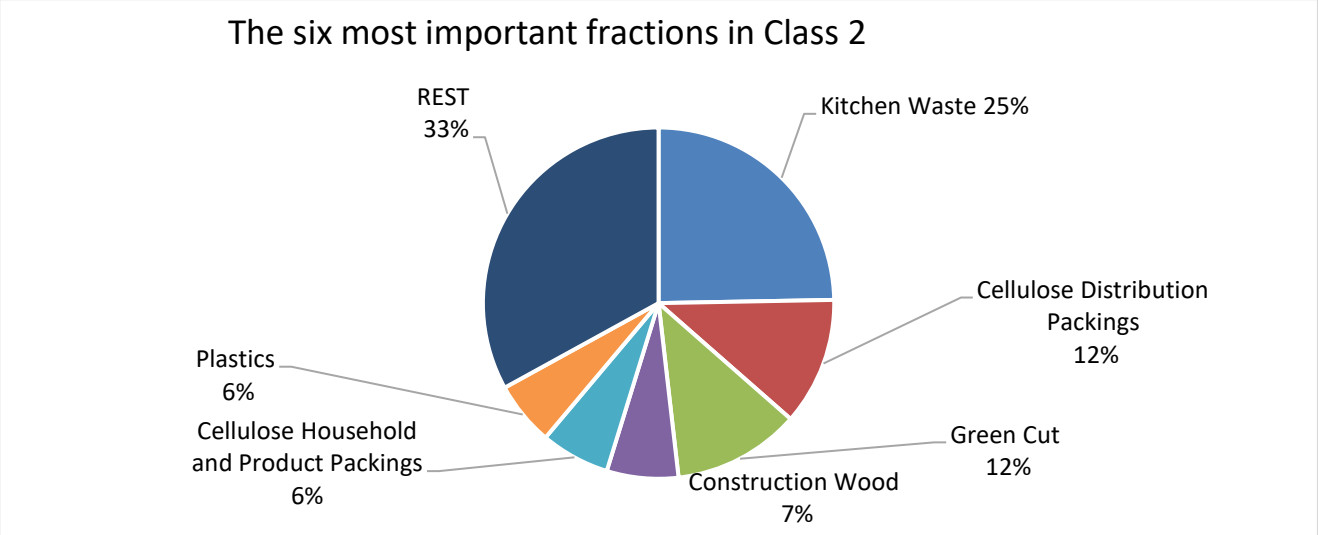

Figure 22: The six most dominant fractions for class 2 (Source: Sorting results January/February 2017)

Fractions with a value higher than 5 % are also sorting rest 7 % and disturbance materials 6 %. These are integrated in REST (33 %) (See Figure 22).
In summary for class 1 and 2, the high percentages of light (kitchen waste), heavy rotting (green cut) organics and cellulose and plastic groups as part of the 8 biggest fractions are playing a non-negligible role for developing a new waste treatment system.

In class 5 the construction wood representing with a value of 34 % the biggest fraction followed by cellulose distribution packings 31 % (See Figure 23 and Figure 24) and plastics 5 %. While comparing the ratios in class 1 and 2 with class 5 there is a clear deviation between the results. For class 1 and 2 the kitchen waste was the most dominant fraction. In Class 5 this fraction has not such an important influence (kitchen waste 4 %). Fractions with values less than 1% can be seen in the detailed distribution attached (See Appendix XY).

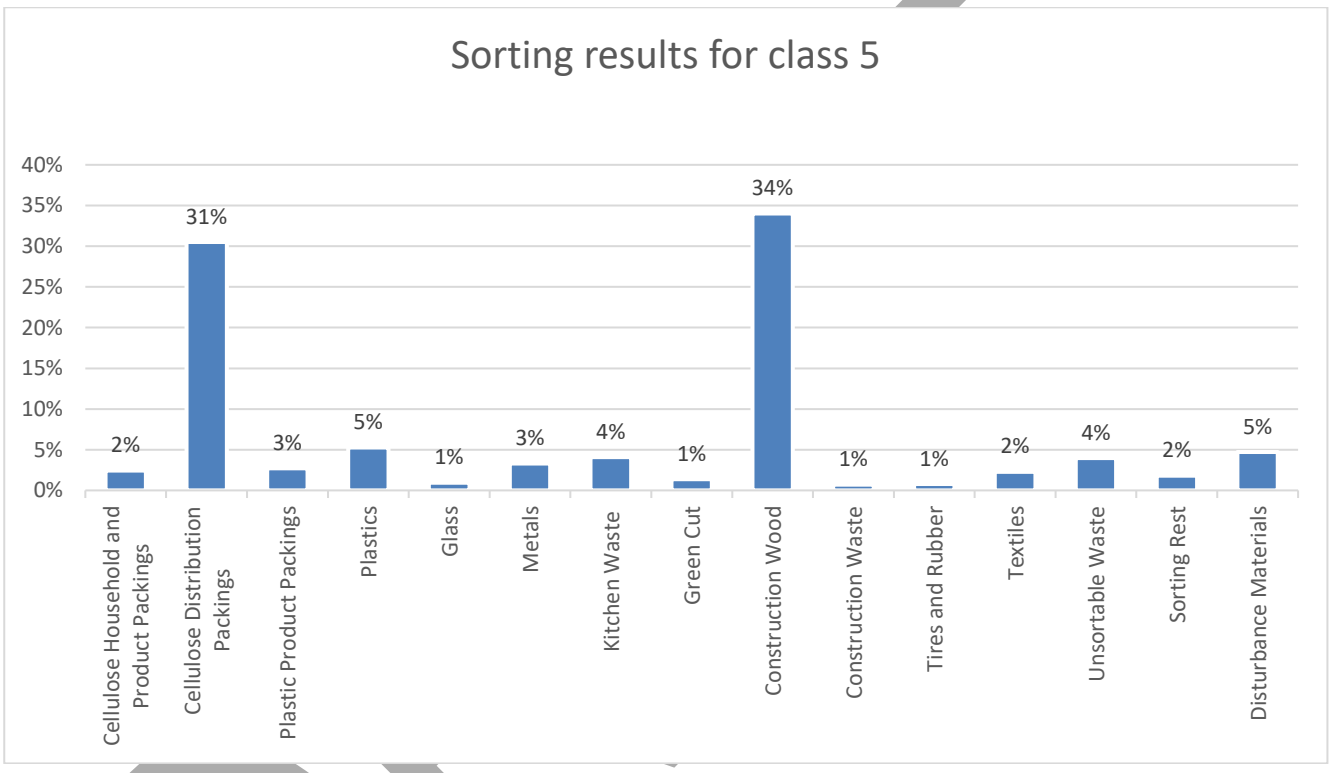

Figure 23: Sorting results for class 5 (Source: Sorting results January/February 2017)

The remaining fractions and the fractions integrated in REST which have a percentage less than 1 % can be seen attached in Appendix XY.

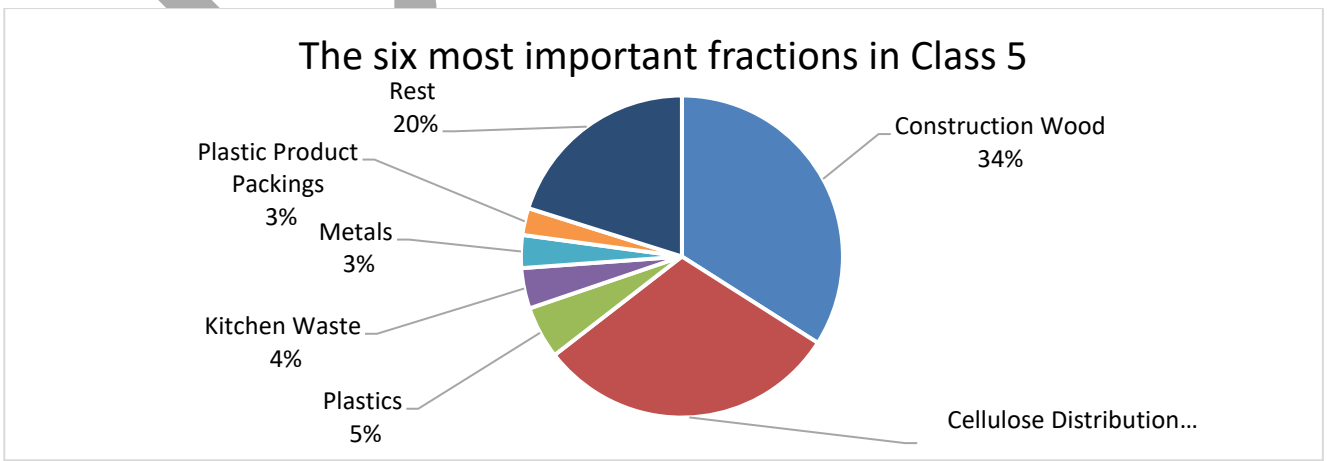

Figure 24: The six most dominant fractions for class 5 (Source: Sorting results January/February 2017, see Appendix XY)

Due to the deviations between the percentages of the fractions in the classes is it not reasonable to calculate a total average for the calculation of the yearly amounts. Therefore, has been a separate value via regression of the total amounts from 1999 to 2016 for each class determined and used for further calculations.

The calculated values via regression for each class are shown in Table 22:

Table 22: Calculated amounts for class 1,2,3,5 via regression of total amounts 1999-2016 (Ladouce, L., personal communication, January 31.03.2017, 2017))

Class	Total amount 2017 [t]
Class 1	27,848
Class 2	9,653
Class 3	2,128
Class 5	23,226
TOTAL	**62,855**

In consideration of the results for each class from Figure 19, Figure 21 and Figure 23 in combination with the total amounts via regression in Table 22 the expected amounts of each fraction for 2017 can be seen in

Table 23:

Table 23: Expected amounts of each fraction of Class 1,2 and 5 for 2017 (Source: Sorting analysis 2016/2017, Mahé, Seychelles and regression)

Fraction		Σ (2017) [t]
1	Cellulose Household and Product Packings	3,201
2	Cellulose Distribution Packings	9,280
3	Plastic Product Packings	2,112
4	Plastics	3,867
6	Composite Product Packings	767
7	Glass	1,933
8	Metal Product Packings	991
9	Aluminium Product Packings	327
10	Metals	1,030
11	Kitchen Waste	8,371
12	Green Cut	3,973
14	Chemicals and Varnishes	87
15	Construction Wood	9,059
16	Construction Waste	1,079
17	Inert	37
18	Tires and Rubber	201
19	Textiles	1,968
20	Electronic Waste	486
21	Batteries	7
22	Unsortable Waste	6,087
23	Sorting Rest	4,237

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24	Disturbance Materials	1,628
	TOTAL [t]	**60,727**

For item number 1 to 21 the content of the fractions is clear identified. For detailed characteristic of item numbers 22 "Unsortable Waste" and 23 "Sorting Rest" is in reason of the non-negligible amount a further analysis necessary. Item number 5 and 13 had values of 0 %. Hence the fractions have been sorted by sample. On average the fraction "unsortable waste" which includes difficult sortable bags can be assumed with a content of circa 50% organics.

The fraction "Sorting rest" was additionally sorted. The results are presented Table 24:

Table 24: Results of the additional sorting of the fraction „Sorting Rest "(Sorting results Seychelles February/March 2017)

Fraction	**Weight [g]**	**Weight [%]**
Cellulose	67.5	6.7%
Plastics	25.4	2.5%
Glass	5.2	0.5%
Construction waste	77.2	7.7%
Green Cut	98.7	9.9%
Organics	369.1	36.9%
Metal	7.6	0.8%
Sorting Rest/Unsortable	348.6	34.8%
Cigarettes	1.2	0.1%
TOTAL	**1,000.5**	**100.0%**

The results of the additional sorting presented Table 24, the analysis of the unsortable waste as well as the green waste of class 3 will be integrated in the total waste amount for Mahé 2017 (Table 23).
The following diagram Figure 25 is presenting the expected summarized amount of waste (Detailed description see Appendix XY) which is used for following calculations in the report:

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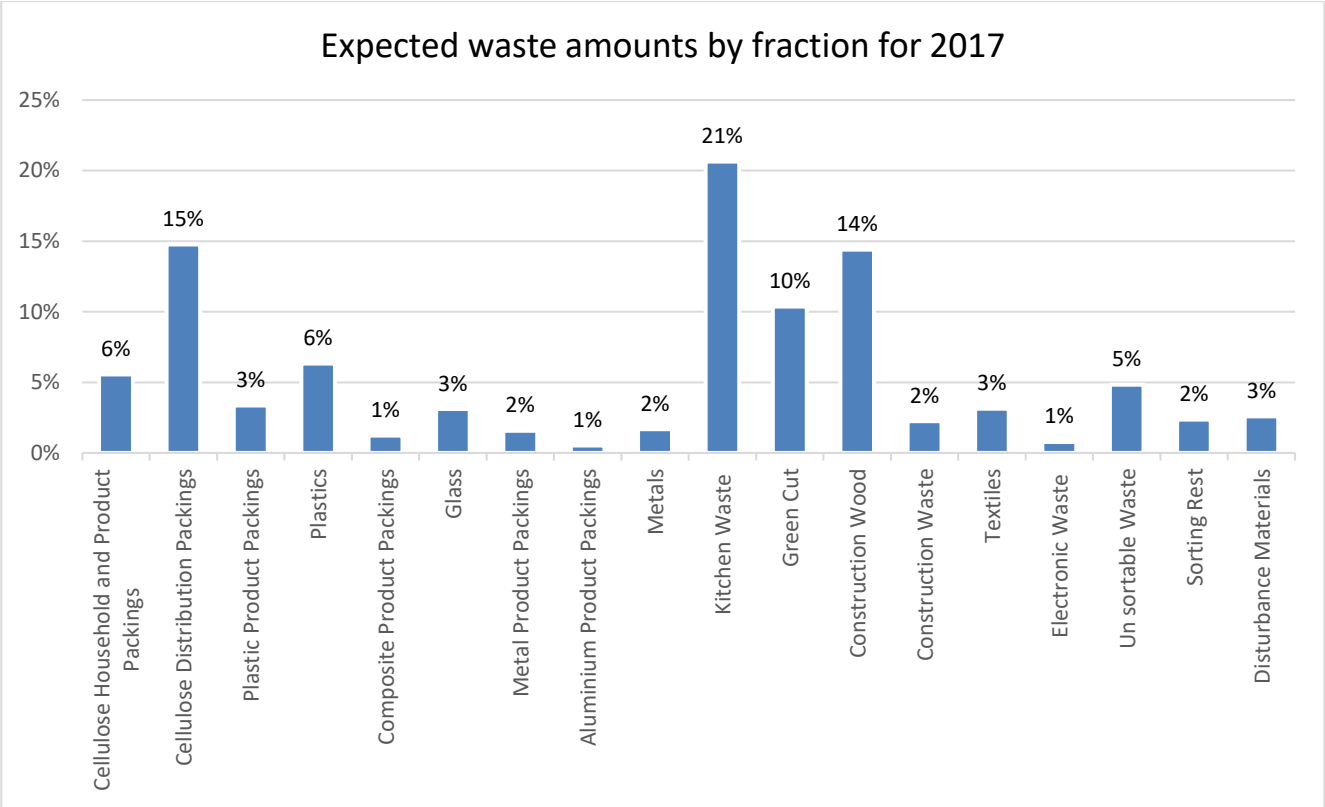

Figure 25: Expected percental waste amounts for Mahé, Seychelles 2017 (Sorting Results 2017, (Ladouce, L., personal communication, January 31.03.2017, 2017))

In preparation for the potential waste treatments the detailed fractions are summarized in reasonable groups and presented in followed diagram in Figure 26:

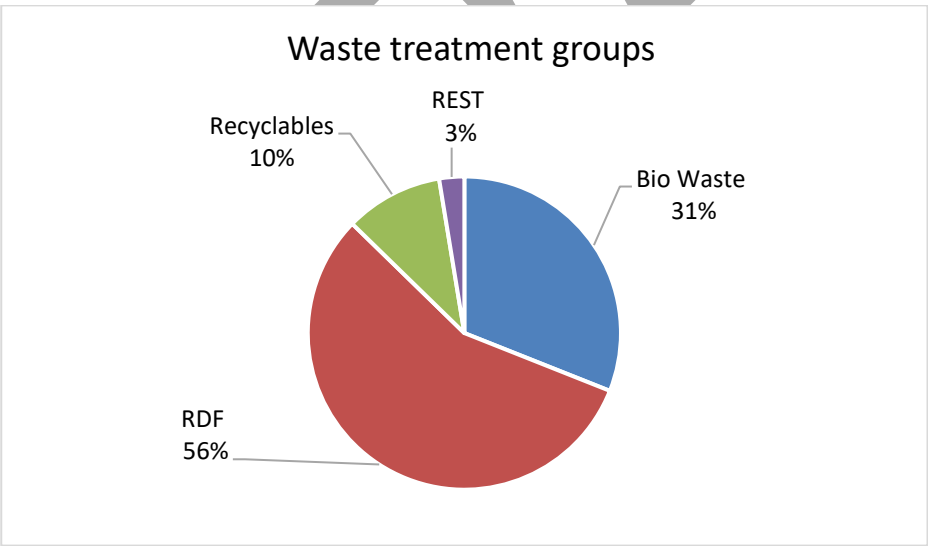

Figure 26: Reasonable groups for potential waste treatment (Analysis Waste Sorting 2016/2017 and Regression)

The first waste treatment group "Bio Waste" (31%) contains fractions for potential biological treatment as anaerobic digestion or composting. The second group "RDF" (Refused Derived Fuel) (56%) contains fractions with high calorific value suitable for thermal treatment as incineration. The third group "Recyclables" (10%) contains fractions for recycling or export and "Rest". In following by using the total amount of waste calculated via regression (See Table 22) could the yearly single amount of each group in tonnes been calculated (See Table 25).

Table 25: Yearly amount of each waste treatment group for 2017 (Analysis Sorting 2016/2017,)

Treatment Group	[%]	[t]	Integrated Fractions
Bio Waste	31	19,496	Kitchen Waste
			Green Cut
RDF	56	35,373	Cellulose Household and Product Packings
			Cellulose Distribution Packings
			Plastic Product Packings
			Plastics
			Composite Product Packings
			Construction Wood
			Tires and Rubber
			Textiles
			Un sortable Waste
			Sorting Rest
Recyclables	10	6,358	Glass
			Metal Product Packings
			Aluminium Product Packings
			Metals
			Chemicals and Varnishes
			Construction Waste
			Inert
			Electronic Waste
Rest	3	1,628	Disturbance Materials
	TOTAL	**62,855**	

8. Potential waste treatment

For the main groups bio waste, RDF, recyclables and rest presented in Chapter 7.2 there are two main treatment methods to consider, the biological waste treatment and the thermal waste treatment. The following chapter focuses on the main waste treatment methods and gives an overview of the potential of the current waste streams on Mahé for each concept.

8.1. Anaerobic Digestion

The biological waste treatment is based on biodegradation of organic substances, which containing fats, proteins and carbohydrates by microorganisms under ambient conditions with air (aerobically) or without air (anaerobically). Both processes resulting in the reduction of organic components of the waste. Technically the recovery potential of organic waste can be used in composting and fermenting facilities or in a combination of both (Bilitewski , Härdtle, Marek, Weissbach, & Boeddicker, 1997).
The fermentation of biodegradable waste under anaerobic conditions is an attractive waste treatment method to combine the reduction of the amount and using the energy potential of the waste. The anaerobic digestion is suitable for liquid and for solid waste. The products of this treatment are a stabilized fermentation residue and a gas mix of methane (CH_4) and carbon dioxide (Co_2). The fermentation residue can after a post-treatment be used as a fertilizer, while the highly-energized methane can be burned and used for energy production in the form of electricity or thermal energy (Kranert & Cord-Landwehr, 2010).
The overview for a general concept for an anaerobic waste treatment is presented in Figure 27:

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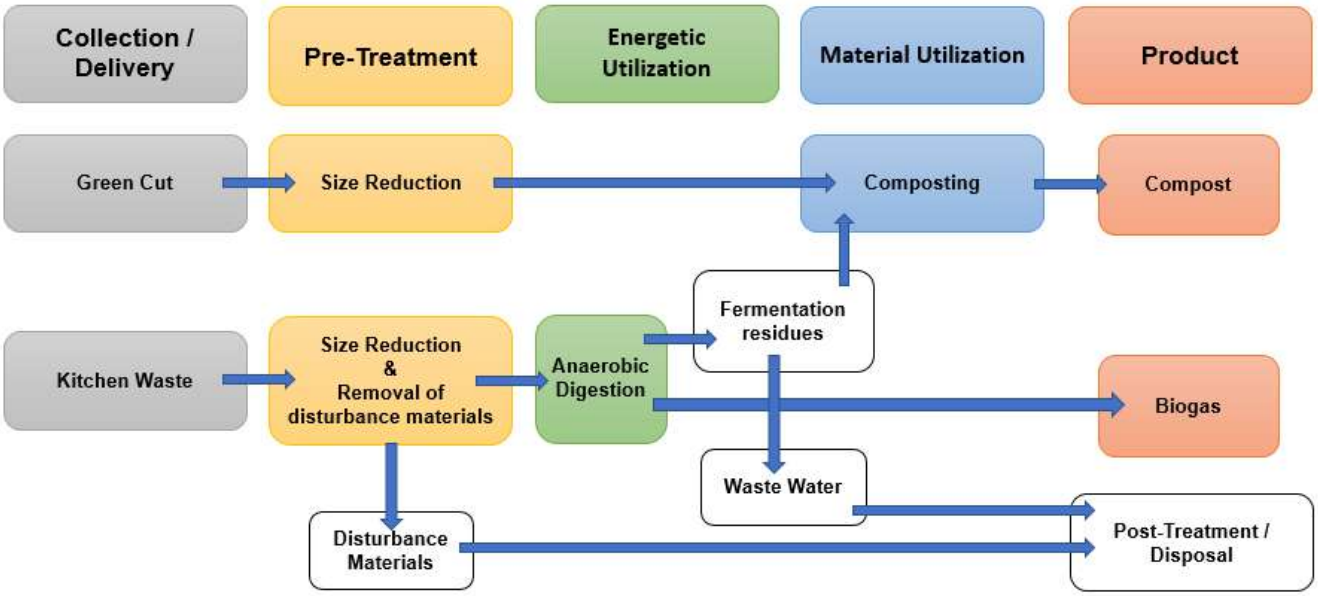

Figure 27: General concept for an anaerobic waste treatment (Brandt, 2017)

The concept can be divided in five main categories:

- Collection and Delivery
- Pre-treatment
- Energetic utilization
- Material utilization
- Product

In the first step the separately collected waste fractions were pre-treated in the second step to reduce the size of the components and to remove disturbance materials like mineral, metal and plastic fractions which could negatively influence the followed processes or the equipment (Kranert & Cord-Landwehr, 2010). The removal of impurities can be realized by visual inspection, screening, magnetic separation and manual sorting (Bilitewski , Härdtle, Marek, Weissbach, & Boeddicker, 1997).
The disturbance materials have to be treated in a post treatment or disposed. During the energetic utilization, the organic fraction is treated by anaerobic digestion in a fermentation facility. The fermentation residues should be post treated and stabilised in a composting facility for material utilization. The product out of this process is a fertilizer which can be used for landscaping and agriculture. The waste water output can either be reused in the process or post treated aerobically. The generated biogas can be burned and used for energy production in the form of electricity or thermal energy.
For determination of the potential of the waste generated on Mahé it is necessary to analyse the mass- energy balance for the current yearly waste flows. Hence a calculation of the exact for the anaerobic digestion available amounts was done.
In reason of not available equipment for determination of chemical and biological parameters (Water content Dry matter, Organic dry matter) reasonable assumptions had to be done. The assumptions (See Table 26) were collected from different technical literature combined with empirical values from research projects in Germany done by the Technical University of Darmstadt.

Table 26: Assumptions for Water Content, Dry Matter, Organic Dry Matter and Gas Formation (Bilitewski , Härdtle, Marek, Weissbach, & Boeddicker, 1997) (Kranert & Cord-Landwehr, 2010), (Kannengiesser, 2017)

Fraction	Water Content [%]	Dry Matter [%]	Organic Dry Matter [%]	Gas Formation Rate [Nm³/t]
Kitchen Waste	65	35	70	100
Green Cut	51	49	63	74

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In Figure 28 is the anaerobic digestion process diagram for the mass- energy balance of kitchen waste and green cut presented:

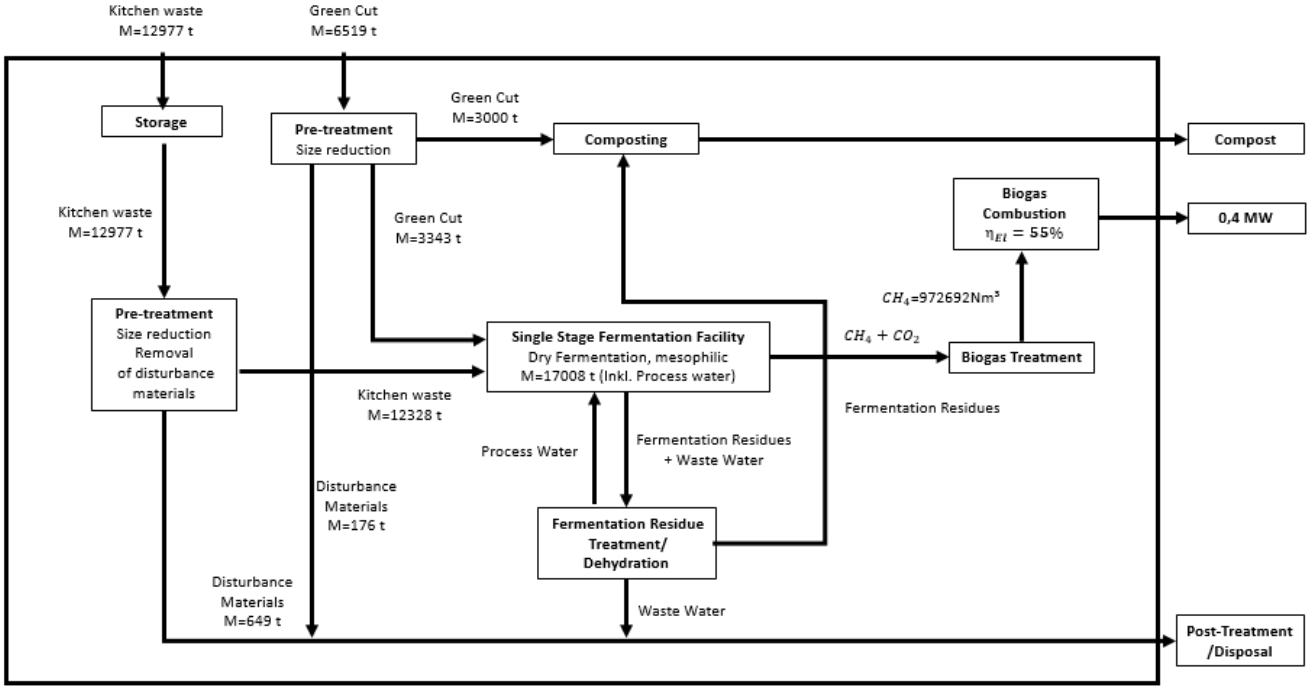

Figure 28: Process diagram for anaerobic digestion of kitchen waste and green cut per year for Mahé, Seychelles (Brandt, 2017). Detailed diagram see Appendix XY.

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The expected amounts for the kitchen waste and green cut were determined and calculated as results from the waste sorting activity 2016 and 2017. Hence the total amount for kitchen waste are 12,977 tonnes and green cut 6,519 tonnes. After deduction of 5 % of disturbance materials, the pre-treated 12,328 tonnes of light rotting kitchen waste can be processed in the fermentation facility. From the pre-treated 6,519 tonnes of green waste have to be 3,000 tonnes of heavy rotting wooden parts deducted and as structural material to a composting treatment facility delivered. The remaining 3,343 tonnes of green cut can be added to the fermentation process.

The loading in the fermentation facility can be realised either continuously or discontinuously. In case of a discontinuous loading process the daily delivered waste has to be stored in a bunker.

Due to the composition of the kitchen waste is a water content of 65% and for the green cut 51% expectable. By mixing the fractions and adding of process water a water content of 65% in total will be achieved. This basic condition is suitable for a single stage dry fermentation process for substrates with a water content less than 85% (Kranert & Cord-Landwehr, 2010). During a retention time of three weeks under mesophilic conditions (35° C operating temperature) 50% of the organic dry solids in the substrate anaerobically decomposed. It is also possible to treat the substrate more efficient under thermophilic conditions (55°C operating temperature). The maintaining of treatment plants under thermophilic conditions is more complex. The reactions under these conditions are more sensitive regarding temperature fluctuations.

The fermentation residues and the waste water out of this process supposed to be additionally treated. After the dehydration of the substrate the fermentation residues should be added to a composting process. Waste water can either be recirculated in the fermentation process or has to be additionally aerobically treated in a waste water facility (Bilitewski , Härdtle, Marek, Weissbach, & Boeddicker, 1997). The average distribution of methane and carbon dioxide in biogas is 60% (CH_4) and 40% (CO_2). The received biogas has to be desulfurized, dried and the contained CO_2 has to be removed.

After the calculation with a gas formation rate of 100 Nm³/t for kitchen waste and 74 Nm³/t for green cut a total usable methane volume of 972,692 m³ is expectable. With a heating value of 6.4 kWh/Nm³ and the electrical efficiency of 55% the combustion of methane results in 3,424 MWh or 0.4 MW total electrical capacity.

During the anaerobic digestion 31 % of the waste in class 1,2,3 and 5 can be treated. This corresponds a mass of 19,496 tonnes of total available material in 62,855 tonnes expected in 2017. The biological untreatable waste groups RDF, Recyclables and Rest (43,359 tonnes) are passing the process step of anaerobic digestion and have to be disposed directly.

Table 27: Demand for Solid Waste Disposal after mechanical biological treatment (Jager & Kannengiesser, 2014)

Treatment	Disposed Mass [%]	Disposal Density [t/m³]	Demand of disposal volume [m³/t raw material]	Disposal Volume [m³]
Untreated	100	0.8	1.25	78,569
Mechanical Biological treated	70	1.3	0.53	33,313

Depending on the treatment method of the waste the volume and density is changing. In case of a mechanical biological treatment of solid waste the disposed mass is reduced by around 30%. The size reduction and the decomposition of the organic compounds is resulting in a higher waste density of 1.3 t/m³ compared with the untreated material (0.8 t/m³). The demand for disposal volume for untreated material can be assumed by 1.25 m³/t and for treated 0.53 m³/t ((Jager & Kannengiesser, 2014) See Appendix XY). Hence the mechanical biological treatment of 62,855 tonnes is resulting in 33,313 m³ waste for disposal. It is a reduction of 57% compared to the untreated volume of 78,569 m³ (See Table 27).

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8.2. Composting

Composting is a process based upon the biodegradation of organic waste under aerobic conditions by microorganisms. During the process under heat dissipation results in a final product in form of compost, a sanitized and stabilised secondary raw material. It is an ecological method with minor negative impact on the environment in reason of returning organic substances and minerals in the natural cycle. Further it is a treatment method which can reduce the waste amount for disposal, secondly the aerobic process can be used as pre-treatment to stabilise the material bevor dumping. Hence it can reduce the negative impacts of the dumped material in form of active potential native organic substances and by decreasing the quantity of landfill gas. It can also reduce the leachate volume and concentrations (Bilitewski , Härdtle, Marek, Weissbach, & Boeddicker, 1997).

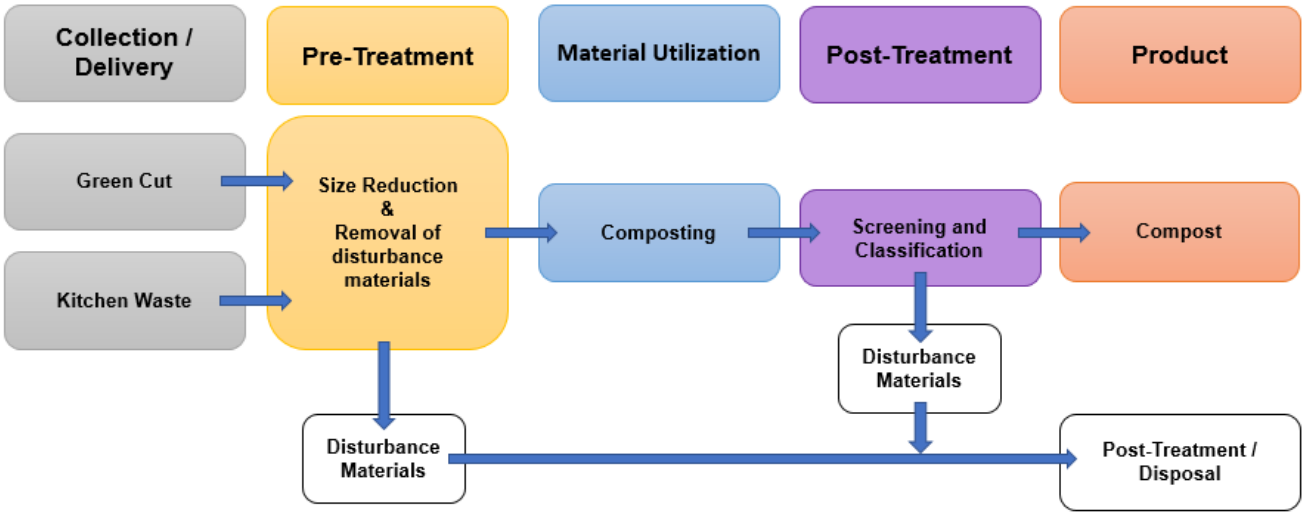

Figure 29: General concept for an aerobic waste treatment (Brandt, 2017)

The concept can be divided in five main categories:

- Collection and Delivery
- Pre-Treatment
- Material Utilization
- Post Treatment
- Product

The collection, delivery and the pre-treatment of the material for the composting is similar to the procedure described in Chapter 8.1. The disturbance materials should be removed, post-treated or disposed. After the size reduction, the material has to be mixed and homogenized as preparation for the composting. The rotting process in a composting treatment is divided in two parts. During the first part the intensive rotting organic compounds were degraded by microorganisms under aerobic conditions and emission of heat, CO_2 and water. In second the material should mature aerobically in windrows. To receive a good compost quality the matured material has to be additionally screened and classified by size. After removal of potential disturbance materials and wooden materials which can be recirculated in the rotting process as structural material, the compost can be packaged and sold.
On Mahé island are the waste fractions kitchen waste and green cut suitable for composting. For a successful rotting process is a water content of 50 % necessary. In Case of a water content lower than 20 % a biological degradation is not possible. For water contents, higher than 60 % the process is switching from aerobic to anaerobic degradation.

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In Figure 30 is the detailed aerobic composting process diagram for the mass- energy balance of kitchen waste and green cut presented:

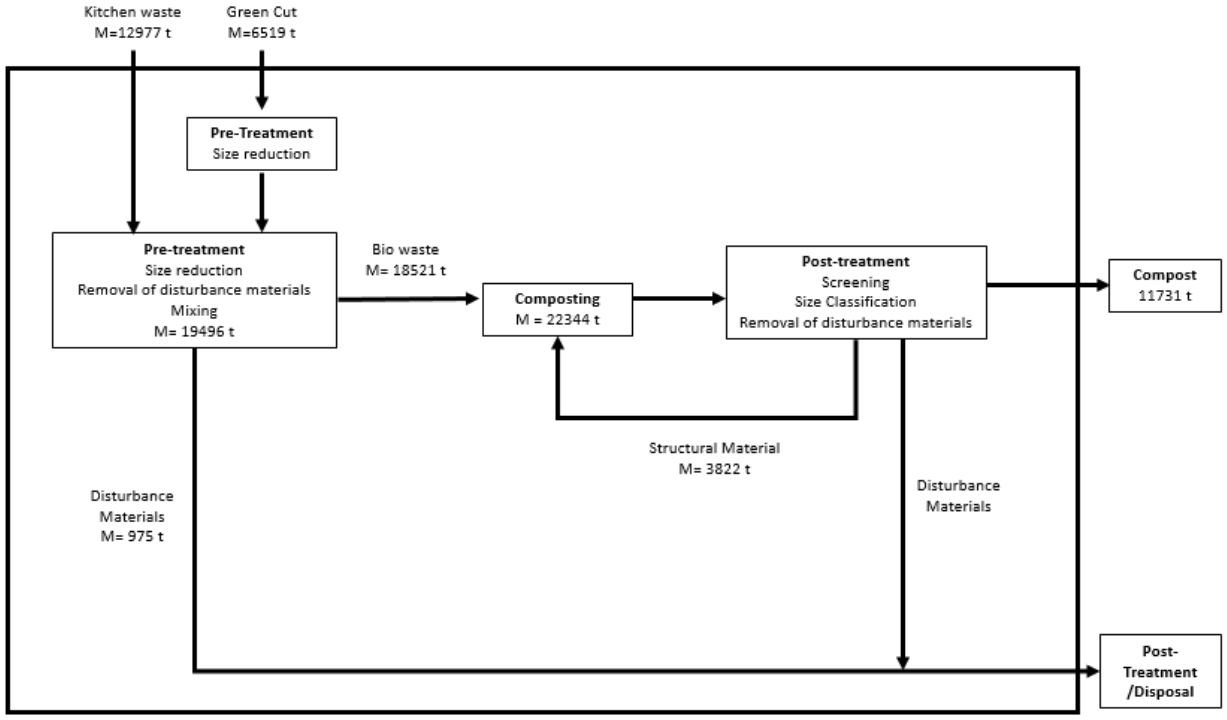

Figure 30:Process diagram for composting of bio waste per year for Mahé, Seychelles (Brandt, 2017). Detailed diagram see Appendix XY.

After removal of approximately 5 % of disturbance material 18,521 tonnes of bio waste can be treated in the composting facility. Referring to the assumptions made in Chapter 8.1 the mixed material has a water content of 60 %. For a successful treatment 3,675 tonnes structural material has to be added to lower the water content. The structural material can be recirculated from the post-treatment. During the rotting process a mass reduction of 55 % is expectable. The input material of 22,344 tonnes of bio waste results in 11,731 tonnes of fresh compost in total.
The volume change for the mechanical biological treatment of solid waste in a composting process is equivalent to the described calculation for anaerobic digestion in Chapter 8.1.

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8.3. Incineration

For the thermal waste treatment, the most important technology is the waste incineration. The method is mainly used for the treatment of nonrecyclable and nonreusable materials like the fractions that are summarized in the RDF group (See Table 25). The incineration treatment minimizes the emissions of any hazardous waste which can negatively influence the environment. During the process, any organic components were destroyed and the inorganic contaminants were concentrated. The volume of the waste and the quantity for disposal were reduced significantly. Further this treatment is an effective protection of resources through recovering the waste´s heat value. It is a possibility to substitute fossil resources in form of utilization of the waste (Bilitewski , Härdtle, Marek, Weissbach, & Boeddicker, 1997).
The incineration is a suitable technology on one hand for separately collected waste summarized in the RDF group and on the other for the treatment of solid waste which contains in this case the bio waste, RDF waste, recyclables and rest group.
The overview for a general concept for the incineration of solely RDF waste is presented in following diagram in Figure 31:

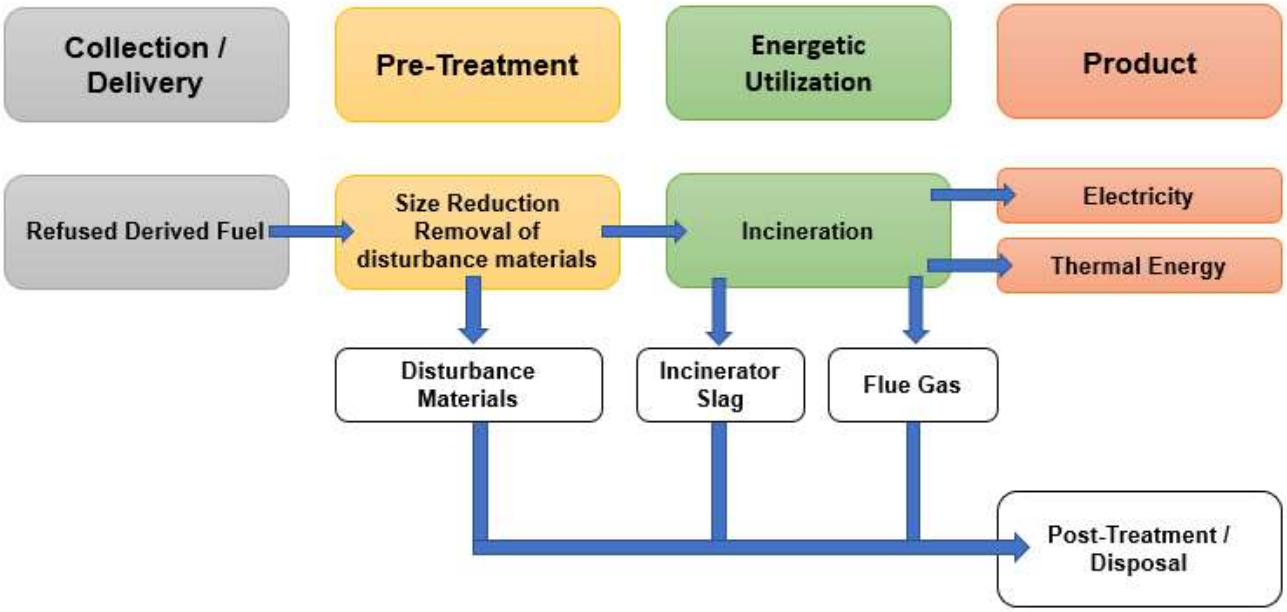

Figure 31: General concept for incineration of RDF waste (Brandt, 2017)

The four main categories for the general concept are:

- Collection and Delivery
- Pre-treatment
- Energetic utilization
- Product

Comparing to the collection of organics, the RDF group can be in the first step collected and delivered without clearly defined separation in each fraction. The components of RDF are celluloses, plastics, wood, textiles and mixed solid waste. In second step is the removal of disturbance materials and the size reduction of for example bulky waste as pre-treatment necessary (Bilitewski , Härdtle, Marek, Weissbach, & Boeddicker, 1997). The disturbance materials supposed to be treated in a post treatment or disposed. During the incineration step the flue gas and the incinerator slag (inert slag) have to be removed and post treated or disposed.
The incineration process can be divided in three parts (Kranert & Cord-Landwehr, 2010):

1. Thermal basic process
2. Heat utilization

3. Fluid gas scrubbing

The incineration contains four processes. The drying (100 °C), which effects the separation of moisture, pyrolysis (heating to 250-700°C), which effects the separation of remaining moisture and gases, gasification (800-1,200°C) and combustion (850-1,300°C) which effects the oxidation of organic compounds (Kranert & Cord-Landwehr, 2010). The technically relevant parameters for an incineration of waste are the upper (H_o) and lower heating value (H_u)). These values describe the chemically bounded energy in a material.

For the calculation of the energy potential for the RDF waste flows with high calorific contents on Mahé the followed typical lower heating values were used (Kranert & Cord-Landwehr, 2010), (Kannengiesser, 2017)):

Table 28: Lower heating values for RDF-Fractions (Kranert & Cord-Landwehr, 2010), (Kannengiesser, 2017))

Fraction	Hu [kJ/kg]
Cellulose Household and Product Packings	8,500
Cellulose Distribution Packings	8,500
Plastic Product Packings	32,000
Plastics	32,000
Composite Product Packings	32,000
Construction Wood	19,550
Tires and Rubber	32,000
Textiles	12,000
Unsortable Waste	12,000
Sorting Rest	12,000

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In Figure 32 is the detailed thermal treatment process diagram for the mass- energy balance of RDF waste presented:

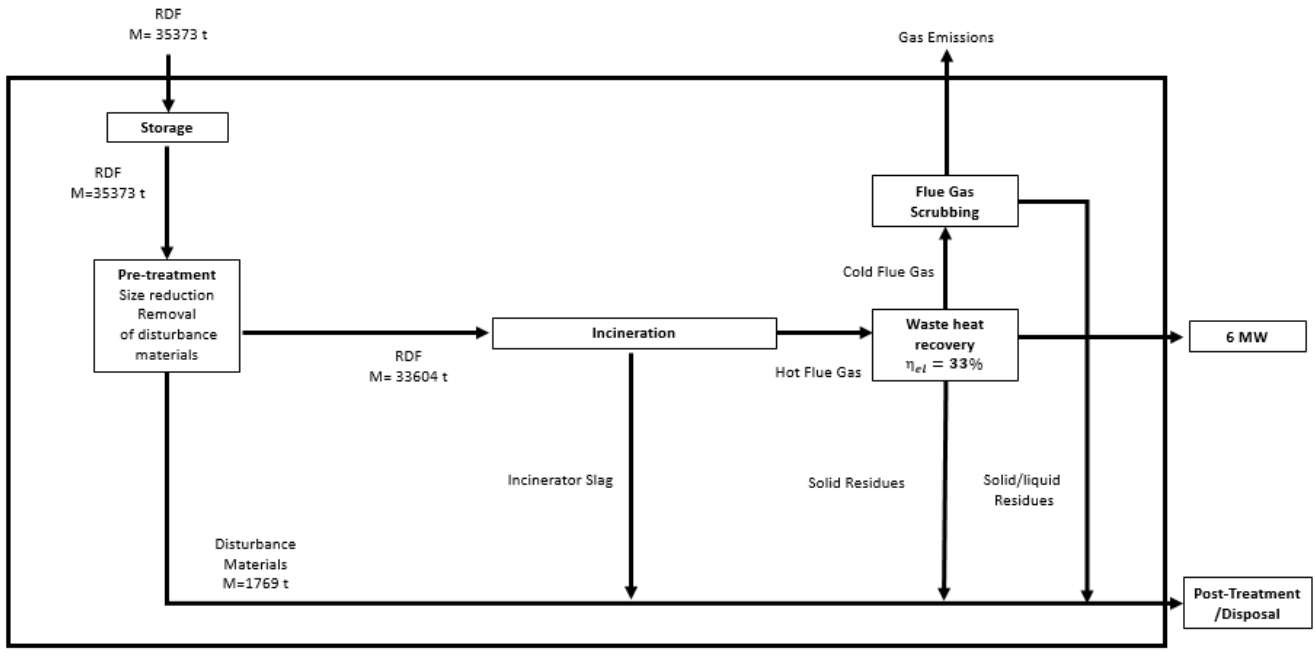

Figure 32: Process diagram for incineration of RDF per year for Mahé, Seychelles,2017 (Brandt, 2017) . Detailed diagram see Appendix XY.

The total amount of RDF waste on Mahé expected in 2017 are 35,373 tonnes. After deduction of 5 % of disturbance materials, the pre-treated 33,604 tonnes of waste can be processed in the incineration process. The

disturbance materials from the pre-treatment, the incineration slag, the solid residues from the waste heat recovery and the solid/liquid residues from the flue gas scrubbing should be post-treated or disposed. The flue gas scrubbing is for removal of acidic pollutants, dioxins, furans and denitrification.
For each fraction was referring to the lower heating values in Table 28 and the single amounts in Chapter 0 (See Table 23) the expected energy values in kJ were calculated and in MW transformed.
With a degree of efficiency of 33 % in the waste heat recovery, the incineration of the RDF waste on Mahé results in 6 MW.
During the incineration of RDF waste 56 % of the waste in class 1,2,3 and 5 can be treated. This corresponds a mass of 35,373 tonnes of total available material in 62,855 tonnes expected in 2017.

In general, it is common to treat the complete amount of solid waste (SW) via incineration. The overview for a general concept for the incineration of RDF waste, bio waste, recyclables and rest is presented in diagram in Figure 33:

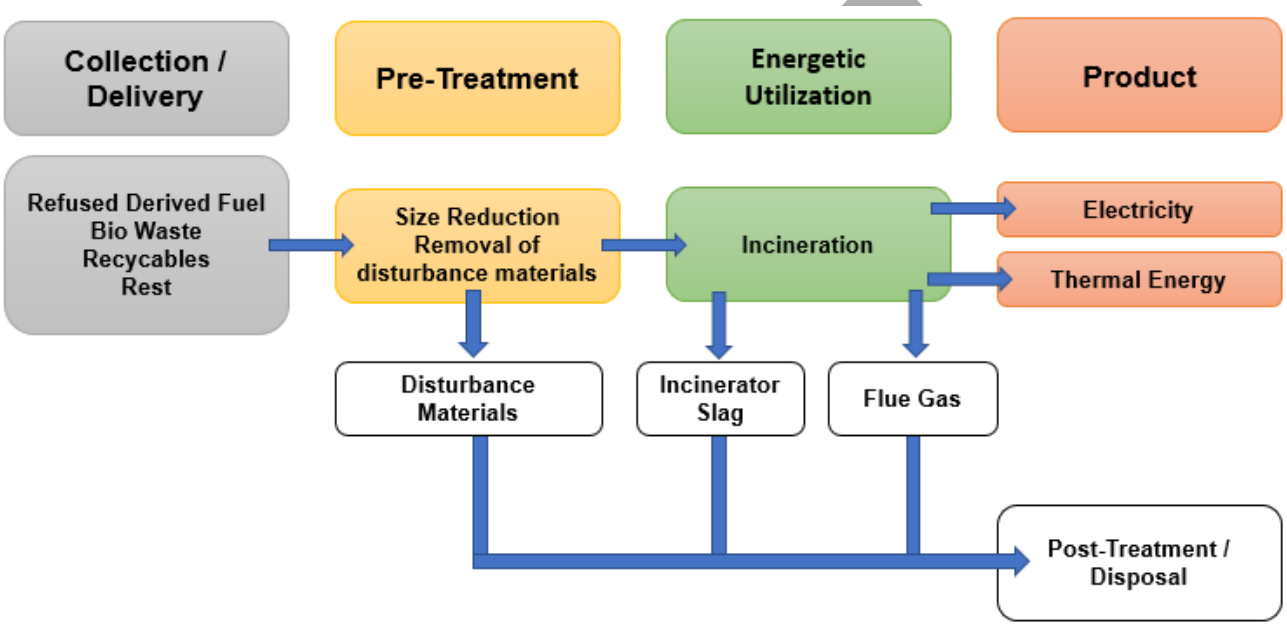

Figure 33:General concept for incineration of solid waste (Brandt, 2017)

The main categories and the incineration process is equivalent to the procedure described for RDF waste. Additionally, to the heating values for RDF waste the heating values for the fractions recyclables, green cut, kitchen waste and rest should be considered for the calculation in a thermal treatment. The assumed values are presented in Table 29:

Table 29: Lower heating values for recyclables, bio waste and rest (Kranert & Cord-Landwehr, 2010), (Kannengiesser, 2017) , (Kern, Raussen, Funda, Lootsma, & Hoffmann, 2010))

Fraction	Hu [kJ/kg]
Recyclables	0
Green Cut	6,000
Kitchen waste	2,000
Rest	12,000

Recyclables are mainly containing the fractions glass, metal, aluminium and inert waste. These categories are passing the incineration process and have no significant heating value. Green cut has an assumed value of 6,000 kJ/kg in reason of containing combustible wooden parts besides leaves. Kitchen waste has an expectable high water content and therefore an assumed low heating value of 2,000kj/kg. In reason of the small

DRAFT

percentage of rest material (3 %) the heating value for the fraction rest is equivalent to the average value of solid waste (12,000 kJ/kg).
In following diagram (See Figure 34) is the detailed thermal treatment process for the mass- energy balance of SW presented:

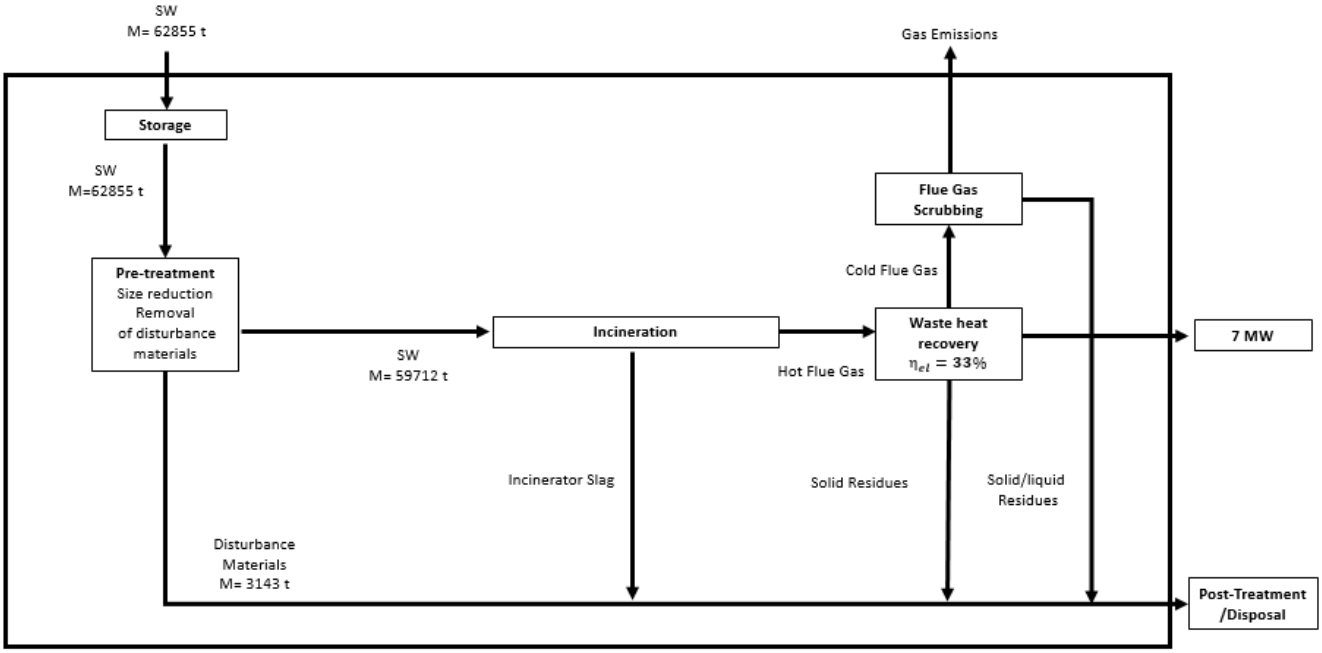

Figure 34: Process diagram for incineration of SW per year for Mahé, Seychelles, 2017 (Brandt, 2017)

By incinerating of the SW with an expected amount of 62,855 tonnes on Mahé island for 2017 is an energy capacity of 7 MW calculated. Despite the higher treatment amount it results in 1 MW more then by the treatment of solely RDF waste. Nevertheless, the treatment of the total amount of waste in the thermal treatment has the benefits:

- Collection of the SW in common collection system
- No separation of single waste groups as pre-treatment necessary
- The waste can be treated in one facility
- Fluctuation of waste amounts within the single waste groups can be balanced

The main advantage of thermal treatment via incineration is the reducing potential of material for disposal. The comparison of untreated material with thermal treated material is seen in Table 30:

Table 30: Demand for Solid Waste Disposal after thermal treatment (Jager & Kannengiesser, 2014)

Treatment	Disposed Mass [%]	Disposal Density [t/m³]	Demand of disposal volume [m³/t raw material]	Disposal Volume [m³]
Untreated	100	0.8	1.25	78,569
Thermal Treatment without post-processing of slag	35	1.53	0.24	15,085
Thermal Treatment including post-processing of slag	5	1.53	0.05	3,143

In case of a thermal treatment of solid waste the disposed mass is reduced by around 65 % in a treatment without post-processing of the incinerator slag and 95 % by including the post-processing of the slag in the treatment. The size reduction and the combusting resulting in a higher waste density of 1.53 t/m³ compared with the untreated material (0.8 t/m³). The demand for disposal volume for untreated material can be assumed

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by 1.25 m³/t and for treated 0.24 m³/t (without post-processing of slag) and 0.05 m³/t (including post-processing of slag) ((Jager & Kannengiesser, 2014), See Appendix XY). Hence the thermal treatment of 62,855 tonnes is resulting in 15,085 m³ (without post-processing of slag) and 3,143m³ (including post-processing of slag) waste for disposal. It is a reduction of 81 % (without post-processing of slag) and 96 % (including post-processing of slag) compared to the untreated volume of 78,569 m³ (See Table 30).

8.4. Comparison of potential waste treatment technologies

For the technological recommendation, it is necessary to compare the three considered treatment methods for Mahé regarding waste characteristics, treatable yearly amount, deliverable products, percentage of total waste amount and the expected remaining waste and residues for disposal. A summarized comparison of the potential treatments for Mahé is presented in Table 31.

Table 31:Comparison of potential treatments for waste of class 1,2,3 and 5 in 2017 for Mahé island, Seychelles (Adapted from Jager, Kannengiesser, 2014)

Treatment	Treated amount [t]	Treated amount weight [%]	Product	Energetic Utilization [MW]	Volume for disposal [m³]
Anaerobic Digestion	19.496	31	Biogas / Compost	0,4	33.313
Composting	19.496	31	Compost	-	33.313
Incineration without post-processing of slag	62.885	100	Heat / Energy	7	15.085
Incineration including post-processing of slag	62.885	100	Heat / Energy	7	3.143

Regarding the material characteristics for biological treatment the solid waste of class 1,2,3 and 5 on Mahé is containing bio waste (including kitchen waste and green matter), yard and park wastes, household-like commercial waste and kitchen waste. These group comprise by weight 31% organic compounds of the total waste in considered classes 1,2,3 and 5. This corresponds 19.469 tonnes of 62.855 tonnes for 2017.
The treatment of these waste fractions can be either realized by composting or anaerobic digestion. The composting is a process for material utilization of waste whereas the anaerobic digestion is an energetic utilization.
The product out of the composting treatment are 11.731 tonnes of fresh compost which can be used as fertilizer in landscaping or agriculture. For anaerobic digestion, the deliverable product is 972.692 m³ methane which can be burned and used for energy production in the form of electricity or thermal energy. The electrical capacity of the potentially available methane is 0.4 MW.
Both treatments are reducing the active potential of organic substances and the quantity of waste. Also, the quantity of the landfill gas and leachate from the aerobically or anaerobically treated waste is decreasing. Depending on the treatment method of the waste the volume and density is successive changing. Hence it results for both treatments in increasing in compactability of the waste and in reducing of waste disposal volume on the landfill and in same way an extension of the landfill lifetime.
After the mechanical pre-treatment and the biological treatment of 62.855 tonnes solid waste it results in 33.313 m³ waste for disposal. It is a volume reduction of 57% compared to the untreated volume of 78.569 m³.
By comparing both mechanical biological treatments the anaerobic treatment is in reason of the deliverable biogas more beneficial then the composting. However, it is to consider the necessary technological equipment and the maintenance of the facilities.

The incineration as thermal treatment with energetic waste utilization is suitable on one hand for the RDF waste solely but also for the total solid waste amount of class 1,2,3 and 5 in one process. The treatment of the RDF group in incineration facilities is achieving a treated amount of 35.373 tonnes which are 56% of the total yearly amount in considered classes. The product of the process is heat which can be used for processing and an electrical potential of 6 MW.
By incinerating the total solid waste of 62.885 tonnes the energetic potential of 7 MW can be achieved. Depending on the facility by adding a post-treatment for the slag the reduction of 81% (without post-processing of slag) and 96% (including post-processing of slag) compared to the untreated volume of 78.569

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m^3 can be reached. Incineration could be not only a solution for current and future issues it is also a possibility of rebuilding step by step the existing landfill.

The total installed electrical capacity on Mahé was in 2013 around 69,5 MW. The energy is generated through fuel oil and gas oil with diesel generators. The Public Utilities Corporation (PUC) operates three main power stations R. Caiman Power Station (Mahé), New Port Power Station (Mahé) and the Baie Ste-Anne (Praslin).
Additionally, in June 2013 PUC put a windfarm in port Victoria in operation. It has a capacity of around 6 MW (Razanajatovo, 2016). By implementing a waste-to-energy concept via anaerobic digestion an electrical capacity of 0,4 MW, incineration of RDF 6 MW and incineration of solid waste 7 MW can be added to the electrical infrastructure.

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9. Recommendation for waste management

Mahé's current waste management that has been reviewed within this project demonstrates substantial challenges and priorities considering the existing capacity and the continued growth of urban areas and touristic (commercial) development that needs to be approached. For any recommendation that addresses the broad challenges of Mahé Island, a perspective on short-, middle- and long-term matters is required. The following summarises short-term as well as middle- and long-term recommendations made upon on the research of this project.

It is apparent that the key area which requires for the moment undivided attention refers to a legal framework regarding waste. Out of the results of this report this is challenged by impeding internal factors (see Chapter 4.2.1). Having said so, providentially, the Republic has *EPA 2016* enacted but the sections do not include specific guidance on waste handling. Regulations that the Minister is enabled to issue are not released and therefore waste management in the Republic are impeded by lack of enforcement. Enforcement, in this matter, hence, includes a systemic approach by establishing proper working conditions (see Chapter 4.2.1 functions of management or PDCA-model for environmental management).

Only with proper conditions for enforcement, a legal framework can be set to handle waste appropriately towards desired objectives for waste collection, treatment and disposal that influence the waste amounts going to the landfill. As the *SSDS* already gives an idea of "where to go" on a normative level it is possible to formulate and draft a waste act. In strategic means which identify the direction, it implies DOE firstly to determine a proper waste classification including definitions. More specifically, it means that waste is classified according to their type, i.e. physical, chemical and physiological property. From there, only then it can be for instance tendered what sort of waste type needs to be collected separately if desired. Moreover, an additional classification upon waste source is needed. This, for example, enables possibilities to charge coherently different waste producers at desired standards. As commercial waste contributes heavily to the waste amounts going to the landfill, for example, different charging system imposed on commercial industries can be applied in order to spare the public to pay for waste collection and disposal for the time being. The charging system would then cover waste collection and disposal as waste disposal is currently not charged at all.

Only after considering the legal framework, potential waste treatment technologies can be regarded. All three concepts in Chapter 8, however, have the precondition of separation and collection of the waste in treatable groups in common.
In general, the collection and transport must include the recovery and collection of household, industrial and commercial waste, the transportation of the collected waste to processing and disposal facilities and the separate collection and removal of recyclables (Bilitewski , Härdtle, Marek, Weissbach, & Boeddicker, 1997). The success rate of a waste separation is sensitive to motivation and participation level within the public and industry.

The implementation of a waste separation as a short-term goal can be realised only step by step. Class 2 as one of the main contributors of waste amounts to landfill is mainly delivered by private companies and is serving most of the big hotels and industry. Most of smaller businesses and shops whose waste collection is served currently by STAR because of EIA conditions to have contracts with LWMA are referred as Class 1 which is another important waste producer. Moreover, those waste producers can be penalised in case of any offence to have not separated their wastes as private bins and skips can be clearly identified on their premises. Therefore, it is an opportunity to use political instruments in form of policies and legislation to start separation in this sector as it is difficult to introduce separation at source of public waste. Hence, clear waste separation guidelines for the commercial establishments and the industry can help to restructure the waste management in this sector.

To tackle public bins, it is necessary to emphasise on education and awareness. People of different ages and socio-economic backgrounds must be motivated to participate in the waste sorting. This can be achieved by education and information started by programs in school and supported by local media and print as already done in small scale. To achieve large-scale awareness, a trail run separating one waste group is suitable. For example, the separation of bio waste under supervision of trained and qualified staff is suitable as a separated

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collection of the aforementioned is beneficial to the proposed treatment technologies composting, anaerobic digestion and incineration of RDF's in any case.

A long-term goal for the waste separation can be the restructure from public bin sites to private bins per household as evident to best practices globally.

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10. Conclusion /Outlook

Chapter 10 Outlook
In order to draft a waste management concept for Mahé the results of this project are supportive and deduced recommendations give guidance on what is necessary to be tackled as first priority. Only if recommendations are applied, subsequent suitable next steps can be tackled. Depending on the Ministry's desire for the development of a waste management strategy these are:

- Illustration for state of technology and good practices adapted to the needs of the Seychelles
- Line-up scenarios in coordination with the Ministry
- Pre-plan scenarios
- Determine costs and economy contemplation
- Compare scenarios
- Recommend the two most matching scenarios in coordination with the Ministry

This outlook will be based on the data of this report.

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12. Appendix (A1-AX)

A1 Monitoring Protocol Mahé, Seychelles 2017 - Part 1

Monitoring - Protocol -Mahé

Island / Area	
Date Delivery	
Participants (TU Darmstadt)	
Participants (SEY)	
Comments	

Licence Plate	Wood	Green Waste	Household Waste	Electronic Waste	Paper Carton Cardboard	Bulky Waste	Plastics	Metal	Glas	Construction Waste	Tyres	MISC	Comments

A2 Monitoring Protocol Mahé, Seychelles, 2017 - Part 2

Monitoring - Protocol -Mahé

Island / Area	
Date Delivery	
Participants (TU Darmstadt)	
Participants (SEY)	
Comments	

Licence Plate	Class	Origin of the Waste/Employer	Deliverer	Load	Filling Level

A3 Sorting Protocol, Mahé, Seychelles, 2017

Sorting Protocol – Mahé

Island / Area	
Date Delivery:	
Date Sorting:	
Participants (TU-Darmstadt)	
Participants (UniSey)	
Comments:	

Nr.	Fractions:	Weight	Tara	Weight	Tara	Weight	Tara	Weight	Tara	Weight	Tara
1	Cellulose Household and Product Packings										
2	Cellulose Distribution Packings										
.....	.....										

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A4 Sorting Results Total Class 1, compactors only (Sorting Analysis June 2016)

Fraction		Average Weight [kg]	Average Weight [%]
1	Cellulose Household and Product Packings	35.56	7.3%
2	Cellulose Distribution Packings	17.46	3.8%
3	Plastic Product Packings	19.03	4.0%
4	Plastics	35.97	7.5%
5	Integrated in 4	0.00	0.0%
6	Composite Product Packings	7.33	1.6%
7	Glass	21.88	4.6%
8	Metal Product Packings	14.13	3.1%
9	Aluminium Product Packings	2.51	0.5%
10	Metals	3.33	0.7%
11	Kitchen Waste	88.29	18.1%
12	Green Cut	41.20	9.1%
13	Oil and Fats	0.00	0.0%
14	Chemicals and Varnishes	0.00	0.0%
15	Construction Wood	11.16	1.9%
16	Construction Waste	10.04	2.0%
17	Inert	0.67	0.1%
18	Tires and Rubber	0.00	0.0%
19	Textiles	22.39	4.7%
20	Electronic Waste	7.10	1.5%
21	Batteries	0.12	0.0%
22	Unsortable Waste	87.18	18.2%
23	Sorting Rest	57.47	11.5%
24	Disturbance Materials	0.10	0.0%
	TOTAL	**482.91**	**100.0%**

A5 The six most important fractions in class 1, compactors only (June 2016)

Ranking	Fraction	Average Weight [kg]	Average Weight [%]
1	Kitchen Waste	88.29	18.1%
2	Green Cut	41.20	9.1%
3	Plastics	35.97	7.5%
4	Cellulose Household and Product Packings	35.56	7.3%
5	Textiles	22.39	4.7%
6	Glass	21.88	4.6%
		REST	48.9%

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A6 Sorting Results Total Class 2 (January/February 2017)

Fraction		Average Weight [kg]	Average Weight [%]
1	Cellulose Household and Product Packings	41.88	6.4%
2	Cellulose Distribution Packings	76.28	11.8%
3	Plastic Product Packings	27.10	3.9%
4	Plastics	3.52	5.9%
5	Integrated in 4	0.00	0.0%
6	Composite Product Packings	16.40	2.9%
7	Glass	36.00	4.7%
8	Metal Product Packings	2.62	0.3%
9	Aluminium Product Packings	6.54	0.9%
10	Metals	5.26	0.6%
11	Kitchen Waste	191.46	24.7%
12	Green Cut	68.18	11.7%
13	Oil and Fats	0.00	0.0%
14	Chemicals and Varnishes	4.58	0.8%
15	Construction Wood	41.72	6.6%
16	Construction Waste	23.38	3.7%
17	Inert	0.00	0.0%
18	Tires and Rubber	1.70	0.2%
19	Textiles	12.28	1.4%
20	Electronic Waste	5.26	0.6%
21	Batteries	0.02	0.0%
22	Unsortable Waste	7.70	1.2%
23	Sorting Rest	50.42	6.4%
24	Disturbance Materials	38.10	5.5%
	TOTAL	**694.40**	**100.0%**

A7 The six most important fractions in class 2 (Sorting analysis Mahé, Seychelles, January/February 2017)

Ranking	Fraction	Average Weight [kg]	Average Weight [%]
1	Kitchen Waste	191.46	24.7%
2	Cellulose Distribution Packings	76.28	11.8%
3	Green Cut	68.18	11.7%
4	Construction Wood	41.72	6.6%
5	Cellulose Household and Product Packings	41.88	6.4%
6	Plastics	37.52	5.9%
		REST	**33.0%**

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A8 Sorting Results Total class 5 (Sorting analysis Mahé, Seychelles, January/February 2017)

Fraction		Average Weight [kg]	Weight [%]
1	Cellulose Household and Product Packings	12.24	2.42%
2	Cellulose Distribution Packings	100.48	30.51%
3	Plastic Product Packings	15.00	2.71%
4	Plastics	18.02	5.26%
5	Integrated in 4	0.00	0.00%
6	Composite Product Packings	1.10	0.22%
7	Glass	5.40	0.92%
8	Metal Product Packings	2.32	0.43%
9	Aluminium Product Packings	2.18	0.40%
10	Metals	13.10	3.30%
11	Kitchen Waste	24.52	4.07%
12	Green Cut	5.60	1.35%
13	Oil and Fats	0.00	0.00%
14	Chemicals and Varnishes	0.22	0.03%
15	Construction Wood	174.62	34.01%
16	Construction Waste	3.32	0.70%
17	Inert	0.14	0.03%
18	Tires and Rubber	3.64	0.78%
19	Textiles	12.48	2.27%
20	Electronic Waste	0.52	0.09%
21	Batteries	0.00	0.00%
22	Unsortable Waste	12.62	3.95%
23	Sorting Rest	9.94	1.82%
24	Disturbance Materials	28.42	4.71%
	TOTAL	**445.88**	**100.00%**

A 9 The six most important fractions in class 5 (Sorting analysis, Mahé, Seychelles, January/February 2017)

Ranking	Fraction	Average Weight [kg]	Weight [%]
1	Construction Wood	174.62	34.0%
2	Cellulose Distribution Packings	100.48	30.5%
3	Plastics	18.02	5.3%
4	Kitchen Waste	24.52	4.1%
5	Metals	13.1	3.3%
6	Plastic Product Packings	15.0	2.7%
		REST	**20.1%**

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A10 Extrapolation results total class 1,2,3,5 including sorting rest and unsortable analysis (Sorting analysis Mahé,Seychelles, January/February 2017)

Fraction		Σ (2017) [t]
1	Cellulose Household and Product Packings	3487
2	Cellulose Distribution Packings	9280
3	Plastic Product Packings	2112
4	Plastics	3974
5	Integrated in 4	0
6	Composite Product Packings	767
7	Glass	1955
8	Metal Product Packings	991
9	Aluminium Product Packings	327
10	Metals	1062
11	Kitchen Waste	12977
12	Green Cut	6519
13	Oil and Fats	0
14	Chemicals and Varnishes	87
15	Construction Wood	9059
16	Construction Waste	1406
17	Inert	37
18	Tires and Rubber	201
19	Textiles	1968
20	Electronic Waste	486
21	Batteries	7
22	Unsortable Waste	3043
23	Sorting Rest	1481
24	Disturbance Materials	1628
	TOTAL [t]	**62855**

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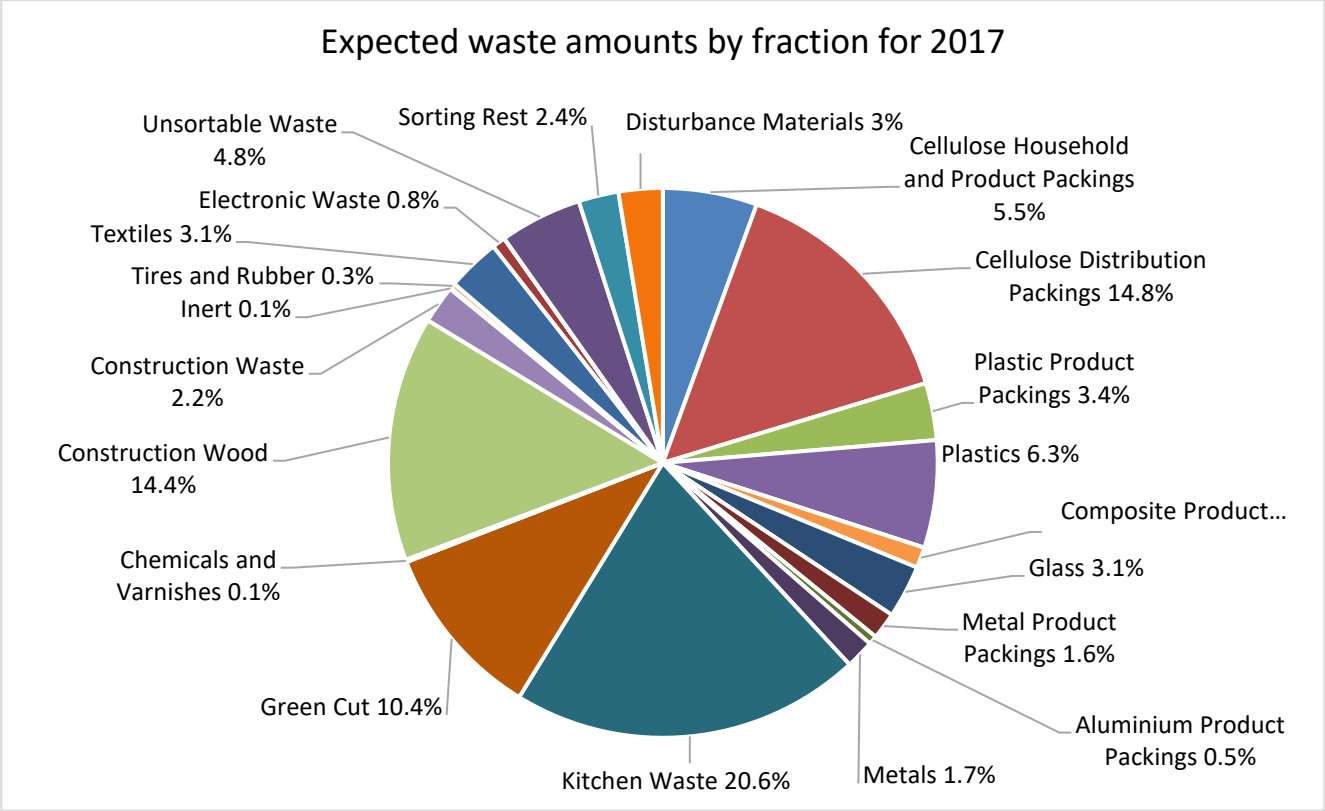
A11 Expected Waste Amounts by fraction for 2017, Mahé; Seychelles (Sorting analysis Mahé, Seychelles June 2016/ January- February 2017)



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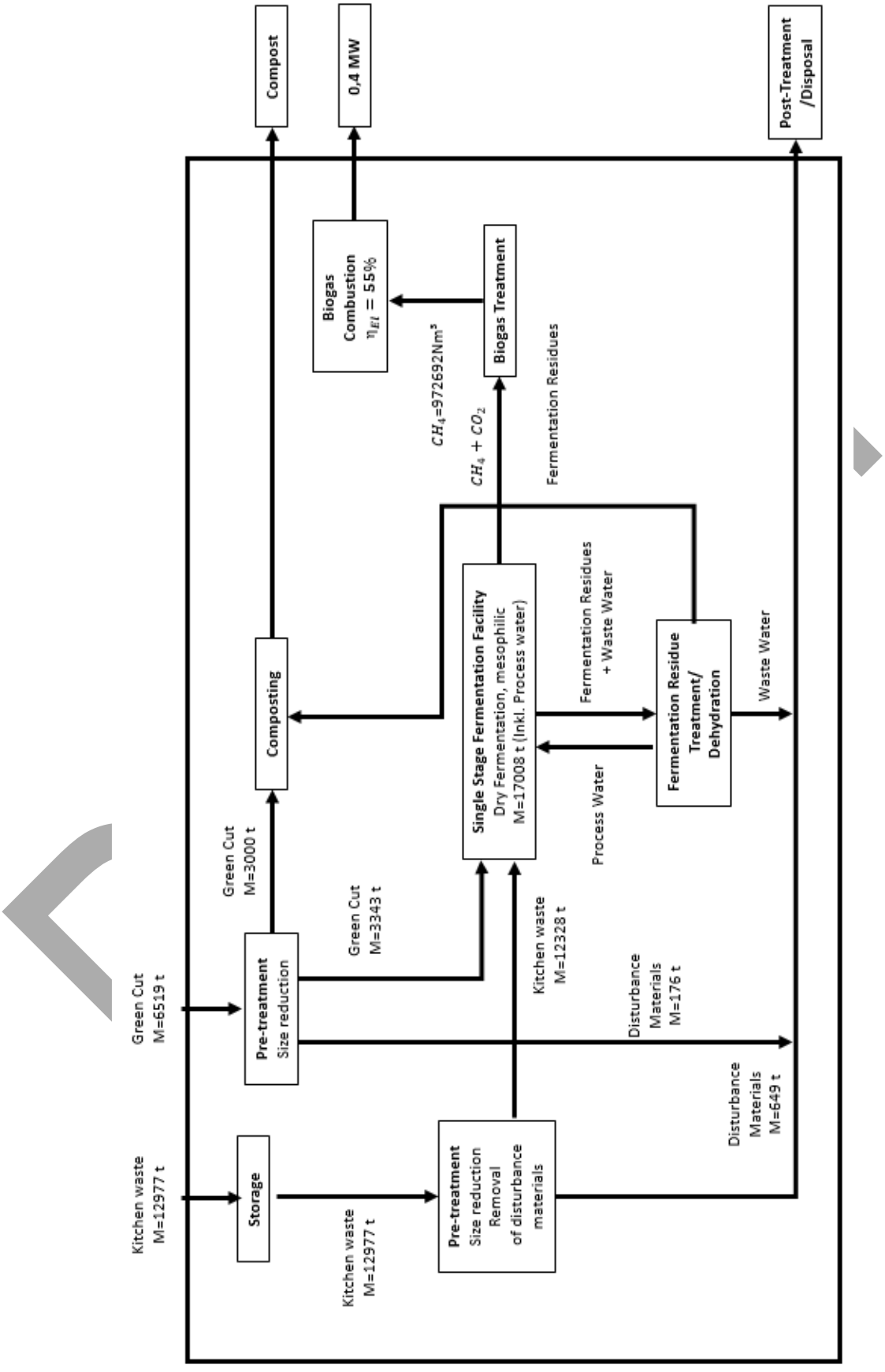
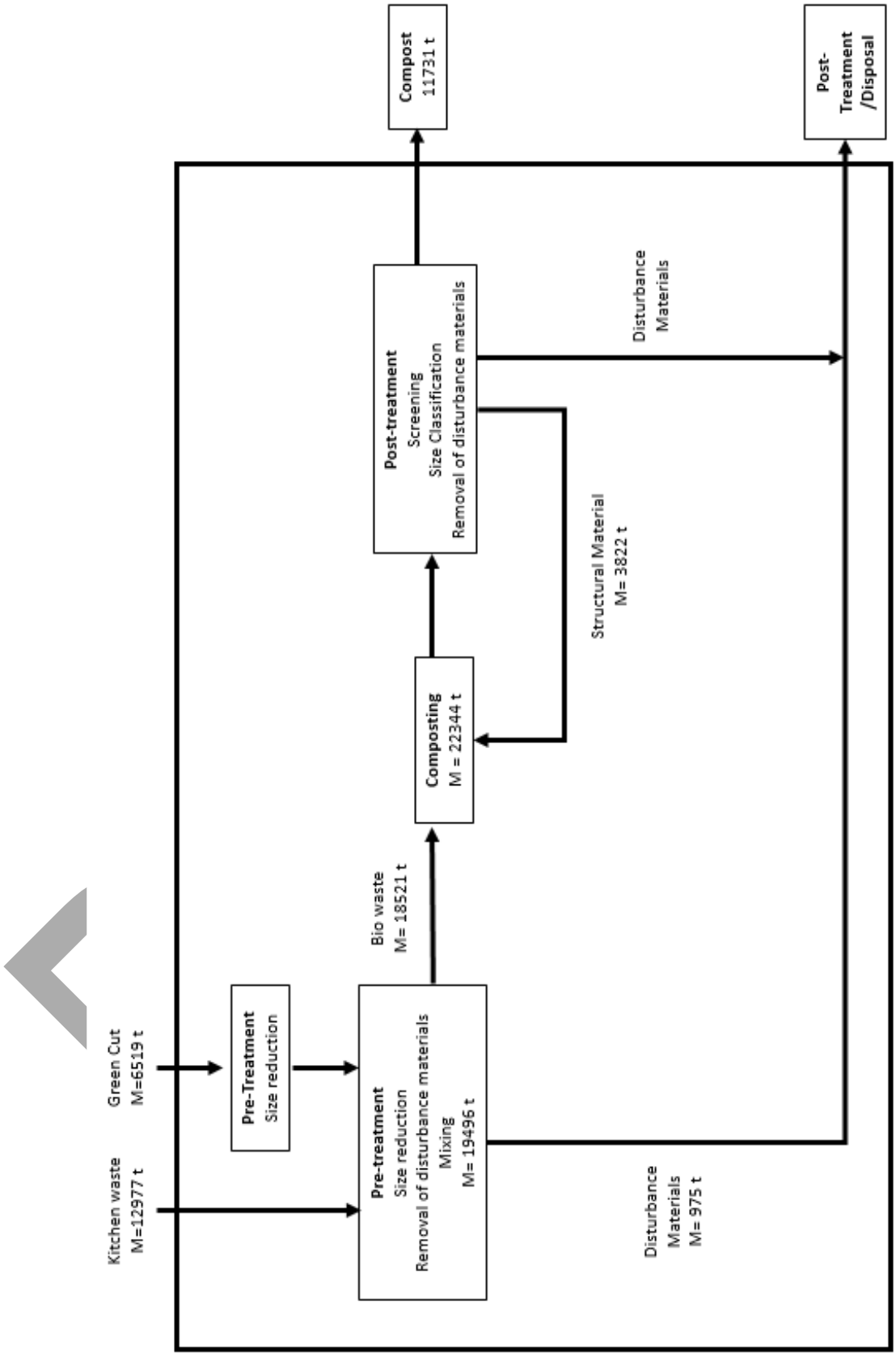
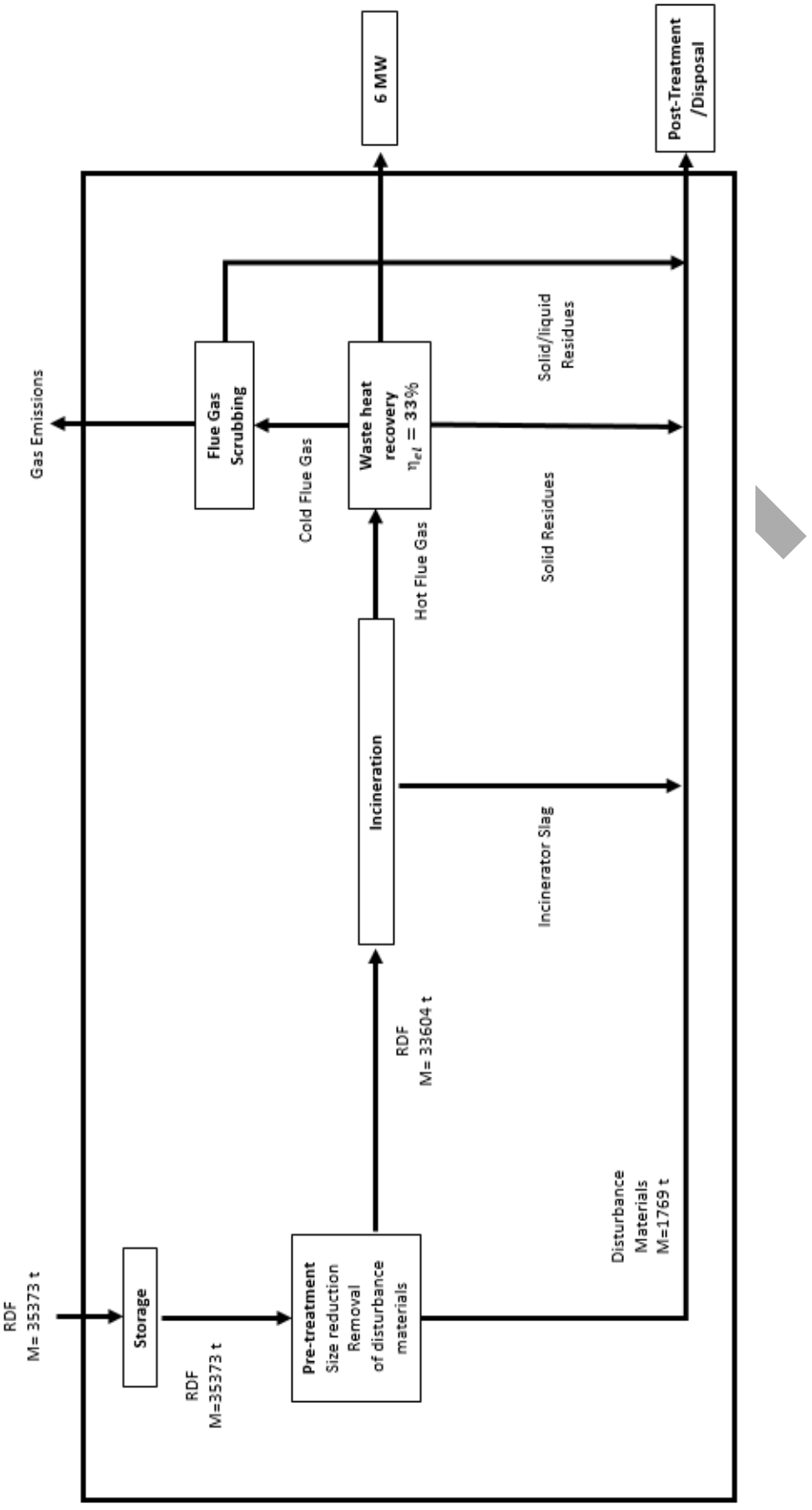
A 12 Detailed process diagram for anaerobic digestion of kitchen waste and green cut per year for Mahé, Seychelles (Brandt, 2017).



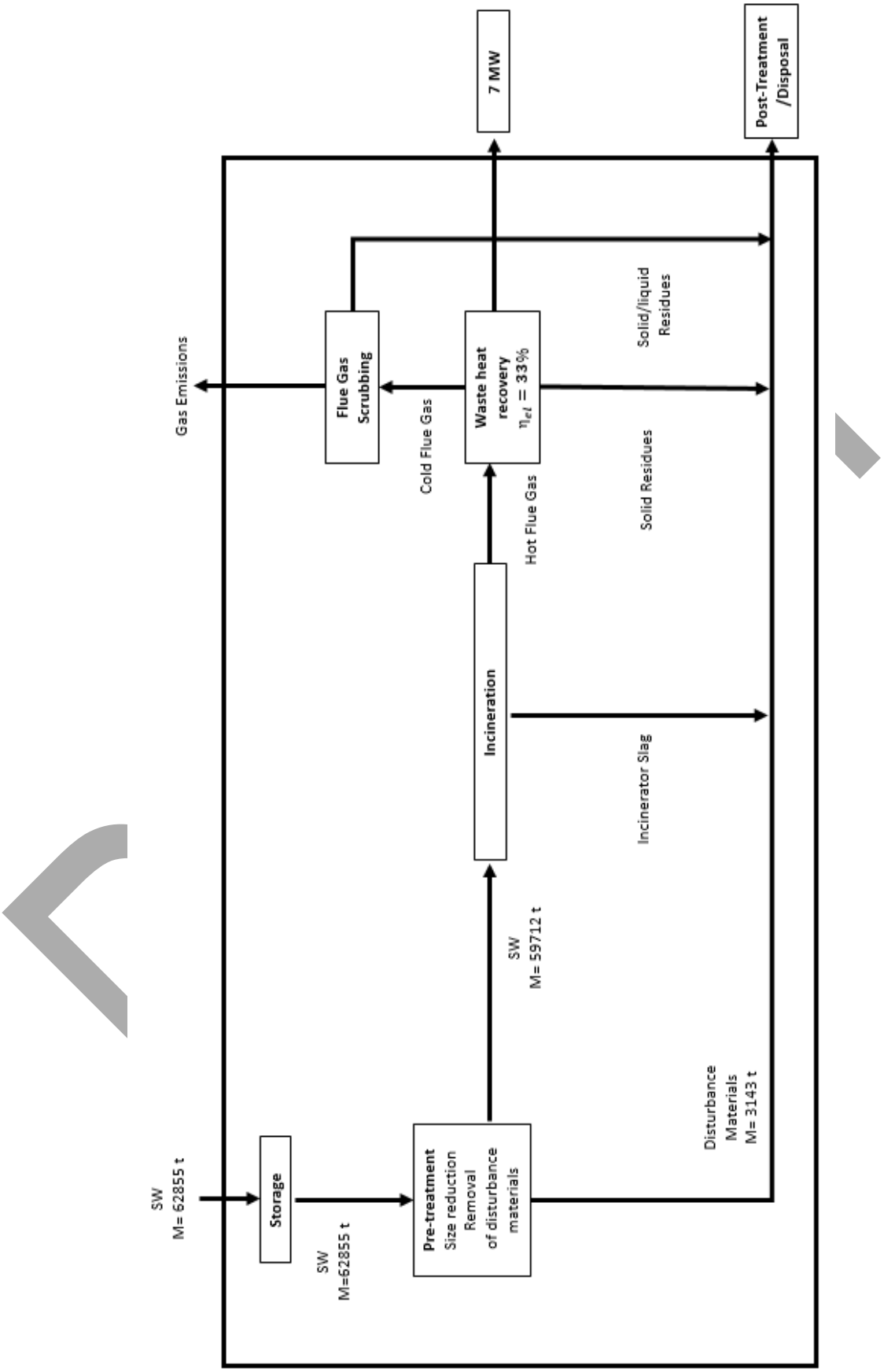
A 13 Detailed Process diagram for composting of bio waste per year for Mahé, Seychelles (Brandt, 2017).



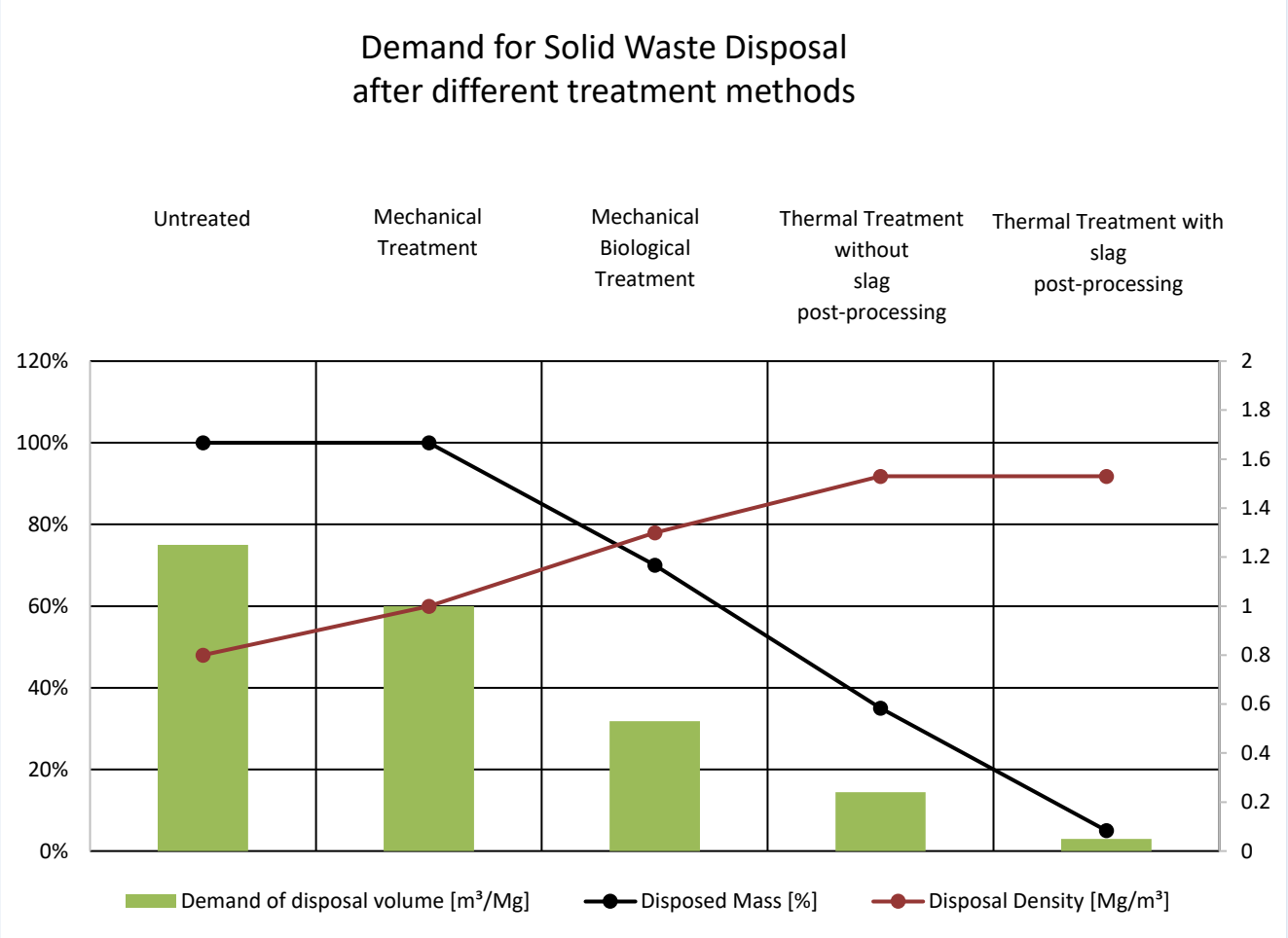
A14 Detailed Process diagram for incineration of RDF per year for Mahé, Seychelles,2017 (Brandt, 2017)



A15: Detailed process diagram for incineration of SW per year for Mahé, Seychelles, 2017 (Brandt, 2017)



A11 Demand for Solid Waste Disposal after different treatment methods (Own diagram based on Prof. rer. nat. Johannes Jager, Dr. Ing-. Jan Kannengiesser, TU-Darmstadt, 2014)



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