Ministry of Environment and Energy

Consultancy Services for Feasibility Study for an Integrated Solid Waste Management System for Zone III (including Greater Male') and Preparation of Engineering Design of the Regional Waste Management Facility at Thilafushi

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Consultancy Services for Feasibility Study for an Integrated Solid Waste Management System for Zone III (including Greater Male') and Preparation of Engineering Design of the Regional Waste Management Facility at Thilafushi

Saafu Raaje Zone III Integrated Waste Management System

Feasibility study Report for the RSWMF at Tilafushi

December 2017

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List of abbreviations and acronyms

ADB	Asian Development Bank
BPEO	Best Practicable Environmental Option
C&D	Construction & Demolition
ELV	End of Life Vehicle
FS	Feasibility Study
FIRR	Financial Internal Rate of Return
GOM	Government of Maldives
GM	Greater Male’
HDPE	High Density Poly Ethylene
IFB	Invitation for Bid
IFI	International Financial Institute
IWM	Integrated waste management
IWMC	Island Waste Management Centres
MEE	Ministry of Environment & Energy
MEMP	Maldives Environmental Management Project
MoFT	Ministry of Finance and Treasury
MoT	Ministry of Tourism
MRf	Maldivian Ruffiya
MSL	Mean Sea Level
MSW	Municipal Solid waste
NPV	Net present Value
P&C	Paper & Cardboard
PPP	Public Private Partnership
RSWMF	Regional Solid Waste Management Facility
SBD	Standard Bidding documents
SWM	Solid Waste Management
TPD	Tonnes Per Day

TS	Transfer station
USD	United State Dollar
WAMCO	Waste Management Corporation
EEEW	Electrical and Electronic waste
WTE	Waste to Energy

Glossary

Intra-Island	Intra island means the management on the island itself. Interface to the Outer Island is the harbour or docking area. An exception of the intra Island waste management is the Greater Male' Region which is considered as a "stand-alone" system
Outer Island	Outer Island is defined as the waste management "on sea" between the Islands and the central waste management Facility in Tilafushi
Greater Male'	Greater Male' is defined as the region encompassing the Islands of Male' city, Hulhumale, Vilingili and Hulhule' (hosting the Velana international airport)
Island waste management centre	Island waste management centre is a decentralized facility to promote composting and sorting on an Island level. Strategy of the Ministry is that each Island should have one IWMC until end of 2018. Exception from this strategy are the heavy urbanized Islands which have the status of a city (like Male' or Hulhumale')
Regional Solid waste management facility	The Regional Solid waste Management Facility is in the case of this study located in Tilafushi and is composed of a : waste acceptance and administrative area with a C&D waste processing plant and an ELV processing facility, the WTE facility, a residual waste landfill as well as other auxiliary facilities (storm water treatment, leachate treatment etc.)
Waste to Energy	In the case of the project the Waste to Energy facility is defined as the grate incinerator facility at Tilafushi

EXECUTIVE SUMMARY

The central purpose of this feasibility study is to justify the commitment of resources (especially finances) to achieve the objectives of an efficient and proper solid waste management system in Zone III. Zone III is the most important region in terms of economic and social development in the Maldives. Hosting the capital of the country (Male') the project region is the centre (not only geographically) of all politicial decisions.

The area is also characterized by an important development of tourism activities. With more than 70 resorts and approx. the same amount under development, it is the most important area in this sector.

In terms of demography this zone is hosts more than 80% of the country's population.

But this situation leads also to countrywide most important environmental problems particularly from the produced waste.

Managing the waste in a proper and efficient manner in this zone would lead to resolving an important part of waste problematic in the country.

The assessment of the actual situations shows that there is a willingness of all stakeholders to improve the situation. Funds have been mobilised (from the government as well as from International Financing Institutes) and the efforts starts to get materialised on Island level. But there is still a lack of a clear strategy, particularly a National Waste Management Plan considering and harmonizing all seven Waste zones of the Maldives needs urgently to be developed. Actually two antithetic strategies are under implementation in Zone III: on one side the Government aims to promote a decentralised concept with the focus on composting and sorting of valuable fractions like plastic, metals and P&C. On the other hand, a need of centralised regional facilities and Incineration was identified (mainly by the IFIs) as the preferred option to manage the waste. In the case of zone III as a stand-alone project, the objective was to reconcile these two strategies. The unique situation in the Maldives (geographical, topographical, natural but also socio-cultural) makes the approach even more challenging. Particularly the logistics aspect of outer Island transport was identified as the most cost-intensive and the more sensitive point.

After an intensive technology, options and scenario analysis process, the preferred option on short and middle term was identified as: to start with an improvement of the Intra-island collection and transport system, using a mix of standardised receptacles (from bags to containers), the adequate vehicles (from push carts to compaction trucks) and some adjusted technologies (open bin trucks, vessel concept etc.). Main objective is to organise the transport of the waste in close receptacle continuously to a centralised Regional Facility in Tilafushi. In this Facility most of the waste will be incinerated in a state of the art manner. The focus on short-term basis is not the sorting and recycling aspects but only the efficiency of collection and transport to the central treatment place.

With increasing waste and the return of the experience of this short and middle term phase it will be possible to optimise the system for different waste fractions. The potential of valuable waste is high and there is a also an important amount of residual waste (from the WTE but also from C&D waste) which could bring an additional economic value.

On long term basis two options or scenarios are possible: To continue with the centralised waste incineration by an upgrading of the existing facility by a third line or promoting the sorting and recycling aspect in order to disencumber the WTE plant and to open other economic aspects.

Technically: The most challenging aspects is the optimisation of the collection and transport system to ensure a continuous stock feed of the WTE plant. All other aspects (Intra-Island collection and transport, RSWMF) could be considered as technically feasible and applicable.

Socially and Environmentally: The implementation of a state of the arte waste management system will definitely have a positive impact of the environmental matters in the region. The development of such a system will reduce illegal dumping and fly-tips and will contribute to higher living standards on the Islands and the cities. The development of waste infrastructure is a job opportunity and the potential to develop a formal sorting and recycling industry is existing.

From *economical* point of view, important investment leads automatically to important financial burdens for all stakeholders. On the other side the potential in the field of sorting, recycling, bi-products (electricity, processed waste from C&D, bottom ash) is so important that in middle term the return of invest could be affordable.

INTRODUCTION

Solid waste remains the most visible environmental threat. With increasing population, developing industries and activities, waste management became a major challenge in the protection of the environment. Solid waste management is in a weak state in the Maldives. Practices vary from community to community, but at most islands waste is building up into many open dumpsites spread across islands and the open burning is common. Large quantities of waste generated in Male' are taken to stockpile at the disposal site on the island of Thilafushi. The stockpile at the site is continuously burned sending massive plumes of dark smoke into the atmosphere, before open dumping in a bunded lagoon. Thilafushi Island also receives wastes from tourist resorts. Overall, there are significant potential impacts of solid waste on the environment and public health, and on the potential sustainability of tourism in the Maldives.

The waste disposal site at Thilafushi is non-engineered low lying and by far the largest solid waste disposal site in the Maldives. The site has minimal environmental protection measures.

Hence, the Government of Maldives is committed to improving waste management across the country, and adopted a national solid management policy in 2015.

The implementation of integrated waste management systems has become a priority and a necessity in many countries. In particular, the Government recognizes that the problems at Thilafushi need to be addressed urgently, and is committed to identifying and implementing solutions.

The aim of this consultancy project is to conduct a Feasibility study for the entire zone III and to conceptualise and detail design an efficient and proper regional waste management facility at K. Thilafushi.

This consultancy looks undertaking a scoping exercise of zone III islands and develop options for a new regional integrated waste management facility at Thilafushi, develop a feasibility study for the regional waste management facility for zone III as part of the national waste management strategy and prepare the designs of an engineer waste management facility at Thilafushi.

This document is the Feasibility study report of the consultant according to the proposal and the ToR.

CHAPTER 1: GENERAL

1. General Objectives

The central purpose of this feasibility study is to justify the commitment of resources (especially finances) to achieve ISWM objectives. In many instances, however, a public sector investment project may be central to achieving the objectives of ISWM. For example, if waste management facility investments are required to give effect to an action plan. In these instances, a feasibility study will be essential to prove the viability over at long term. A feasibility study must address the required aspects of ISWM in order to evaluate the overall feasibility of the proposed project.

Thus, an ISWM project must be feasible from technical, legal/institutional, social, environmental and financial perspectives. A project that fails to demonstrate viability in one of these perspectives represents a risk to the entity planning to invest in the project. If technical aspects of a project are not considered viable, on a long-term, capital investments are clearly at risk; if legal/institutional frameworks are not adequately in place, ISWM system performance will suffer and objectives may not be met. If social and environmental aspects of the project are not adequately addressed, the project may cause social or environmental disruptions that may also threaten the viability of the project; if the initiative cannot be sustained financially, it will deteriorate over time. A feasibility study therefore demonstrates how all these issues will be addressed in the project implementation. Demonstrating in a feasibility study that these issues will be adequately addressed provides an investor with confidence that the project will be successful over the long term and is, therefore, worth the investment.

2. Structure of the report

This report provides the technical and financial feasibility of the preferred integrated solid waste management system for Zone III through the application of the BPEO assessment.

The report is structures as follows:

Chapter 1 - General: This chapter discusses the aim and objective of the study along with the structure of the report.

Chapter 2 - Actual situation: This chapter provides detail on the project area, target population, waste generation and characteristics of the waste management and the waste in the area

Chapter 3 - Projection and planning: This chapter discusses the projections and design parameter elaborated for this study.

Chapter 4 - Scenario and BPEO: This chapter present the BPEO process and the outcomes, which leads to the preferred option.

Chapter 5- Scenario development: This chapter provides technical details of the preferred Regional Waste Management System including the waste collection system, transfer and treatment technology at the selected site location.

Chapter 6 - Financial Analysis: This chapter provides financial analysis of the preferred Regional Waste Management System.

Chapter 7 - Procurement: This chapter an overview of the actuals status of procurement of the project

3. Approach and strategy

Main approach was to develop an integrated SWM strategy for the zone III in line with actual National policy and the approaches throughout the world. The new policy, which was formulated in 2015, was developed to be more in line with the actual needs and developments in the Maldives in terms of social behaviour, consuming modes and of course waste generation.

Two main aspects are:

- To continue to promote the decentralization of the waste management by transferring a bigger part of the responsibilities to the Atolls, Islands but even to the citizen (polluter/payer principle)
- Renewing the policy with the 3R principles of waste : Reducing, Reusing, Recycling

Practically the waste regulations and policies needs to be strengthen with a certain number of decrees, edicts and prescription in order to be implemented in a more effective way on a local basis.

Focus of Maldives environmental and waste development programs were, the improvement of waste infrastructures and the awareness, which has conducted to positive effects, but also to major expectations in the population.

The implementation of a coherent and state of the art SWM system in the Maldives is challenging, complex and address many issues and coordination works between all the stakeholders.

The approach was:

- To consider the requirement of the NSWM Policy that all Island (except Male & Hulhumale) should have one ISWMC till 2018;
- That the chosen ISWM system should be the Best Environmental and Practical option (BPEO);
- To introduce a harmonization and a standardisation of the waste management procedures throughout the country;
- To introduce state of the art technology which had proven efficiency;
- But with a certain flexibility and adaptation to the specific local Maldivian context;
- And finally to continue to be in line with previous Feasibilities and strategies made in the Maldives with regard to the harmonisation of this complex process.

CHAPTER 2: ACTUAL SITUATION

1. Project area

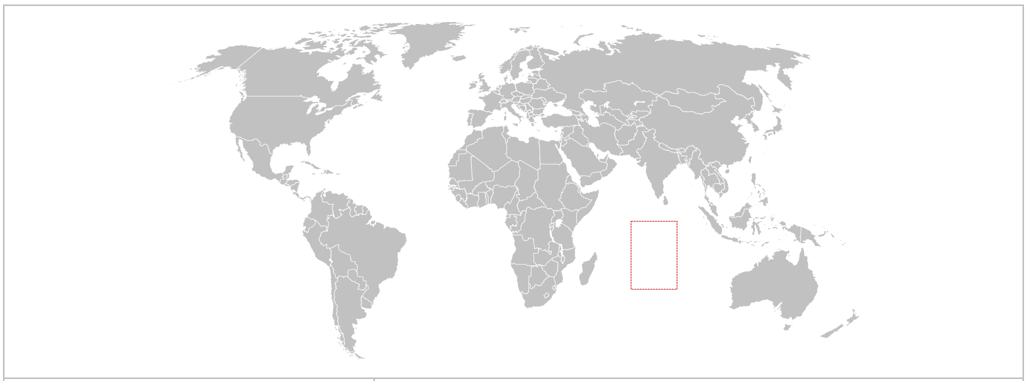
The catchment area encompasses the islands in the North Ari Atoll (Alifu Alifu Atoll), South Atoll (Alifu Dhaalu Atoll), Male' Atoll (Kaafu Atoll) and Vaavu Atoll which are zoned as zone 3 in the national waste management system.

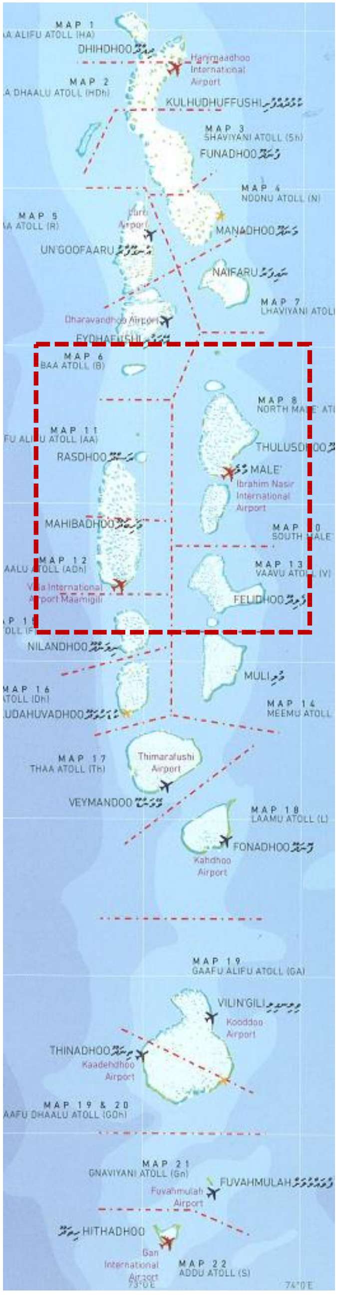
The Zone 3 has 157 used islands (including proposed resort islands) excluding uninhabited islands.

Categories	Alifu Alifu Atoll	Alifu Dhaalu Atoll	Kaafu Atoll	Vaavu Atoll	Total
Inhabited	8	10	12	5	35
Resort	13	17	44	2	76
Proposed Resort	3		38	1	42
Agricultural/fisheries		1	1		2
Airport		1	1		2
Total	24	29	96	8	157

Table 1: inhabited, resort, agriculture and commercial islands of zone III

Exact location of inhabited islands, resorts and Industrial islands within the project area are provided in Annexe 01.





1. Kaafu Atoll
2. Alifu Alifu Atoll
3. Alifu Dhalu Atoll
4. Vaavu Atoll

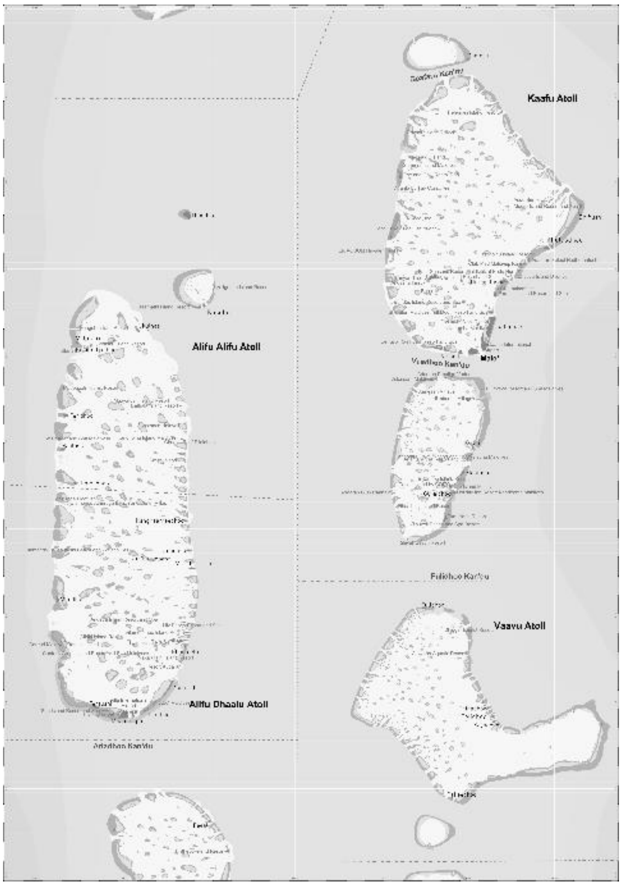


Figure 1: Location of the project area

Kaafu

Kaafu atoll is located on the eastern chain of atolls in the central region of the Maldives. Consisting of four natural atolls, the Kaashidhoo Island, Gaafaru atoll and the South and North Male' atoll, the capital of Maldives, Male' is also located within the Kaafu atoll, however Male' does not fall under the administrative Kaafu. The atoll capital of Kaafu atoll is *Thulusdhoo.*

Alifu Alifu

Located in the central region of atolls on the western chain of the double chain formation of atolls, Alifu Alifu atoll is the administrative atoll that is mainly the Northern half of the geographical Ari atoll along with Rasdhoo atoll and Thoddoo. The atoll capital of A.A atoll is Rasdhoo. Alifu Alifu has had a rapid development in their tourism industry and has the 4th highest concentration of resorts.

Alifu Dhaalu

The administrative Alifu Dhaalu atoll consists only of the Southern half of the geographical Ari atoll. Ari atoll was divided into their administrative atolls A.A and A.Dh in 1984. This atoll also has one of the four International Airports located in Maamigili and the atoll capital of A.Dh atoll is Mahibadhoo. The largest Marine Protected area is also in A.Dh atoll which covers an area of 42 Km^2. This area consists of a diverse and unique ecosystem of turtles, mantas and whalesharks, etc. It is so unique because this is the only region where whalesharks are seen throughout the year whereas seasonal aggregations are found elsewhere in the world.

Vaavu

Vaavu atoll is located South of Kaafu atoll and lies on the Eastern chain of the country comprising of the natural atolls Vattaru and Felidhe. Vaavu atoll has the lowest population in all of Maldives and has the least number of inhabited island. However, this atoll has the second largest reef in the Maldives. The atoll capital is Felidhoo.

2. Demography

Zone III is the most important zone in terms of inhabitants while hosting the greater Male' region (Male', Hulumale, Vilingili/Vilimale) and its capital Male'.

Name - Administrative Status			Population Census	Population Census	Population Census
			2000	*2006*	*2014*
Kaafu Atoll	Dhihffushi	Island	893	767	1.053
	Gaafaru	Island	849	800	1.066
	Himmafushi	Island	878	1.007	1.725
	Hulhumale'	Island	-	2.866	15.769
	Huraa	Island	703	849	1.300
	Kaashidhoo	Island	1.572	1.696	1.865
	Male'	City	67.939	92.555	127.079

Name - Administrative Status			Population Census 2000	Population Census 2006	Population Census 2014
	Thulusdhoo	Island	837	1.148	1.408
	Vilin'gili	Island	4.291	6.956	7.790
	Gulhi	Island	623	662	912
	Guraidhoo	Island	1.225	1.220	1.738
	Maafushi	Island	1.858	2.000	3.025
Kaafu Atoll			81.668	112.526	164.730
Vaavu Atoll	Felidhoo	Island	469	448	506
	Fulidhoo	Island	323	331	372
	Keyodhoo	Island	506	510	675
	Rakeedhoo	Island	237	158	106
	Thinadhoo	Island	114	55	152
Vaavu Atoll			1.649	1.502	1.811
Alifu Dhaalu Atoll	Dhan'gethi	Island	600	624	824
	Dhigurah	Island	363	420	610
	Dhihdhoo	Island	113	116	153
	Fenfushi	Island	539	560	837
	Hangnaameedhoo	Island	439	458	517
	Kun'burudhoo	Island	384	322	462
	Maamigili	Island	1.551	1.671	2.359
	Mahibadhoo	Island	1.714	1.780	2.074
	Mandhoo	Island	279	294	367
	Omadhoo	Island	638	676	883
Alifu Dhaalu Atoll			6.620	6.921	9.086
Alifu Alifu Atoll	Bodufolhudhoo	Island	458	456	608
	Feridhoo	Island	483	439	441
	Himandhoo	Island	471	515	724
	Maalhos	Island	389	248	434
	Mathiveri	Island	512	483	662
	Rasdhoo	Island	921	900	1.067
	Thoddoo	Island	1.071	1.199	1.534
	Ukulhas	Island	535	615	1.005
Alifu Alifu Atoll			4.840	4.855	6.475
Zone III			94.777	125.804	182.102

Table 2: Demography of Zone according latest three Censes

3. Climate

The climate of the Maldives is influenced by the Asian monsoon as the country lies on the equator in the Indian Ocean. The atolls in Zone III experiences a climate that is consistent throughout the country However slight variations in weather are seen. Figure 2 shows the regional variation of mean monthly rainfall in the Maldives and the line indicating Male' can be expected of Zone III. It is warm and humid throughout the year with temperature ranging between 25.5°C and 30.4°C and average relative humidity of 80%. Islands in Zone III have an annual rainfall of 1900 mm. The constant sea breezes keep the humidity relatively high. The two monsoons that govern the climate are Iruvai, the Northeast monsoon (dry season) that extends from January to March and the Hulhangu, Southwest monsoon (wet season) that extends from mid-May to November. The month of December and April are considered as monsoon transitional periods. Surface currents and winds, humidity, rainfall, temperature and salinity are strongly affected by the monsoons.

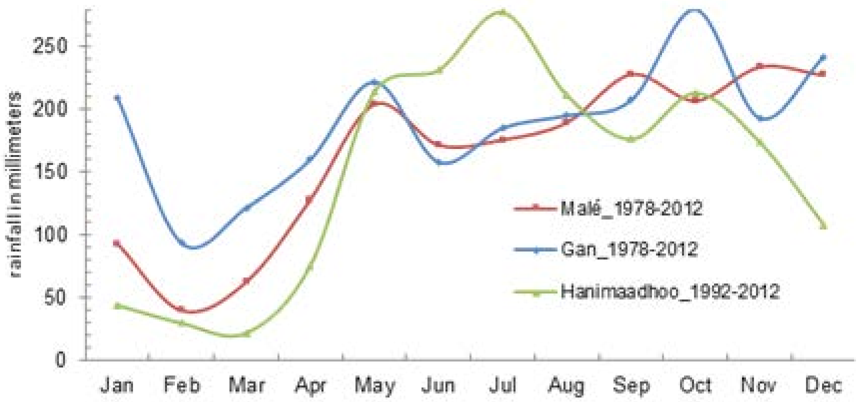


Figure 2: Regional variation of mean monthly rainfall in the Maldives

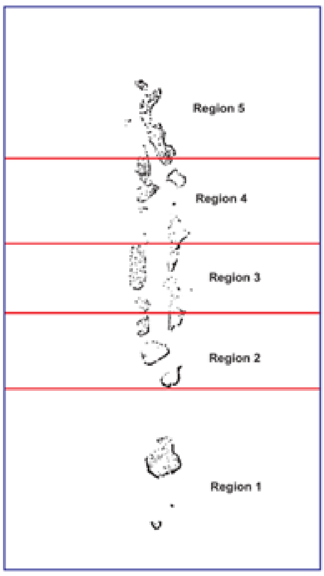


Figure 3: Regions to capture Cyclones passing through Maldives for Hazard zoning

The major climate hazard that the Maldives is exposed regularly are windstorms, heavy rainfall, drought, sea swells, and udha. Most serious among these are the swell waves, heavy rainfall and windstorms because of their high frequency and great potential for causing damage by flooding, erosion and other impacts. In addition to these, tides and storm surges can be extremely destructive if there were combined. Heavy rain and strong winds are generally brought in by the Southwest monsoon.

Maldives is located outside the normal cyclonic zones and thus violent storms are rarely expected. However the Northern atolls are affected by weak cyclones that are formed in the southern part of the Bay of Bengal and the Arabian Sea. Zone III lies in between region 4 and region 3 of the 5 regions of cyclone hazards categorized by disaster risk assessment profile by UNDP. Figure 3 shows the 5 classified regions for cyclones passing through Maldives. There were 21 cyclonic disturbances within the 500 kilometres radius during 1877-2004 with an average speed of 28 knots and Maldives has not been affected by cyclones after 1993.

4. Socio-Economics

Tourism and fisheries are the two main industries in the Maldives that are heavily dependent on the reefs and the sea, which is the main resource for the country. Tourism is the largest economic activity in the country, which accounts for 30.2% of the GDP and especially in atolls located in zone III as they have high concentration of resorts. The government has leased new islands from the A.Dh atoll for tourism development and agriculture. This aims to create more job opportunities for the locals. The number of inhabited islands with smaller population has become one of the main development challenges of the atoll. In this regard, relocation of people from smaller islands to larger islands has now become one of the priorities of the government. This work has intensified after the devastating Indian Ocean tsunami of December 2004. The relocation of M. Madifushi people from Madifushi to Maamigilli was completed in 2005 after the 2004 tsunami.

Aside from tourism and fisheries, some islands also have allocated large areas for agricultures. Such an island is A.A Thoddoo with a population of 1,320. Another reason for the population influx and settlement is these atolls is the Villa International Airport located in the island of Maamigili as it serves as the hub for the region. Aside from Vaavu atoll, the region has seen a lot of economic development with increase in resorts and residents in the inhabited islands.

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The income poverty outlined in the Poverty and Vulnerability assessment 2004 shows the atoll average the national index for income poverty. The index is measured on a scale of 0-1, where higher score signifies higher vulnerability.

Atoll	Headcount ratio, percentage of the population with less than MRf. 15 per person per day	Average income of the population with less than MRf. 15 per person per day (MRf)	Income poverty index
Maldives	21	10.6	0.10
Male’	3	11.0	0.01
Kaafu (excluding Male’)	23	10.5	0.11
Alifu Alifu	36	10.8	0.16
Alifu Dhaalu	24	10.5	0.12
Vaavu	15	11.4	0.06

Table 3: Income poverty (Ministry of Planning and National Development, 2004)

Health care centres are present in most of the inhabited islands of these atolls to provide pharmaceutical drugs and to treat simple ailments. At least one well-equipped hospital is present in each of the atolls. Each one of the inhabited islands provide education at different levels. The number of schools, teachers and students are given in the table below.

Atoll	no. of schools	no. of students	no. of teachers
Kaafu	57	33,201	2,546
Alifu alifu	17	1,772	214
Alifu dhaalu	20	2,138	277
Vaavu	6	348	65

Table 4: Number of schools, students and teachers in Zone III

5. Urban Development of Male’ and Hulhumale’

Hulhumale’ is the reclaimed island located 8 km off the North East Coast of Male’ and 6.5 km from Velana International Airport, Hulhule’ in Kaafu atoll. This project was aimed to relieve the congestion and housing crisis in Male by plans to accommodate the growing population with a design incorporating both urban and island life. Population of Hulhumale’ reached 30,000 in the year 2013 and has been increasing since. This project can accommodate two thirds of the entire population of Maldives.

The housing crisis in Male’ has worsened over years by internal migration from smaller, poorly developed island for better education, employment and healthcare. While there is some amount of inter-atoll migration, Male’ is the main destination for both temporary and permanent migration in the Maldives. Figure 3 shows the growth of Male’ population as a percentage of the total population. When the census was undertaken in 1911, Male’ accounted for about 7.25 percent of the total population of the country and now it has risen to 42% of the total population as of the 2014 census. The extreme congestion and housing crisis has social consequences such as land availability and decrease in quality of life.

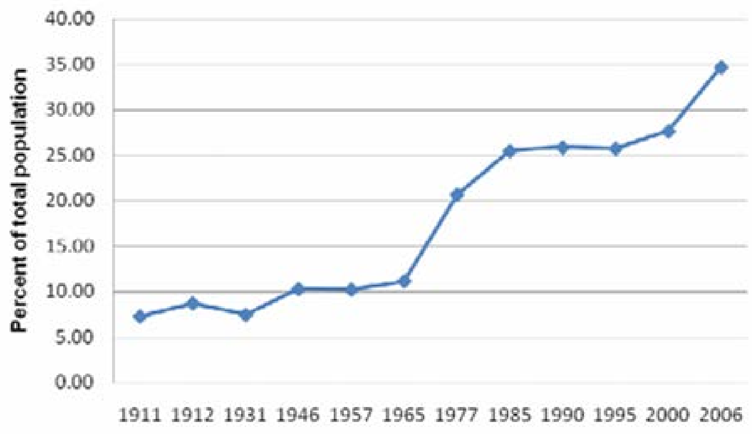


Figure 4: Growth of Male' Population as a proportion of the total population

In Maldives as in other small island developing states (SIDS), internal migration and growth of a large urban centre (Male') can be attributed to spatial inequality due to urban bias in the availability of economic opportunities and provision of services and income disparities between Male' and other atolls. With the current trends of population increase in the urban centre of Maldives and the plans of population consolidation such as Hulhumale', the population is expected to rise. Therefore, with the increase is population influx of Kaafu, Alifu Alifu and Alifu Dhaalu atoll, Zone III will have more developed economies and industries which would be crucial to the growing population in this area.

6. Catchment area and specific considerations

The Maldives with a conglomerate of approx. 1,200 Islands present a unique challenge in the field of planning a functional and sustainable SWM system. The islands could be mainly divided into four categories:

Category 1: the inhabited Islands: These islands are mainly populated by Maldivian citizens. Closely spaced islands forming a "ring shape" are commonly characterised as an atoll. The most populated Island is the atoll capital. For administrative purposes, the Maldivian government organised these atolls into twenty-one administrative divisions. In the field of waste management, these administrative divisions are grouped again into seven waste catchment areas or zones.

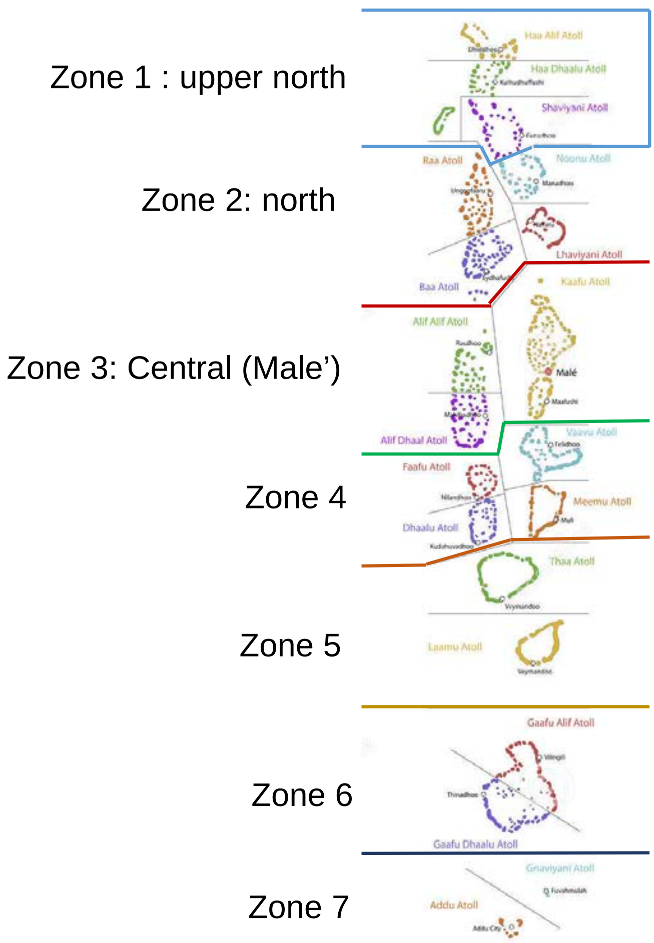


Figure 5: Waste management catchment areas in the Maldives

The project area Zone III compasses 4 atolls. Most of inhabitant islands in the Maldives have a rural character and are defined by single storey and single-family housings. Most of the roads are not asphalted and the economic activities are poor. Atoll capitals are more developed and have all basic infrastructures. Islands with more than 1,500 inhabitants have been more urbanized with some paved main roads. Only few Islands are heavily urbanised. In zone III, *the Greater Male* region is presenting an exception.

Category 2: the resort Islands: These islands are dedicated exclusively for international and a few national brands of hotels and resorts. All resorts have their own facilities and services.

Category 3: the industrial and commercial islands. Some islands are dedicated for industrial and commercial purposes. In zone III, main Industrial Island is Tilafushi, which is also the preferred location for the future RSWMF. These islands have not been developed for habitation purposes and consequently have not the character to host citizens for living, but it cannot be excluded that some people (foreign and native workers) lives there. Airport Islands (f. ex.: Velana International airport Hulule', which is the main airport for the Maldives and Male') could be considered also in this category.

Category 4: the uninhabited Islands. These islands are characterised either by their small surfaces to create acceptable living conditions or by their unexplored nature. Some of these islands have been foreseen for future economic development (industrial Island, Resort Island) or for migration/resettlement due to climate change hazards (Tsunami, etc.).

Considering the geographical, demographical and specific aspects of this zone, the catchment area was divided into 4 subzones:

- *Zone III a:* The northern part of the Kaafu atoll (except Greater Male' region)
- *Zone III b:* The southern part of the Kaafu atoll (except Greater Male') and the Vaavu Atoll
- *Zone III c:* The Alifu Alifu Atoll and Alifu Dhalu Atoll
- *Zone III d:* The Greater Male' Region (Male', Hulumale', Vilingili/Vilimale') and some of the nearby resorts and islands (Tilafushi)

The zoning is presented in the following figure:

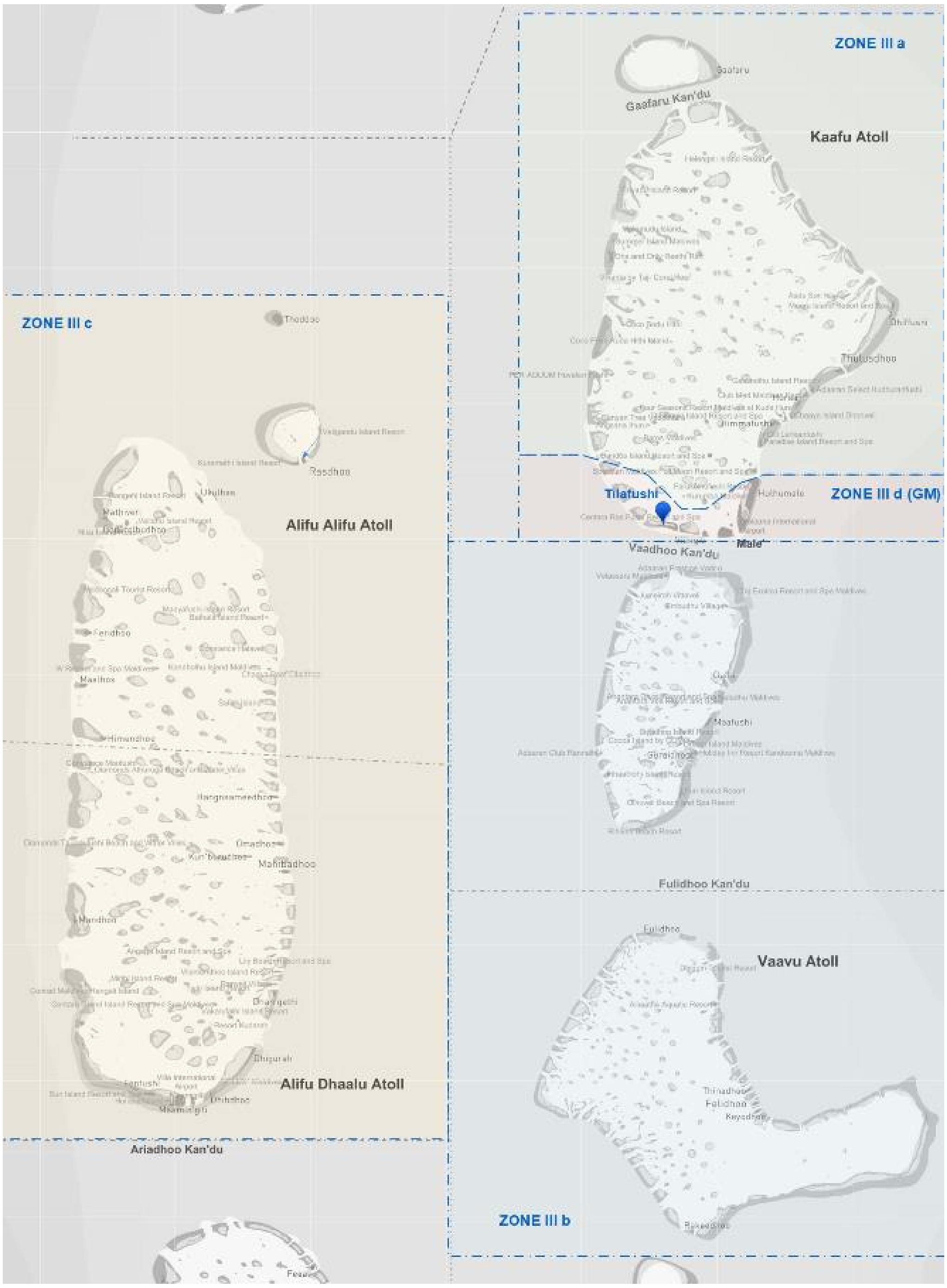


Figure 6: Zone III waste catchment area and sub-zones

7. Legal and institutional analysis

7.1. National Solid Waste Management Policy

The first National Solid Waste Management Policy was developed in 2008 by the former Environment Research Centre of the Ministry of Environment, Energy and Water (currently EPA), to address the issue of solid waste management in the Maldives, so as to create a healthier environment. The policy was developed through consultations with the community and after intensive research on the existing waste management practices at the time.

This first policy was adapted to continuous changes and needs of the country in terms of development and social behaviour, and therefore a *new policy was formulated and adopted in 2015*.

A set of strategic and governance principles which also represent universally accepted practices for waste management lay the foundation for this.

The key fundamentals of the policy are:

Policy 1: on an individual level, all individuals take responsibility for the waste that he or she generates, and this should be in accordance with the regulations set out by the municipal council or the relevant authority where the individual is present in at a given time.
Policy 2: on a household level, a household deals with the waste generated by the household in accordance with the regulations set out by the island council or the relevant authority that the household falls under
Policy 3: in every inhabited island, the residents of the island along with the island council coordinate in developing a waste management plan for the island, proposing this plan to the relevant authority, and implementing this plan once approved by the relevant authority.
Policy 4: in accordance with the procedure whereby fees are collected for household waste collection, fees will be collected from every household, business, and other institutions. The collected fees will be used to fund the waste management systems.
Policy 5: under an agreement, government utility companies that operate on an island will be facilitated in undertaking waste management on that island.
Policy 6: on inhabited islands, a waste management system should be developed that is representative of the waste generated on the island, and the relevant facilities needed for the island's waste management system should be provided by the government.
Policy 7: for waste management purposes, Maldives will be divided into regions; an island within each region will be allocated for waste management of the region and a waste management system will be put into practice on this island and all relevant facilities will be provided by the government.
Policy 8: on inhabited islands, the waste management plan of the island should include a mechanism to remove leftover waste after the waste management process is carried out.
Policy 9: on instances where waste management can be utilized in generating revenue, emphasis should be given in using the generated revenue in the waste management operation, and this should be facilitated.
Policy 10: nationwide awareness and training should be provided on proper waste management practice

Goals to be achieved through implementation of waste management policies:

- Renewing the 3R concept and spreading awareness of the concept in the Maldives with the intention of reducing waste
- Raising awareness on proper waste management practice in all levels of the community
- Establishing the Ministry of Environment and Energy as the regulatory body for all aspects of the national policy on waste management in the Maldives and establishing a mechanism to monitor the operation of the waste management systems in the country
- Developing a waste management plan in all inhabited islands of the Maldives and carrying out waste management in the islands according to the relevant plan
- Developing a legal framework relating to waste management and carrying out waste management in accordance with this framework
- Evaluate regulations regarding the management of clinical and infectious waste and hazardous waste, and begin managing these types of waste accordingly
- Collect statistics related to waste on an island level and national level and make this information available to the public
- Developing a mechanism to collect waste management fees from sources of waste generation
- Developing a waste management system for all inhabited islands that are best suited to the specific needs of the island, providing any required equipment and facilities to realize the waste management system, and implementing this in practice.
- Training the relevant staff to sustain the waste management systems
- Creating an inventory for the waste management systems on all inhabited islands and keeping this inventory up to date
- Divide the Maldives into regions for waste management purposes and establishing a waste management facility for each region
- The transfer of leftover waste from islands to the respective regional waste management facility in accordance with regulations and proper management of these leftover waste at the regional waste management facilities
- Conducting research on cutting edge technology for waste management
- Emphasizing on the development of waste management plans in industrial islands and monitoring the progress of these islands in implementing the waste management plan
- Establishing a National Trust Fund for waste management

7.2. Solid Waste Management Regulation 2010

The Solid Waste Management Regulation was drafted by the Ministry of Housing and Environment in 2010 and *has been officialised in 2013* with the aim of implementing the first National Solid Waste Management Policy formulated in 2008. The administrating authority for the regulation was identified as the Environmental Protection Agency at the national level and island/city councils at the provincial level. Implementation of the Solid Waste Management Regulation will aid to protect the environment through:

- Minimizing the impact of waste on the environment including, in particular the impact of waste so far as it directly affects human health;

- Establishing an integrated framework for minimizing and managing waste in a sustainable manner; and
- Put in place uniform measures to seek to reduce the amount of waste that is generated, and where waste is generated, to ensure that waste is reused, recycled and recovered in an environmentally sound manner before being safely treated and disposed.

Parts II, III, IV and V of the Regulation provide detailed clauses on the following in the respective order:

Part II – Waste management measures. This part highlights detailed clauses on waste management standards and plans, declaration of priority wastes, extended producer responsibility, prohibition of unauthorized disposal of waste, littering, collection containers in public places, waste collection at sea and waste collection facilities at ports, reduction, reuse, recycling and recovery of waste, waste management activities list and restrictions on provision of waste management services.

Part III – Waste Management Licenses. This part gives detailed clauses on waste management licenses, license periods and licensing requirements, standards to be observed by licensees, bundling of services and transferring or surrender of license, waste management license fees and how to charge the relevant fees, financial securities and the license register.

Part IV – Transportation of waste. This part gives detailed clauses on duties of persons transporting waste and duties of receivers of waste, export and trans-boundary transportation of hazardous waste, transportation of waste from one island to another and accidents at sea.

Part V – Monitoring, Inspection, Auditing and Enforcement. This part gives detailed clauses on duty to furnish information and duty to report, notice from the Administrating Authority requiring a review of activities carried out under a license, revocation of a license, defrayal of Administrating Authority costs, register of fines and administrative actions, Inspectors, establishment of a national waste information system and National waste management status reports.

In Conclusion: the National Waste Management Policy (of 2015) and the Solid Waste Regulation (of 2013), sets out the key principles to guide approaches and meet the worldwide-accepted statutory objectives for waste management.

These are summarised below:

Figure 7: Waste Hierarchy

Waste Prevention: The Maldivian Government should working on to promote programmes on waste prevention and minimisation. These are aimed primarily at producers of commercial and industrial wastes. In addition awareness campaigns should be developed to facilitate a major waste prevention campaign aimed at household wastes.

Reuse and Refurbishment: Major reuse and refurbishment opportunities exist in the management of end-of-life furniture, electrical and electronic equipment (including household appliances), and other products. These can provide significant business and employment opportunities, as well as potential training and social inclusion benefits for low or unwaged people.

Recycling and Composting: Recycling and composting are the primary means of maintaining the value of end-of-use materials. For these options to be viable, two core issues must be addressed. Firstly, the materials must be capable of being recovered in a form in which they can be used. Secondly, there must be a demand for the products.

Energy Recovery: The recovery of energy from waste materials is a beneficial part of integrated resource management and can take many forms, including conventional techniques, such as mixed waste incineration, or using alternative technologies including gasification, and pyrolysis.

Disposal: At the end of the hierarchy is safe disposal. Although this remains the least desirable option for waste, significant progress should be made in developing better-engineered landfill sites for the future.

Proximity and Self-Sufficiency: The proximity and self-sufficiency principles require waste to be dealt with as close as possible to where it is produced.

Polluter Pays: The potential environmental and human costs of waste production, treatment and disposal should be reflected in the price of products and in the charges made for waste management services. The objective is to provide a fair system and one that discourages producers from generating waste in the first place.

Best Practicable Environmental Option: Taking the preceding principles together, the Strategy proposes that choices on waste management should be made in accordance with the principle of the Best Practicable Environmental Option (BPEO).

The achievement of this objective is feasible since the NWMS promotes the implementation and enforcement of the waste management hierarchy, meaning that prior investments in waste infrastructures will have to go for waste minimization, separate waste collection at source, reuse, recycling and recovery, and drastically reduce the amount of waste to dispose of.

In practice, much of the early progress in increasing recycling and composting will be achieved by widespread provision, by relevant waste authorities, of segregated waste collection services and mechanised post collection separation across the Maldives.

A new concept was also introduced through this strategy, based on regional waste disposal infrastructure. What the strategy suggests is to leave behind the concept of "1 Island-1 dumpsite" and move to at least *1 Solid Waste Management Facility per region/Atoll*. Municipalities/Islands under the same Atoll have to make agreements for where to build the Facility, how to manage it, how to make it financially sustainable. This will save space, investments, environmental impacts, etc.

7.3. Maldives Tourism Act

The Parliament enacted Law No. 2/99 (Maldives Tourism Act) outlines the regulations for the protection and conservation of environment in the tourism industry.

The regulation inherent to this law is the *Regulation on the Protection and Conservation of Environment in the Tourism Industry*. The objective of the regulation is to protect the environment related to the tourist industry and to encourage and facilitate sustainable development of tourism. This regulation became into effect on July 20, 2000.

This regulation on the tourist industry covers any island leased for the development and operation for a resort, hotel, guesthouse, yacht marina, and islands leased under the Maldives Uninhabited Islands Act (Law No.20/98) and all other places and facilities registered under.

Section 5 of this regulation addresses the provisions *concerning solid waste management* for the tourism sector. Among the requirements of the regulation are:

- Waste collection bins with lids are to be placed for convenient use on leased tourist properties such as resorts.
- The components of discarded wastes (food, glass, metals, toxic or hazardous materials) are to be separately collected.
- Waste disposal is to be done in a manner that will have the least impact on the environment.
- All tourist resorts have to use incinerators, compactors and bottle crushers.
- Waste is to be disposed in the designated in a region or, in the absence of a designated area, disposed in a manner that is least harmful to the environment.

- Food and other biodegradable wastes may be dumped in the sea in the absence of a designated area for waste disposal in a region. Ocean dumping of biodegradable waste is to be done in the sea outside an atoll. The dumping is to be done taking into account wind and water currents so that it will not land on the shores of islands.
- Waste burning is only to be done in an incinerator, which means open burning is prohibited.
- Combustibles such as plastics that may produce noxious emissions are not be burned but rather separately collected and delivered to a designated waste management area.
- Monitoring data on vessels, including the capacity and proper logs on trips made for waste disposal in an island or part of it leased for tourism purpose, are to be maintained.
- Tourist vessels such as safari boats are to have a system for waste collection and storage until such waste can be taken to a designated place for waste management.

7.4. Stakeholder analysis

A large number of stakeholders have an interest in, or may be affected by, waste management. The principal stakeholders and their roles in the process of developing and implementing the measures to achieve compliance with state policies and legislation on waste management are identified below.

The Ministry of Environment and Energy takes the lead for overall regulatory framework for all types of waste. It cooperates with the Ministry of Housing and Infrastructure for construction for demolition waste and car scrap metal, with the Ministry of Health for hospital waste, with the Ministry of Economy, and Trade for industrial and bulky waste and with the Ministry of Tourism for resort waste.

The Islands/Atolls are the main responsible body for the waste management collection and transport for their own municipal waste by the *Decentralization Act of 2010* *(chapter 24)*.

Key stakeholder	Comment
Public sector	
Regional/Atoll Council	Main actor for the implementation on the Integrated waste management system on regional level
Island council	Main actor for the implementation of the facilities such as Island Waste management centres.
City council	(Special form of an Island council): some of the Islands have the status of a city (due to the size and level of urbanisation). These are special administrated areas with more autonomy.
WAMCO	Main public operator of SWM
Civil society	
Island Inhabitants	Main beneficiary of Waste management improvement

Primary stakeholders	Comment
Public sector	
Environmental Protection Agency	Main stakeholder for monitoring, control, environmental permitting. Institution belonging to MEE
GMEIWMP	PIU/Greater Male Environmental Improvement and Waste Management Project (ADB Financed)
Civil society	
Environmental groups	Non-governmental Organisation responsible for awareness and multiplication of information
Journalists/media	Responsible for awareness and multiplication of information
Sorting & Recycling corporation/Informal sector	Important Chain-supply actor and part of the waste management system. Informal sector are mainly foreigners. Sorting and recycling corporation are not existing yet but could be created in future.
Private sector	
Technical advisors	International or national experts supporting the implementation of the program through technical assistance, training etc.
RSWF Operators	Private investor or Private companies responsible for the operation and transfer know-how of the Regional solid waste Management facilities (in cooperation with public company or public owner)

Secondary stakeholder	Comment
Public sector	
Ministry of Environment and Energy (MEE)	Legal framework and conditions Strategy development Project development and Mobilization of funds Owner of the Main SWM facilities
Ministry of Housing and Infrastructure (MoHI)	Permitting and land reclamation issues, strategically consultation, coordination actions
Ministry of Finance and Treasury (MoFT)	Mobilization of national and additional funds Administration of funds
Ministry of Tourism	Supporting actor, strategically consultation, coordination actions. Responsible body for resorts
Political decision makers	Supporting actor, project and strategy development

Secondary stakeholder	Comment
Civil society	
Schools	Beneficiary of awareness campaign. Actor for sustainability of the project
Mosques and religious councils	Responsible for awareness and multiplication of information
Private sector	
International consultants	International supporting the implementation of the program through design, tendering, work supervision, practical training etc.
Private operators	Private investor or Private companies acting in the field of waste management (other than the operation of the facilities: for example waste collection, waste transfer and transport etc.
Private service providers	Private companies acting in the field of Waste management or Energy services. For example: Awareness, Public relations, energy connection, maintenance etc.
International funding Institutions	
International funding Institutions	Asian Development Bank Country-specific aid and funding programs (JICA, GIZ, etc.) IRENA Islamic Development Bank World Bank Etc.

An overview of the main stakeholders in SWM in the region is presented in the following

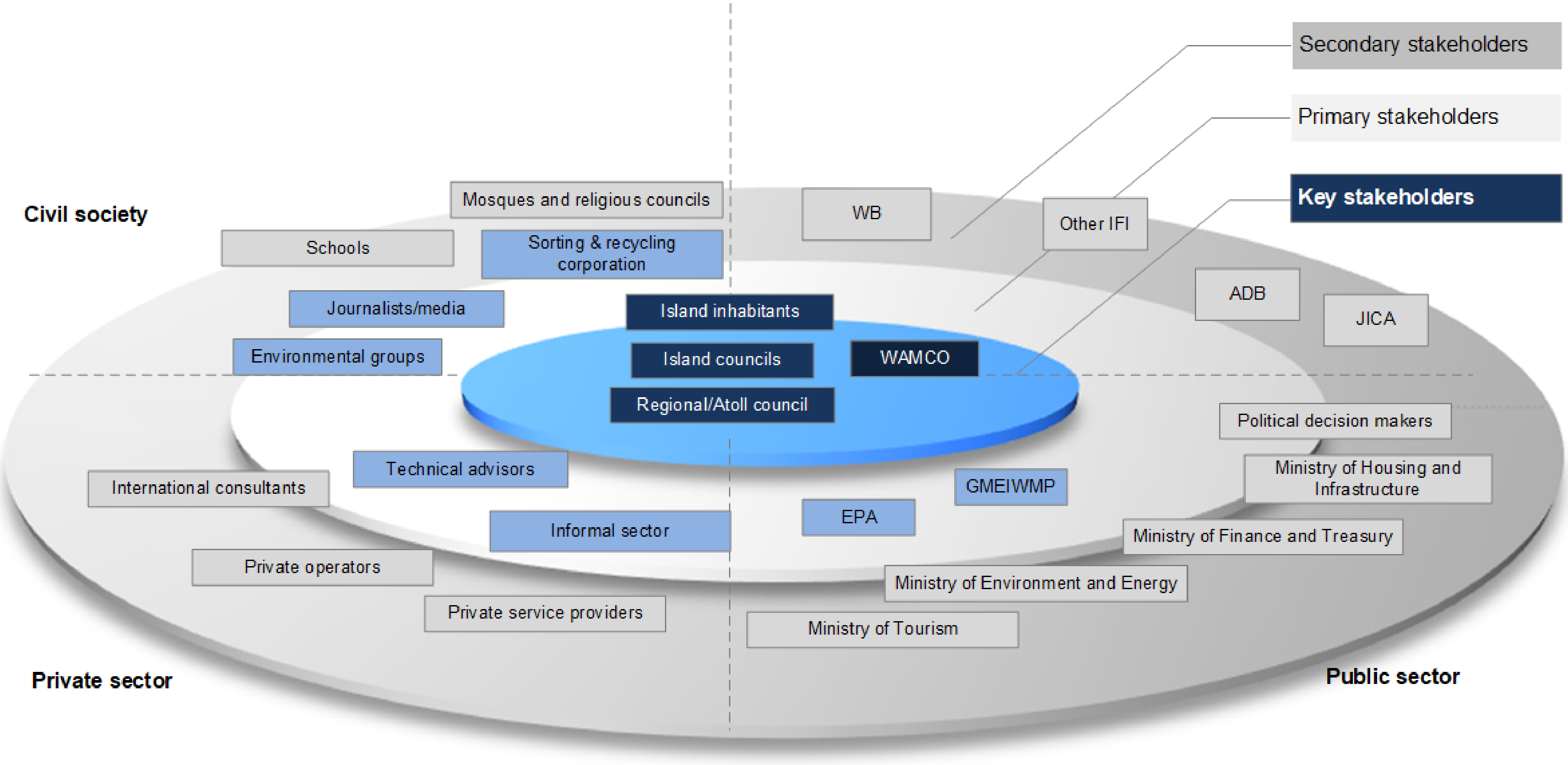


Figure 8: Stakeholders

7.5. General Administrative Framework

Knowing about the relationship of the different actors and the complexity of the system is to know about the situation of the solid waste management in the country. The following figure shows the interaction of the different institutions in the field of SWM in the Maldives and the interfaces.

The influence of the private sector is actually negligible.

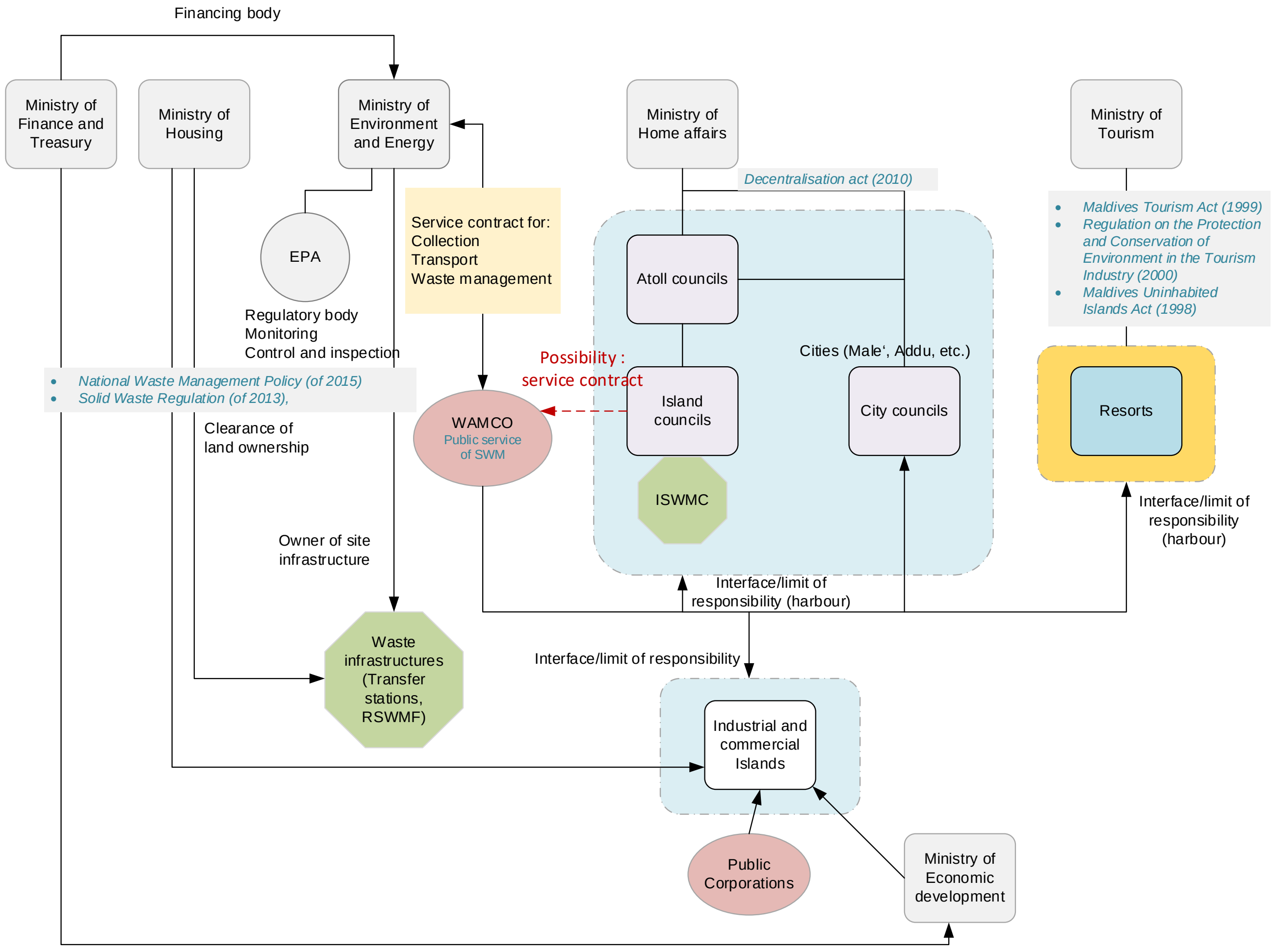


Figure 9: interaction and interfaces between different public institutions in SWM

7.6. National Government Institutions

National government institutions are ultimately responsible for achieving and maintaining compliance with state policy and legislation on waste management. They have a duty and obligation to secure compliance in a manner and within a programme either stipulated in the relevant legal instrument. They are also responsible for developing and implementing national waste management strategy.

The *Ministry of Environment and Energy* (MEE) is the main institution involved with waste management, waste project preparation and prepares and publishes reports for the implementation of the waste law and the related DCMs.

Preparation of permits conditions for waste related infrastructure and activities, are undertaken by the *Environmental Protection Agency* (EPA).

The Environmental Protection Agency (EPA) is a central public institution responding to the MEE whose jurisdiction covers the whole territory of Maldives through its central office. Being the implementation arm of the MEE, EPA is in charge of the National Environmental Monitoring Programme, drafting of annual State of Environment Reports, advice to local governments related to environmental policy, establishment and management of environmental information, ensuring public environmental information and access to decision making, ensuring implementation of the environmental liability principle, etc. All of the above duties apply on environmental issues in general and on waste issues in particular.

The EIA Regulation of 2007 describes the waste related facilities and activities that need an environmental permit. EPA will prepare the permit conditions for most of them. EPA is also involved with the EIA process for waste related facilities and activities.

Concessions can be issued by the contracting authorities, between other activities, for collection, transport, processing, and management of solid waste. The contracting authority is any ministry or Atoll, which is responsible for the economic activity for which the concession is issued. Following its mission f. ex. the MHI (Ministry of Housing and Infrastructure) is the contracting authority for the concessions of economic activities under its responsibility, i.e. public services, including waste management, too, therefore for waste concession projects. This is to be decided by the Council of Ministers.

The Ministry of Tourism administers the regulations specifically directed at waste management in the resorts, which were promulgated in response to Law 2/99, and are known as the Regulation on the Protection and Conservation of Environment in the Tourism Industry. For the tourism sector on a national level there is monitoring on compliance of the MoTAC regulations. Tourist resorts are visited annually by MoTAC staff. Unfortunately, the expense of visits to resorts are paid for by the resorts, which means that the resorts have amply advance notice of a visit and are thus able to correct any non-compliance issues in advance of the arrival by MoTAC monitors. The only other monitoring system identified was the waste tracking program at the Thilafushi disposal site. A program to log delivery of waste to the site was instituted by WAMCO. The objective of the log is to be able to account for the use of the unloading dock, which is used as the basis for assessing a charge to the entities that deliver waste to the site.

7.7. WAMCO

The Waste Management Corporation Ltd (WAMCO) is a state-owned enterprise created to implement an environmentally responsible and sustainable solid waste management system in the Maldives. On the 14th July 2015, the corporation was revived with the appointment of five members to its board. On 1st January 2016 the Ministry of Environment and Energy entrusted the waste transfer and disposal functions of Greater Male' to WAMCO.

The core business is the collection, transport and the management of household (municipal and communal) waste, industrial, and construction waste, as well as bulky household waste in the catchment area.

The company is responsible in their catchment area for:

- Determination of waste management fees
- Household waste collection and transport
- Support to the recycling activities
- Disposal of household waste
- Disposal of medical waste and industrial waste
- Monitoring and control of all waste management activities (as self-control)
- Public relations, information and waste advisory service (including support for the municipalities and communes)

Organisational Structure

The organisation of the WAMCO, encompass the following decision making bodies:

- The Board of Directors is the main organ of WAMCO and it can hold regular or extraordinary meetings. All members of the BoD can participate in the meetings.
- The Managing Director is responsible for the general management of the Corporation.

Administrative Structure

The administrative structure consists of:

- Corporate Affairs Department: general management, administrative affairs, human resources, business development, marketing and PR
- Operations Department: planning, operations, monitoring
- Logistics and Maintenance Department: Logistics, Procurement and Maintenance
- Finance Department: financial management, commercial activities, contracting

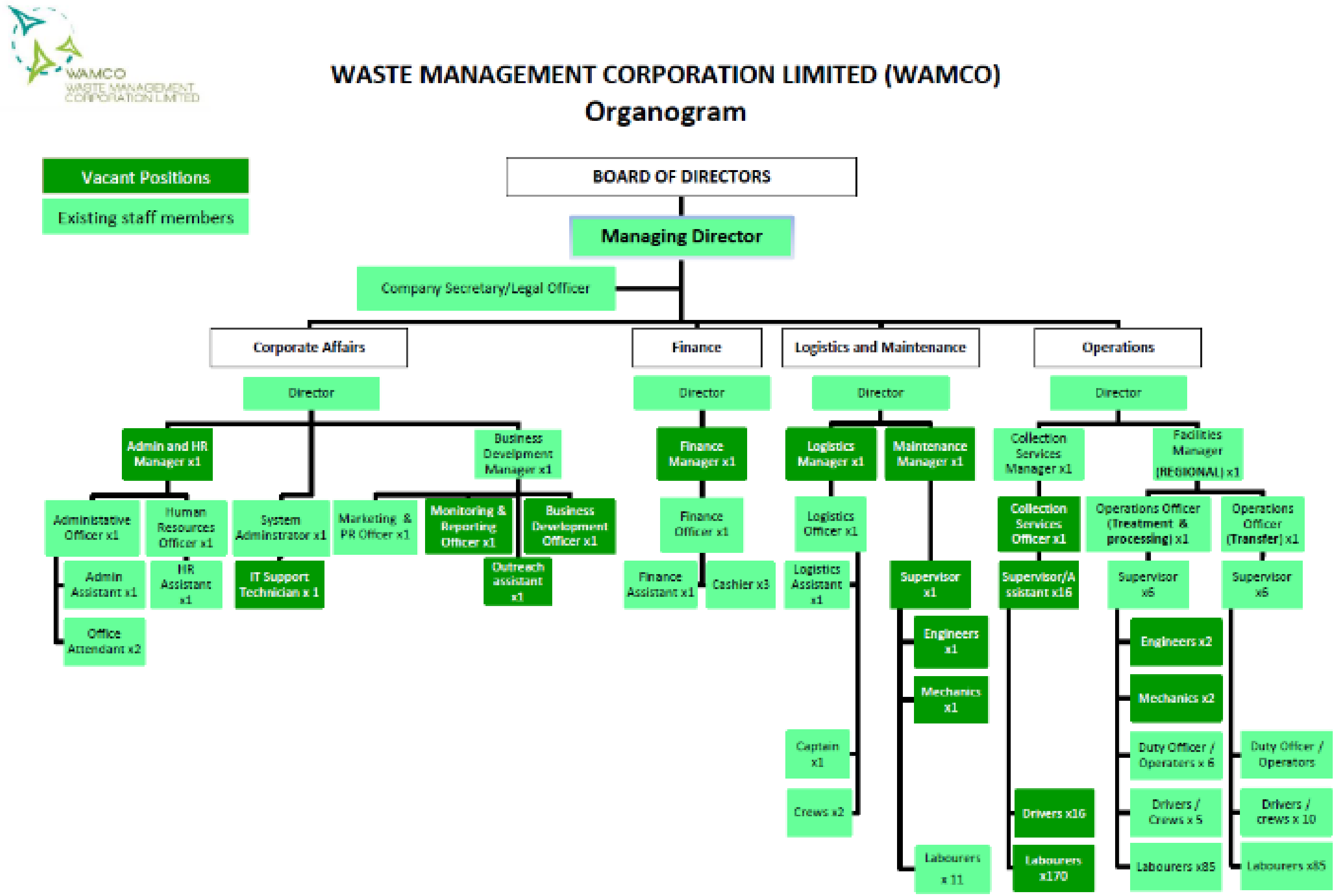


Figure 10: WAMCO actual management chart

7.8. Private sector involvement

The system of waste collection for the recycling business is mainly informally organized. Foreigners were mainly dominate the business in Male'. These individual collectors for all type of recyclables and for HH waste are un-equipped according H&S requirements, un-trained and have no formal agreements with their scrap buyers. With increasing waste and waste potential the situation became attractive to International NGO's (Parley) and local private parties. Since the start of WAMCO in January 2017, recycling starting to get more organised on a national and public level. Since July 2017 foreigners are banned officially from waste collection system.

7.9. SWOT Analysis

Strength

S

- A readapted SWM Policy
- A national waste management initiative – Saafu Raajje Initiative
- A public corporation for waste management : WAMCO
- Awarness and ownership
- International fundings
- Community participation

Weakness

W

- Anthitetic strategies (ISWMC vs RSWMF)
- Lack of clear responsibilities/interfaces
- Legal implementation procedures (Decrees)
- Lack of National standards and norms
- Insufficient National funds
- Limited technical capacities

Opportunity

O

- Increased foreign investment in Environmental sectors and promotion of private investment by Locals
- Better matching of waste collection systems to processing
- Strategies and market development for recyclables
- New jobs on island level
- Creating feedback mechanisms and best practice cases for further development

Thread

T

- Rising sea level, land scarcity
- Change in political priorities
- Inefficient collection schemes may create negative backlash from residents.

Figure 11: SWOT analysis of Zone III SWM system

8. General Waste management

The waste management system in the Maldives and consequently in the project region is under a permanent improvement. With the development and the actualisation of the waste management legislation, all islands and resorts are now in the responsibility to implement, with the support of the government, an integrated waste management.

8.1. Inhabited Island

The lack of a waste management in zone III present challenge to the inhabited islands. In most of the islands, waste disposal practices are inadequate, with random dumping of waste being widespread. Waste collection services are carried out individually or through community private entities.

Figure 12: waste collection at Ulhukas (Alifu Alifu atoll).

Household waste is deposited by the households in front of the door, loosely (bottles, paper) or in not standardized receptacles like old paint bins. The waste is then collected by an open dump truck. Depending on the size of the island and their capacities, the truck is manned with 240 l bins which carries the waste to the municipal dumpsite or to an ISWMC. In case of very small islands, the waste is brought individually to the municipal dumpsite (by hand, pushcart or wheelbarrow).

The most common method of disposal from households include disposal of waste to designated waste management area (dumpsite) at the island. The other methods of disposing waste including dumping to beach, burning at household backyard, disposing at the beach to reclaiming the island or burying at the household compound.

Figure 13: Land reclamation by waste deposit

Figure 14: Waste Management Site at Guraidhoo in South Male‘ Atoll

In Zone III the implementation of Island Waste Management Centres is still ongoing and slow. Island capitals were manned by the “first generation” of Island Waste management centres. However, due to the lack in the design of these infrastructures (under-dimensioning, wrong site allocation, etc.) they have not been operated properly and became uncontrolled dumpsites. Island waste management centres generally consists of :

- an allocated fenced area
- with a concrete platform for composting
- Concrete or masonry wall boxes with a steel shed for the storage of sorted fractions like plastic bottles, metal cans, paper, sometimes also Electronic waste

Bigger Islands and Island capitals have been provided additionally with a small-scale incinerator. The equipment of the ISWMC consists of a baler, a glass crusher, a metal can crusher and a wood copper.

Figure 15: example of an ISWMC of the 1st generation

First generation of ISWMC are under-dimensioned and present some technical lacks (access areas for vehicle not planned well, too small, storage capacities not sufficient). They do not have any administrative and social facilities. The second generation of ISWMC (from 2011-2015) have been built with more space for vehicle access, storage and composting but they present still some technical lacks. The third generation (from 2016 upwards) have additional social and administrative facilities. This type of ISWMC is actually *not existing* in Zone III.

Figure 16: example of an ISWMC of the 3rd generation (South atoll)

Main difficulties for the Islands is to find a customer for the sorted fractions. Most of the time the boxes are overloaded which leads to a decrease of sorting motivation. Compost is made on low scale level in quantities sufficient for self-sufficiency. Composting is estimated as 20% of the island household waste, while plastic and metal cans are around 10%. Residual waste is dumped under the conditions presented before.

The actual situation for the implementation of the ISWMC is presented in the following table:

Name - Administrative Status			IWMCs				
			Build and operated	Build but not operated	Under construction	planned	not planned
Kaafu Atoll	Dhihffushi	Island					✓
	Gaafaru	Island					✓
	Himmafushi	Island					✓
	Hulhumale'	Island				transfer station	
	Huraa	Island	✓				
	Kaashidhoo	Island					✓
	Male'	City				transfer station	
	Thilafushi	Island				RWMF	
	Thulusdhoo	Island					✓
	Vilin'gili	Island	✓			transfer station	
	Gulhi	Island					✓
	Guraidhoo	Island					✓
	Maafushi	Island		✓			
Kaafu Atoll			2	1		4	7
Vaavu Atoll	Felidhoo	Island					✓
	Fulidhoo	Island			✓		
	Keyodhoo	Island					✓
	Rakeedhoo	Island					✓
	Thinadhoo	Island					✓
Vaavu Atoll					1		4
Alifu Dhaalu Atoll	Dhan'gethi	Island		✓			
	Dhigurah	Island	✓				
	Dhihdhoo	Island					✓
	Fenfushi	Island	✓				

Name - Administrative Status			IWMCs				
			Build and operated	Build but not operated	Under construction	planned	not planned
	Hangnaameedhoo	Island					✓
	Kun'burudhoo	Island					✓
	Maamigili	Island		✓			
	Mahibadhoo	Island					✓
	Mandhoo	Island					✓
	Omadhoo	Island					✓
Alifu Dhaalu Atoll			2	2			6
Alifu Alifu Atoll	Bodufolhudhoo	Island					✓
	Feridhoo	Island					✓
	Himandhoo	Island					✓
	Maalhos	Island					✓
	Mathiveri	Island		✓			
	Rasdhoo	Island					✓
	Thoddoo	Island	✓				
	Ukulhas	Island	✓				
Alifu Alifu Atoll			**2**	**1**			**5**
Zone III			**5**	**4**	**1**	**4**	**22**

Table 5: Actual status of implementation of ISWMC in zone III

Actually only 25% of the inhabited islands have an ISWMC. 14 % are planned or under construction. 61 % ISWMC have not been planned yet. Objective of the government is that all Islands should have an ISWMC by 2018.

Islands waste management (except greater Male/urbanized areas) in zone III

- No standardized receptacles at HH level
- Door 2 door collection or individual transport to dumpsite
- Collection by small or medium open dump truck
- Collection of loose fractions or dump truck manned with bins
- Mixture of rudimentary practices and under-dimensioned standard receptacles
- Only 25 % of islands have an ISWMC
- ISWM of first generation : under-dimensioning, not operated well
- Sorting and recycling activities very limited : no storage capacities, no buyer
- Simple composting, self-sufficiency only 20% of compostable fraction (potential)
- Consequently : open burning and illegal dumpsite is still common practice
- No waste transfer to adequate facility (non-existence of an adequate facility)

8.2. Resorts Islands

The tourism regulation requires the resort to have waste management equipment on the island. The regulation does not indicate that the resort should have a waste management site. However, all the resorts have an area which is dedicated to the use of the equipment and storage of waste. The Waste Management Regulations states that all waste management sites at "islands" should be registered at EPA. However it is referred only to the inhabited islands so that resorts are note registered at EPA, therefore there is a limitation in control and monitoring of the current waste management practices at the resorts.

Figure 17: Waste Management Site at a Resort in North Male'Atoll

Sorting of waste is carried out in a number of resort in zone III. It was found that 17 of 21 resorts that were surveyed stated that they separate plastic bottles and aluminium cans while 19 of 21 stated that they separate paper separately.

Some resorts carry out compositing of organic waste.it was found that 2 out of 21 resorts in North and South Ari Atoll, compost their green waste and other compostable wet waste fractions. The composting system developed on the islands provides compost and soil conditioner to the landscaping operation at the islands.

Each resort has an incinerator (small scale) to incinerate residual waste, a glass crusher to crush the glass and a baler to compact and bale the metals and the paper. The food waste collected from the kitchen is dumped and/or burned in an uncontrolled manner on the island itself or thrown into deep sea. The compacted metals, crushed glass, residual waste at the waste site and waste from incinerator are regularly transported to Thilafushi for final disposal. The mode of transportation varies across the resorts in the zone. Some resort use the resort supply Dhoni to transport the waste to Thilafushi, other resort outsourced the transportation of waste to a contractor and some resort use larger vessels to transport their waste to Thilafushi including landing crafts and barges.

During the survey 9 of 21 resorts stated that they use their supply Dhoni to transport the waste to Thilafushi while, 7 of 21 resorts stated that they have outsourced the transportation to a contractor's supply Dhoni, and 5 of 21 resorts stated that they use larger vessels to transport their waste to Thilafushi including landing crafts and barges. During unofficial and anonymous discussions with resort manager it came out that most of the resorts tried to treat their waste on site or send it to nearby inhabited islands, which seems to be the preferred option by the resort, reducing their effort (transport and maintenance) of waste handling. This situation was evaluated *as conflictual* on government level. In consequence the option on political level was either to include the resorts in the SWM management by providing them a collection service through WAMCO or by continuing to bring their waste to Tilafushi by themselves and paying a “gate fee”.

Resort Waste Management in Zone III

- Efforts in practicing sorting
- High class resort (4-5 stars) practicing 3 R strategy with composting and incineration (small scale)
- Low class resort different approaches
    - Periodical transport to Tilafushi (gate fee)
    - “illegal” dumping of food waste into the sea (after sorting recyclables)
    - Uncontrolled dumping and waste burning on the resort island itself
    - Transport of waste to nearby island (to dumpsite or ISWMC) against “fee”

8.3. Male’ & Hulhumale’

The actual situation in Male’ concerning the overall waste management can be described as passing from “poor” and “not state of the art”, to “under improvement”.

Since August 2017 Household waste is collected mainly by the state owned waste management company WAMCO. Citizens were asked to registry themselves for a door-to-door collection, but due to the lack of adequate equipment and resources, the implementation is endeavouring. Some efforts are ongoing to ensure a smooth transition between the previous foreigner-dominated waste collections to WAMCO. Due to the heavy urbanised and dense situation in Male’ (Multi-storey buildings mainly dominate the city) the waste collection is challenge. There are no standardised receptacles (bins, bags, etc.) at the household. Most of the waste is collected by hand by the workers, brought downstairs (from most of the high-rise buildings in Male) in front of the street and picked up by electric tricycles, transferred to small pick-up or compaction trucks.

Actual equipment of WAMCO:

Description		Numbers (actual)
	Tricycles (electrical) Capacity 240 l	25

	Compaction truck (HD 72) Capacity 5 m³	10
	Small dump truck Capacity 1,5 t	2

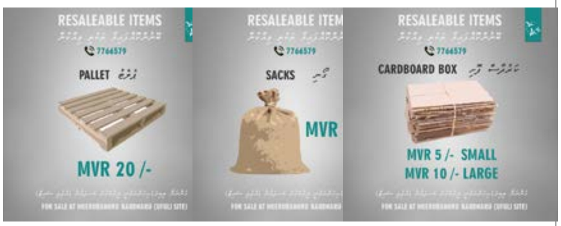
Waste is transferred to the upcoming site for the new Male' transfer station (under design) at the new reclaimed area called "industrial village". The waste is transferred on bigger trucks; some valuable fractions are sorted out. The bigger trucks unload the waste on the waste vessels, an excavator on the vessel makes some spreading and compaction, and soon the maximum filling grade is reached, the vessel brings the waste to the dumpsite at Tilafushi Island.

Figure 18: Vessel (landing craft type) at transfer site in Male

The dumpsite at Tilafushi could be characterized as an uncontrolled and not state of the art dumpsite. Incoming waste is dumped without any safety measures against leachate infiltration in the underground, safe and controlled drainage of biogas. The risk of landslide, uncontrolled fire and other hazards could not be excluded. Sometimes the fire was set deliberately in order to gain space.

Figure 19: View on Tilafushi dumpsite

Recycling activities are still on a low level. Plastic bottles (mainly 5 l bottles) are collected separately and stored in big bags at Male Industrial village (Future location of the Transfer facility). WAMCO is aiming to resell any possible residual waste item by having prices and tariffs and by storing these items for possible buyers, ("WAMCO" shop concept). But these actions are on a small scale basis and brings neither a substantial waste reduction nor an important income for the company.

	
Recyclables (K Vilingili)	Examples of WAMCO reselling items

The potential in the field of recycling activities is important particular in the context of the future trends of waste generation and the strategical decision whether a 3rd WTE line will be implemented or not, the improvement of the sorting rates and the recycling activities will play a major role.

8.4. Household waste characteristics

The main general approach was to combine four elements:

- Reviewing the previous documents and surveys received (WAMCO market survey, Household waste survey conducted by the Ministry in 2008, and other surveys of zones in the Maldives)
- Assess the situation on site by interviews, own investigations etc.
- Using benchmarks from other regions and nearby countries with same consuming behaviour

- Conducting additional household waste quality and quantity survey in the area to confirm preliminary results

8.4.1. Waste quantification

Waste audit survey at the inhabited islands

The rate of solid waste production depends on the socio-economic situation, the level of industrialization, type and numbers of industries, climate, and land use. According to the available data retrieved from the waste audits estimated waste production rate ranges from 0,5 kg/person to 1.0 kg/person at inhabited islands. Hence a waste audit survey has been undertaken to quantify the existing waste generation rates at selected islands and resorts. The objective is to understand the quantity and the composition of the waste generated from the islands and resorts in the zone. The waste audit survey was carried out as follows:

Inhabited islands: the waste audit was carried out at 5% of households at selected islands from four atolls in the zone III. The data collected from the households is assumed to be representative and indicative of the household waste composition across the region.

Male': The waste quantification was done by the assessment of previous studies in combination with a household waste survey held in October/November 2016.

Samples have been taken from all districts with different household composition and living structures.

Methodology of the Household waste survey in Male'

Sampling

For sampling purposes, it was assumed that geographically, there is no differentiation by wards in terms of living standards. Hence, it is subsequently assumed that there is no differentiation in waste generation in the four wards of Male'. Simple Random Sampling was used to decide on 20 different households in Male' to be part of the sample.

A sample size of 20 was deemed sufficient for the survey as the main purpose was to validate the findings of previous waste surveys conducted in Male' and subsequent estimations to present day conditions. Additionally, the survey was looking to assess the waste composition on a household level.

Survey Design

After the households were selected for sampling, the households were approached to participate in the survey and instructions were given for waste sorting at the household level. The main instruction was to separate the household waste into two bags; one bag to be allocated for wet waste and the other for dry waste. To facilitate the segregation at household level, the participating households were provided with an information sheet specifying the types of waste that are classified as wet waste and the types of wastes that are classified as dry waste.

Following this, the participating households were instructed to segregate their wastes according to these instructions for 24 hours, from 10:00 am the day after the instructions were handed out, to 10:00 am the following day when waste was to be collected.

Waste Collection

Waste Collection was carried out on two separate days; Wednesday, the 16th of November 2016, and Tuesday, the 25th of November 2016. On each of the days, waste was collected from a total of 9 households. The lack of segregation as well as prior waste disposal prevented waste collection from two of the sample households, leaving a total of 18 households comprising of the sample.

Members of Water Solutions carried out waste collection using a hired puck-up truck. The waste collection team collected waste from each of the households, labelling the waste with numbers assigned for each household. Following the collection from the designated households, the waste was transported to the waste collection ‘Dhoni site’ for data collection.

Data Collection

The main data collected in the survey were mass and volume of the different waste components. The waste components of interest in the survey were wet waste, plastics, paper and cardboard waste, metal waste, and hazardous waste.

The mass of the waste components was measured using a simple electronic hook scale *(see figure 20)*. This was preferred over the use of an electronic measuring balance due to the mobility it offered in being carried to the waste collection point, as well as the flexibility the hook afforded in weighing bags of waste. The disadvantage of using the electronic hook scale was its precision to the nearest 100 grams.

Figure 20: Electronic hook scale used to measure the mass of waste during the survey

Measuring the volume of the waste components in situ was a challenging task. The method decided upon in measuring volume was to use a container with uniformity in cross-sectional area, such as a cylinder or box. The container was to be marked equally throughout its height, which is recorded on site, enabling the volume to be calculated later on when multiplied with the cross-sectional area. Due to the variation in size of the waste depending on type and also between households, three different-sized containers were used for the volume measurements *(see table 6).*

Table 6: Receptacles used to measure the volume of the waste

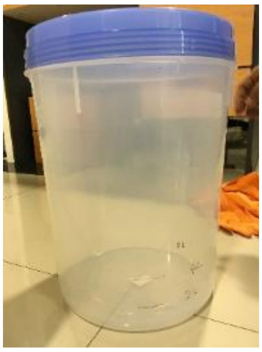
Container	Dimensions	Volume (cm³)	
Container A	r: 28 cm, h: 38cm	10,800	
Container B	r: 10.75 cm, h: 30 cm	93,500	
Crate	36 x 50 x 90 cm	210,600	

Figure 21: data collection of the waste survey being carried out

Sample Profile

The distribution of the survey households among the four wards of Male' can be seen in *Figure 22*, 9 households were located in Galolhu, while there were 3 households each in Machangolhi, Maafannu and Henveiru.

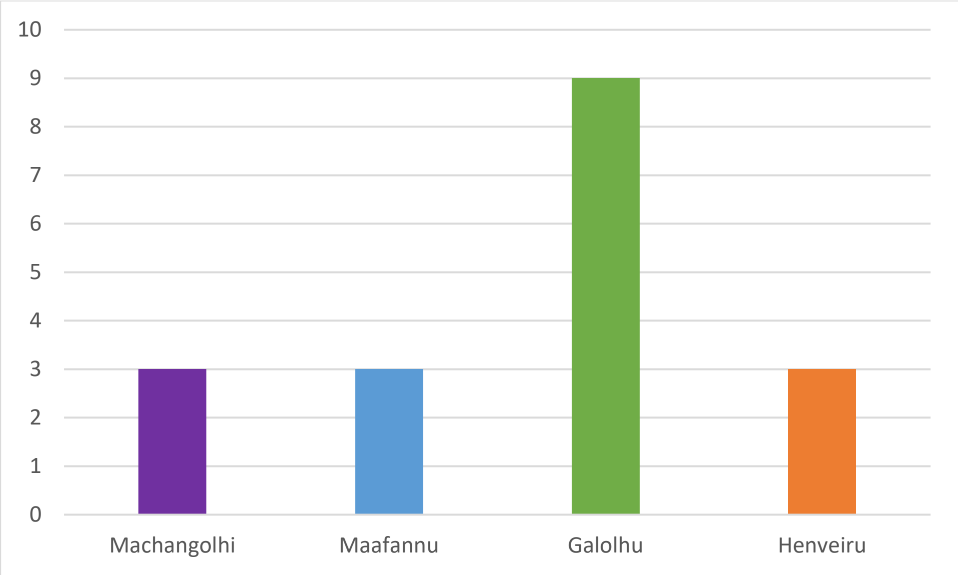


Figure 22: the distribution of the sample households among the four wards of Male'

Among the eighteen households the greatest number of inhabitants in a household was 19, while the smallest number was 3. After ignoring the outlier, the average number of inhabitants was calculated to be 5.

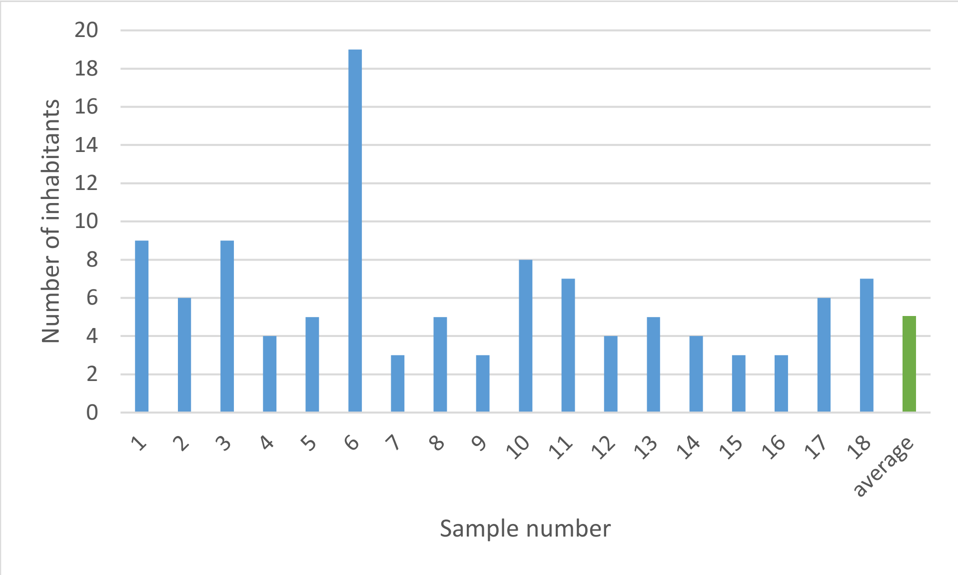


Figure 23: the number of inhabitants in the sample households and the average number

The results from the additional household survey are the following

Designation	unit	Machang.	Maafannu	Galolhu	Henveiru	Total
Household/ward		3	3	9	3	18

Designation	unit	Machang.	Maafannu	Galolhu	Henveiru	Total
Inhabitants		22	24	58	14	118
kg/ward	kg	30,7	11,6	31,4	10,5	84,2
kg/cap	kg	1,40	0,48	0,54	0,75	0,71
kg wet waste	kg	17,6	4,4	22,9	3,3	48,2
kg dry waste	kg	13,1	7,2	8,5	7,2	36
Volume wet waste	m³/HH	0,05	0,02	0,10	0,02	0,05
Volume dry waste	m³/HH	0,25	0,06	0,21	0,12	0,16
density wet waste loose	t/m³	0,34	0,19	0,23	0,15	0,23
density dry waste loose	t/m³	0,05	0,13	0,04	0,05	0,07
% wet waste	%	57,33%	37,93%	72,93%	31,43%	57,24%
% dry waste	%	42,67%	62,07%	27,07%	68,57%	42,76%

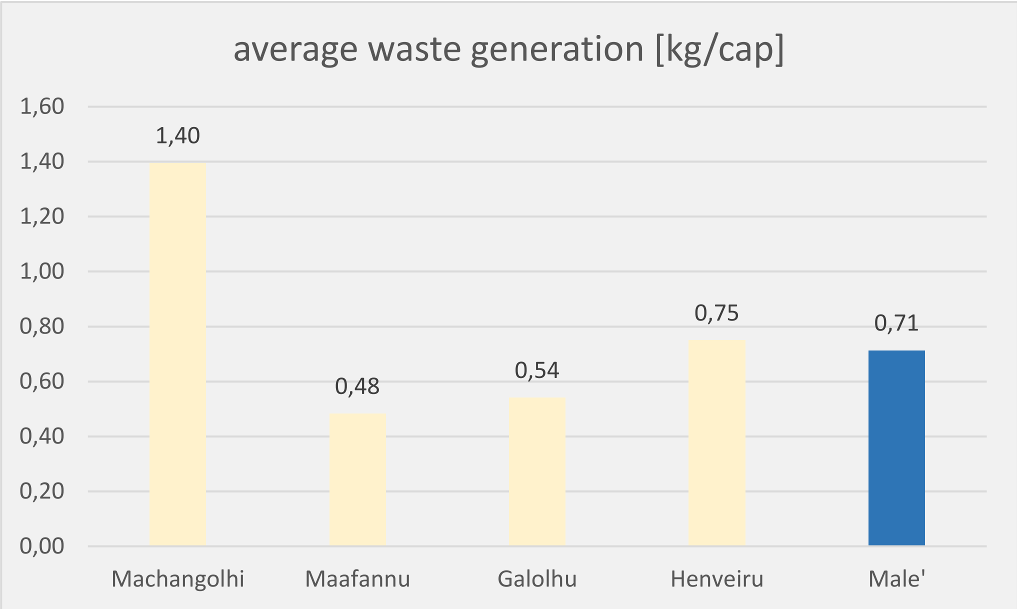


Figure 24: Wage quantity per kg/cap in the districts of Male ‘City

Certain limitations were identified before, during, and after the waste survey that has the potential to affect the results of the survey. These limitations are highlighted below:

- Some households did not segregate the waste properly so it is possible that the recorded values for mass and volume are off from the true values.
- Waste collection was conducted on two weekdays – this could mean that the data collected is not necessarily representative, since the waste

generated is different on weekends or holidays, especially in households where there are a high proportion of working people.
- As only household waste generated over 24 hours was collected, some of the waste components generated during the time were too small to quantify – this enabled the quantification of waste only into their dry and wet components for some of the households.
- While the method implemented for volume measurements yielded reasonably accurate results, the measurements themselves were approximations, done by assuming that the entire volume below the height of the waste bag in the containers are occupied by the waste. Thus, it is possible that the volume measurements are overestimates.
- The electronic hook balance is able to measure the mass of objects to the nearest 100 grams. Thus, it was not possible to measure the mass for some waste that were below 100 grams in mass.

The results confirm the estimation from previous surveys and the benchmarks of similar heavy urbanized cities in developing countries.

Waste audit survey at resort Islands

The waste audit would be carried out at a luxury level serviced resort and non-luxury level serviced resort in the zone. All the resorts in the region are generally have common features such as buffet meal plans, an average 1:2 staff to guest ratio and standard operating procedures for waste management. Luxury level resorts would have high number of food and beverage outlets and more levels of services. Therefore, it is hoped that the data from the selected resort in the zone would be provide a high confidence level waste generation and composition data. The waste quantification at resort Islands have been based on the observation and interviews of the resort responsible comparing with previous studies and results. In total 21 resorts out of 75 have been visited and interviewed.

Waste survey at Tilafushi Island and WAMCOs data log

In order to have a more accurate view on the figure an additional waste survey was held at Tilafushi Island with the observation of a daily incoming waste in combination with a comparison of data log provided by WAMCO. The data log were given for the period of January to March 2017. The evaluation of the data log gives an average amount of 335 tpd of mixed waste (HH, C&D waste etc.) arriving at Tilafushi based on visual estimations and an unknown formula developed by WAMCO. These figures have to be considered as not reliable enough.

8.4.2. Waste Composition

The waste composition assessment was done by comparing the different studies undertaken in the Maldives as well as some benchmarks from similar countries of the region. With the additional waste survey of October 2016 it was possible to develop a sufficient approach for the determination of the waste composition as well as some trends.

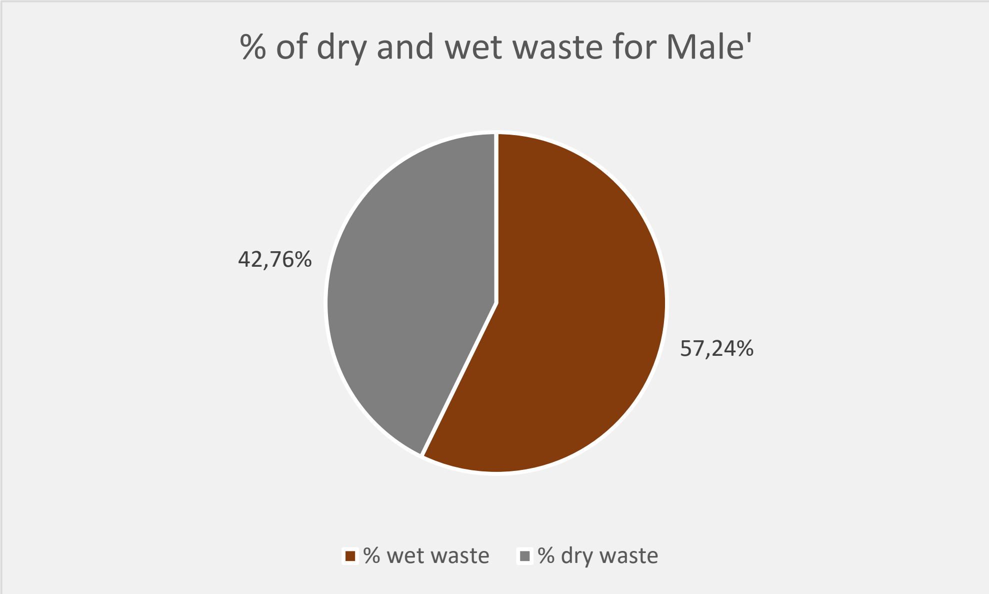


Figure 25: Percentage of dry and wet waste in Male'City

Household waste

Waste composition	%	Trend
Organics	60%	constant
Garden waste	*10%*	
Kitchen waste	*40%*	
other organics	*10%*	
Paper & cardboard	10%	constant
Glass	3%	decrease by 1%
Plastics	10%	increase in the next years probably by 1-2 %
Metals	4%	constant
Hazardous wastes (including clinical)	3%	constant
Other (inert & dust)/mixed waste	10%	decrease
Total	100%	

Table 7: Waste composition for household waste

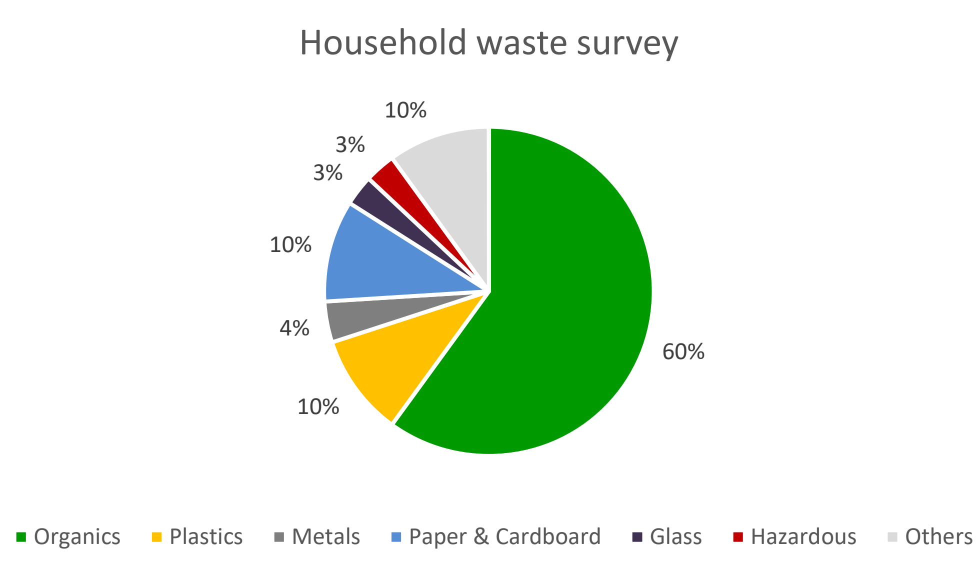


Figure 26: Household waste composition

Resort and Hotel waste

Resort and Hotel waste composition was developed through the analysis of previous surveys, and confirmed through site visits and interviews with respective resorts responsible for environmental issues.

Waste composition	%	Trend
Organics	74%	constant
Garden waste	*10%*	
Kitchen waste	*54%*	
other organics	*10%*	
Paper & cardboard	9%	constant
Glass	5%	constant
Plastics	5%	constant
Metals	2%	constant
Hazardous wastes (including clinical)	0,5%	constant
Other (inert & dust)/mixed waste	4,5%	constant
Total	100%	

Table 8: resort, hotel and guesthouse waste composition

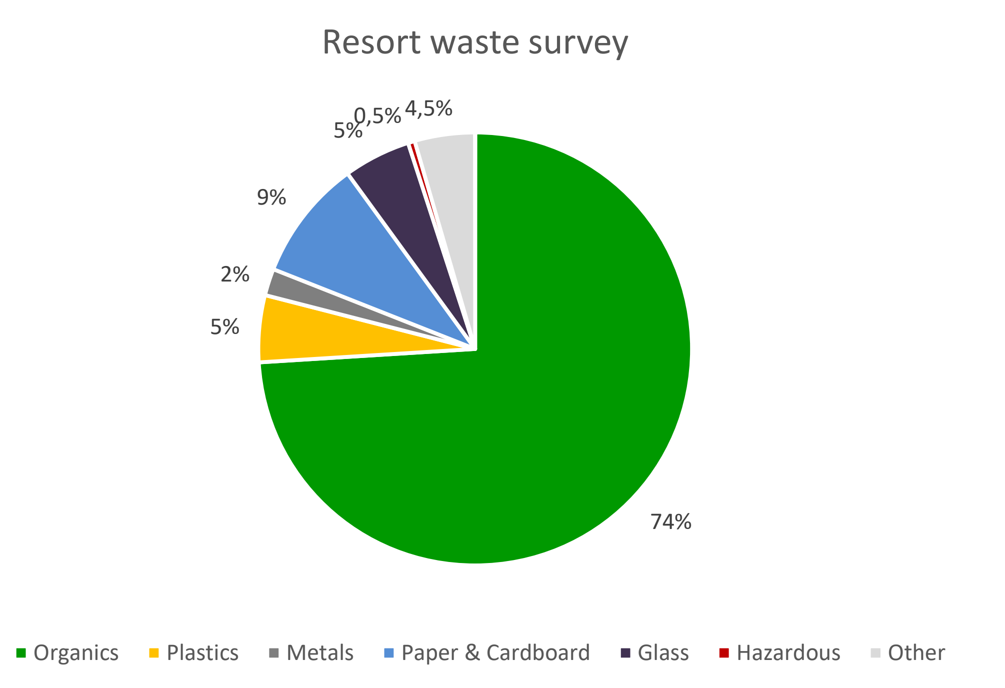


Figure 27: Resort waste composition

8.4.3. Market waste

An additional assessment of the waste generated by the market area in Male' was undertaken during December 2016.

This area is characterized by two centralized traditional market spots, one fish market and approx. thirty shops/resellers along Boduthakurufanu Magu. The assessment was undertaken during late afternoon right before closing so that the identified waste quantities are reliable for the evaluation of a daily generated quantity.

Figure 28: Market waste from small shops along the street

Figure 29: Market waste samples

Along the main road, the waste generated by the small shops is mainly characterized by packaging (paper, cardboards, drinking packages, etc.). The quantity was estimated as 300-600 kg in total (for approx. 30 shops).

The waste from traditional market is mainly dropped out in two special dropout places. The quality is mainly characterized by peelings, packaging and green waste. Some of the generated waste is simply dropped out into the sea. Market Waste quantities generated daily could be estimate to 2-3 tons.

Figure 30: Waste drop out into the sea near the market

Figure 31: Market waste drop out place

Figure 32: Market waste quality

The dropout place is a good way to canalise the waste streams into a centralized place and to avoid the illegal dumping into the sea but the facility is not state of the art in terms of hygiene and safe waste handling.

8.4.4. Airport waste

Velana International Airport, also known as Male' International Airport, previously known as Ibrahim Nasir International Airport, is the main international airport in the Maldives. It is located on Hulhule' Island between the capital island Male' and Hulhumale'

The airport resides at an elevation of 6,2 m above mean sea level. It has one asphalt runway measuring 45 m × 3,200 m. The adjacent waterdrome which serves the large seaplane operations at Velana has four water runways. The airport has three terminals. They are the International Terminal, the Domestic Terminal and the waterdrome seaplane Terminal. The airport includes the corporate headquarters of Maldivian Airways. The tourist flow is approx. 1,2 Mio per year. In order to increase the capacity new developments are underway include:

- A new passenger terminal with a built-up area of 90,000 square meters which can accommodate 7.5 million passengers.
- 9 new passenger boarding bridges.
- State-of-the-art baggage handling systems.
- Expanded duty free shops
- Food and beverage outlets.
- A New Code-F runway measuring 3,400m x 60m
- The Expansion of main apron to include 13 stands with additional stands for 4 Code-E aircrafts and parking provision for 2 Code-F aircrafts
- New fuel storage which has 3 times the current capacity.
- New cargo terminal with a total area of 18,000 square meters which can handle more than 120,000 tons of air-cargo a year.

The airport management corporation has provided the data of waste generation for 2016. The average mixed waste generation was about 9,4 t/day.

		2011	2012	2013	2014	2015	2016
Tourist flow	per year	931.333	958.027	1.125.202	1.204.857	1.234.248	1.286.135
Aver. tourist flow	per day	2.552	2.625	3.083	3.301	3.382	3.524
% change over prev. year	%		2,87%	17,45%	7,08%	2,44%	4,20%
HH waste airport	t/day						Approx. 9,4

Waste Details (data from Airport corporation)	Tonnage
Food waste	2.624
Green waste	1.896
General waste	4.856
Dry waste	
Bulky waste	0.856
Construction and demolition waste	
Waste generated on a daily basis	***9.376***

8.5. Other priority waste streams

8.5.1. Construction and Demolition (C&D) waste;

Construction and Demolition (C&D) waste is generated by activities such as construction, demolition and maintenance of civil infrastructure and facilities. The local authorities do not have accurate data on C&D waste, despite the fact that there is a dedicated service for collection and removal of this waste stream under implementation, there are no separate collection points and there is lack of infrastructure.

Removal is made based on occurring needs and not on proper planning. Therefore this specific stream is reported by all stakeholders as a growing problematic in terms of the high expenditures that collection and transportation services require. Due to the lack of specific locations and suitable containers for the removal of this specific stream, the risk that citizens and private businesses deposit their C&D waste (small non-industrial quantities) in a centralized collection place or mix it with common household waste. It is not a seldom practice to encounter piles of C&D waste that is illegally disposed at by the sides of road axes. A special on demand pick-up service for bulky and C&D waste is installed by WAMCO, and some of the industries might bring bigger quantities to the transfer station site in Male.

C&D waste is identified as a priority stream because of the high recycling and reusing potentials. Special C&D elements can be used for road construction and maintenance, draining projects, etc. In addition to this, the current technologies for segregation and recovery of these fractions have advanced. The C&D stream can be easily accessed and is relatively cheap.

Construction and Demolition waste has been estimated from the observation and asset of previous docking station dedicated exclusively for Industrial and C&D waste (October/November 2016).

Figure 33: Industrial and C&D Waste transport at Male' City

A series of surveys on estimating amount of construction and demolition waste generated in Male' were conducted 1 year later, to estimate the average composition and amount of the construction and demolition waste brought to the Male' transfer station. The waste transfer station is opened to incoming vehicles from 06.00 am to 02.00 am. Construction and demolition waste, Household and other waste is the loaded onto a vessel and taken to Thilafushi. The size of vehicles that carry C&D waste varies from 350kg to 5T.

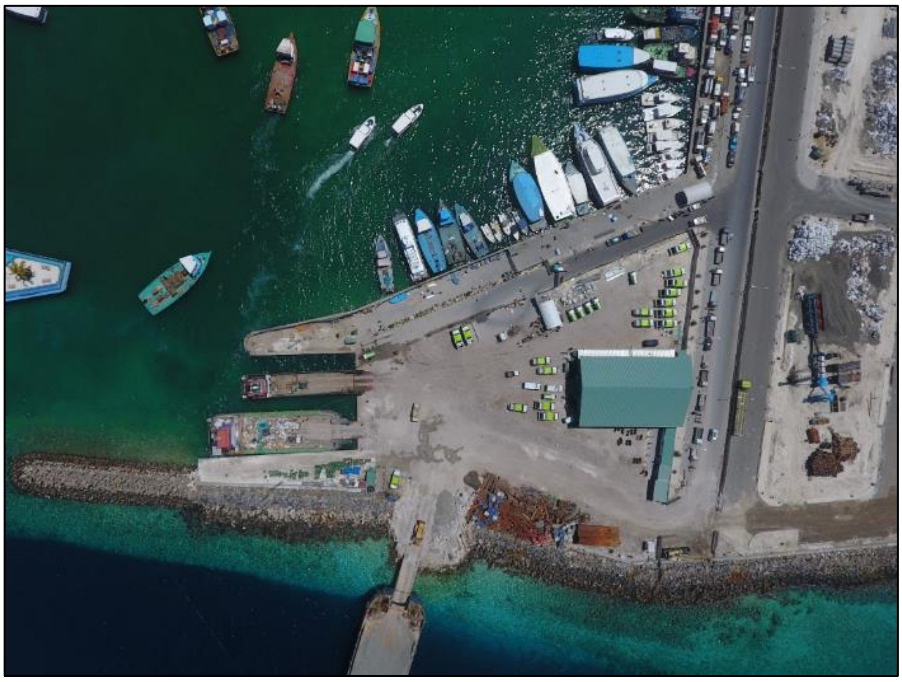


Figure 34: Male' Waste Transfer Station, WAMCO

Survey 1 was conducted on 29th October 2017 at Male' transfer site by 5 members from Water Solutions. A total of 41 vehicles containing C&D waste were surveyed and its content were recorded.

A method of visual characterization of disposed waste from construction and demolition activities produced for the State of California in October 2006 was used as a model in this survey to estimate the composition of C&D waste. This generally involves measuring the volume of the waste loads and visually characterizing the waste to a set of materials which were categorized by this method. The volumes measure were converted to mass using industry-accepted density values. The volume was measured when the trucks arrive and stop to make the entrance payment. The length and width of the loading section of the truck was recorded and an average from two readings for the height of the waste pile was taken to calculate the volume. An excel tool was also provided with the instructions for said method. This was used to estimate the percentage composition of the different materials.

The following estimates in *figure 35* were generated by the aforementioned excel tool. About 92% of the C&D waste was aggregates and dirt, which is mainly concrete from houses that have been demolished, sand and rocks after excavations from foundation works. Most of the plastic was from polypropylene woven sacks that contained sand, rocks and small pieces of concrete. The wood materials were mostly pallets and lumber beams; however, sawdust and wood shavings from carpentries were also included. Paper materials were mostly just cardboard boxes.

Estimated Composition by Weight for All Loads

Material	Total	Component	Share
Paper	**0.5%**		
		Unwaxed OCC	0.5%
		RC Paper	0.0%
Plastic	**0.5%**		
		Non-bag Film	0.5%
		Polystyrene Packaging	0.0%
		Rigid Plastic	0.0%
		RC Plastic	0.0%
Metal	**0.2%**		
		Major Appliances	0.0%
		HVAC Ducting	0.0%
		Other Ferrous & Non-Ferrous	0.0%
		RC Metal	0.2%
Organic	**0.0%**		
		Prunings, Trimmings, Branches, Stumps	0.0%
		RC Organic	0.0%
Carpet	**0.0%**		
		Carpet	0.0%
		Carpet Padding	0.0%
		RC Carpet	0.0%
Aggregates & Dirt	**91.8%**		
		Dirt, Sand, Soil	41.0%
		Concrete	42.6%
		Asphalt Paving	0.0%
		Brick, Ceramic, Porcelain	0.0%
		Rock, Gravel	8.1%
		RC Aggregates & Dirt	0.0%
Roofing	**0.0%**		
		Roofing	0.0%
		RC Roofing	0.0%
Insulation	**0.0%**		
		Insulation	0.0%
		RC Insulation	0.0%
Wood	**7.1%**		
		Clean Recyclable Lumber, Pallets, Crates	7.1%
		Other Untreated & Recyclable Wood	0.0%
		Painted, Stained, Treated Wood	0.0%
		RC Wood	0.0%
Gypsum	**0.0%**		
		Clean Gypsum Board	0.0%
		Painted Gypsum Board	0.0%
		RC Gypsum	0.0%
Misc. C&D	**0.0%**		
Glass	**0.0%**		
Electronics	**0.0%**		
HHW	**0.0%**		
Special	**0.0%**		
Mixed Residue	**0.0%**		
TOTAL	100.0%		

Figure 35 Estimated composition of C&D waste from Male' Transfer Station

Figure 36: Barge at Male' TS that contains a mixture of C&D waste and household waste

The mass of the waste load was calculated for individual materials by using their density values.

Sample no	Materials	Volume (m^3)	Mass (kg)	MAM of Vehicle (kg)	Difference
6	Aggregate and Dirt- Concrete	5.02	4,300	2,000	2,300
8	Aggregate and Dirt- sand	4.3	3,900	2,000	1,900
11	Aggregate and dirt, Wood	6.1	4700	1,500	3,200
17	Dirt, Wood, Plastic	7.68	5,820	1,500	4,320
19	Dirt Wood plastic	3	2,900	350	2,550
23	Aggregate & dirt	7.14	6,100	2,000	4,100
28	Wood, metal	3.9	645	350	295
31	Aggregate & Dirt	6.2	5,300	5,000	300
36	Plastic, cardboard, wood	1.49	340	350	-10
39	Aggregate and dirt	5.8	5,400	5,000	400

Table 9: Mass of waste and MAM for randomly selected trucks.

The calculated mass for the waste was observed to be much higher than the Maximum Authorized Mass (MAM) of the vehicles. A vehicle could carry more than the MAM, but some reading showed values that were more than twice, even thrice of the amount. Hence, these results are not reliable. These overestimated values maybe due to the empty areas in volume that was not accounted for when converting to mass.

Figure 37: (a) Aerial view of a 2T truck containing concrete waste (b) Truck containing sand and rocks in polypropylene woven sacks with wooden pellets on top (c) Aerial view of a 2T truck containing concrete waste (d) Truck containing soil.

Date	No. of trucks carrying Concrete							No. of trucks carrying Wood					No. of trucks carrying Sand			
	350 KG	1.5 Ton	2 Ton	3 Ton	4 Ton	5 Ton	Total (Ton)	350 KG	1.5 Ton	2 Ton	4 Ton	Total (ton)	1.5 Ton	2 Ton	4 Ton	Total (ton)
27/10/17	6	4	25	6	1		80.1	11	1	4		13.35				0
28/10/17	8	12	71		3	2	184.8	6		3		8.1		6		12
29/10/17	9	15	59			14	213.7	4	2	3	1	14.4	1	14	1	33.5

Table 10 Number of different sized trucks carrying concrete waste, wood, and sand, and their total tonnage from MAM of the trucks

The entrance posts at the transfer station keep logs of the time, plate number, MAM and the type of waste. The three types of waste that were considered to be C&D waste in these logs were concrete, wood and sand. *Table 10* shows the number of truck of each size that carried a certain material of waste. By adding up the frequency and capacity of these trucks we get 93.45T for 27th (Friday), 204.9 for 18th (Saturday) and 261.6 for 29th (Sunday) of C&D waste.

About 92% of the C&D waste was comprised of 'Aggregates and dirt', which refers to the demolished concrete waste, rock, and sand from excavation works. However, most of the loads that contain sand, rocks, and even smaller concrete that have been smashed to smaller pieces are packed into polypropylene woven sacks and then transferred. This obstructed us to see exactly what was in these sacks and if all the sacks has the same content. We also asked the drivers about the contents and if its demolition waste, they would say it is either wood, Gaakundi (Dhivehi word for demolition waste and similar material) or sand.

Figure 38: (a) Soil and rock in polypropylene sacks (b) truck overflowing with wooden pellets and other mixed waste (c) Large pieces of demolished concrete (d) Truck overflowing with mostly wooden pellets with some metal containers on top.

A lot of the trucks also carried mixed waste of C&D. The individual percentage composition of these trucks were harder to get as waste is loaded as an overflowing pile and we cannot see very well what is underneath. *Figure 38 (b) and (c)* are examples of such vehicles. However, the regular shape of the loading section of the truck made it easier to estimate the percentage of the material.

As mentioned before, the large overestimation of the mass of the load compared to the MAM of the vehicle was due to the empty spaces that were not accounted for. Trucks carrying large concrete slabs and columns on top of each other would have many empty spaces and would have an irregular shape but we calculated volume with the assumption that the load was a regular cuboid. *Figure 38 (c)* shows the width of the waste load being taken and the empty areas within the volume measured. Therefore sand, concrete and rock material that have high densities would give a much higher value for mass than the actual value if the empty is not taken in to consideration.

Although a daily amount of C&D was found from the log sheets acquired from WAMCO, these values only reflect the MAM of the trucks and not the actual value. It is seen that these trucks usually load more than they can carry and some vehicles even have thin plywood attached to the sides to load high piles of waste. The purpose of this survey was to find a value closer to the actual and not just rely on the vehicles capacity. Therefore, a second survey was conducted that estimated a percentage empty space along with the types of material.

The second survey was conducted on 2^{nd} of November and recorded a total amount of 20 trucks. The main purpose of this survey was to account for the empty space of the measured volume for load.

The same method was used to measure the volume and visually characterize the type of C&D wastes, except this survey includes a percentage for empty space. By doing so, a value closer to the actual mass of the load can be estimated. However, it would not be possible to use the excel tool to assess the composition of the waste as empty space is not an option given in the tool and the total percentage for materials need to add up to 100 for every sample. So this survey would only look into the amount of C&D waste brought into Male' transfer station.

Mass for each sample was calculated using the percentage volume and the industry-accepted density values for the specific materials in that load.

To find the total mass of C&D waste brought in the Male' TS on a day, the average difference between the MAM and mass was calculated as a percentage for 2T trucks containing most of 'aggregates and dirt' material. This percentage increment was added to the total mass of 'concrete' and 'sand' materials logged by the WAMCO staff at the entrance post. The MAM were used for trucks containing wood because percentage composition of wood is significantly lower than aggregate and dirt. This also has a much higher density than wood, therefore contributing more to the discrepancies in mass calculated.

Table 11 shows the Volume, percentage empty space estimate for each load, mass calculated for each sample, MAM of the truck and the difference between the MAM and the mass calculated. Rows that have been highlighted in light green shows the samples that contained a majority composition of 'aggregates and Dirt' material. The maximum difference between MAM and mass calculated was 2,711.8kg and the average difference was 1,181.75 kg which is 59.1% of the MAM.

Table 12 shows the total daily mass of C&D waste brought in to Male' TS after the percentage increment of the average difference between MAM and the calculated mass.

Table 11: Volume, percentage empty space and Mass for the 20 samples

No.	Volume (m³)	% Empty	Mass (kg)	MAM (kg)	Difference
1	6.944	15	3654.15	2000	1654.15
2	8.1	70	2089.8	2000	89.8
3	6	20	4711.8	2000	2711.8
4	8.1	60	2786.4	2000	786.4
5	6.786	65	2042.59	2000	42.59
6	3.906	10	3506.5	1500	2006.5
7	4.59	30	2921.1	2000	921.1
8	4.86	40	2845.53	2000	845.53
9	4.96	27	3182	2000	1182
10	4.08	25	2698.94	2000	698.94
11	6.72	22	4706	2000	2706
12	5.28	18	3952	2000	1952
13	2.2185	23	1534.8	2000	-465.2
14	1.116	42	317.88	350	-32.12
15	6.72	30	3035.81	1500	1535.81
16	4.8	15	3447.6	2000	1447.6
17	4.464	25	3971.77	2000	1971.77
18	5.1	25	2625.49	2000	625.49
19	6.12	45	215	2000	-1785
20	5.27	35	222.12	1500	-1277.88

Table 12 Total daily mass with percentage increments of 59.1

Date	Concrete		Wood	Sand		TOTAL (ton)
	Total (ton)	% increase of 59.1	Total (ton)	Total (ton)	% increase of 59.1	
27/10/2017	80.1	127.4	13.3	0	0	140.7
28/10/2017	184.8	294.0	8.1	12	19.0	321.2
29/10/2017	213.7	339.9	14.4	33.5	53.2	407.6

The deviations of the calculated mass from MAM can be more acceptable here compared to the first survey. Most of these trucks were observed to be carrying overflowing amount of C&D waste and could be carrying more that it's authorized mass.

As the station is opened from 06.00 am to 02.00 am, conducting a survey to record all the vehicles would be very challenging. For that reason, log sheets from WAMCO were obtained to have a sense of the capacity and number of vehicles coming in. It was also helpful that they noted the general materials in the trucks. Although some of the trucks contain mixed C&D waste, these forms only have one general material recorded. This data could have been used to find the daily mass brought in to Male' TS using the deviation from the MAM of different trucks containing different materials. Unfortunately, 16/20 trucks recorded during the second survey were of 2T and these values could not be generated for 350kg and 1.5T trucks. Similarly, most of the materials were also concrete and sand and an average increment for wood and other materials could not be found. For wood, this was not even necessary as the calculated mass of these trucks did not deviate too much from the MAM and some of these were negative as well as seen from *Table 11.*

According to WAMCO staff, Friday is the day the station get the least amount of C&D waste and is higher is Saturdays and weekdays (Sunday to Thursday are weekdays in Maldives). And so, Male' TS receives an estimated amount of 321 T to 408 T of C&D waste on an average day and about 140 T on Fridays.

8.5.2. Hazardous hospital waste

Hospital waste management should be carried based on the National Healthcare waste management policy issued by the Ministry of Health date 29.04.2016. The regulation does clearly define technical protocols and standards for administration of hospital waste, aimed at protecting public health and environment. The central element of the strategy should be consisting on segregation of hazardous hospital waste (infective, radioactive, cytotoxic, pharmaceutics, chemical etc.) from non-hazardous hospital waste (cooking waste, laundry, offices, urban waste from hospital wards, etc.). Hospital waste producers should be defined by the regulation as the only responsible actors for segregated hospital waste collection (at least of the two most important of hazardous and non-hazardous streams). The Regulation should also clearly define transportation conditions (packaging protocol, labelling, temporary storage) as well as hospital waste treatment methods, such as incineration or autoclave sterilisation.

The only source of information which were available for the waste quantification was the data provided by the two main hospitals in Male. An average of *1,5 t/day of stabilised/autoclaved waste* has been assumed based on the data given.

8.5.3. Lube Oil

Actual situation is characterised by a lack of strategy and planning of this waste stream. Lube oil is characterised as a special waste stream which is not part of the "classical" Household, commercial and resort waste management strategy. Nevertheless, lube oil could be threatened as additional combustion element in the Waste to energy concept.

Based on the data received from the Ministry of Environment and Energy for the total of Zone III an amount of *1 t/day or 5-6 barrels/day (1 barrel = 200 l)* has been estimated actually.

8.5.4. Electrical and Electronic Equipment Waste (EEEW);

The data on management practice and waste generated amounts of this waste stream are lacking. A better organized system for segregated collection, reuse and recycling of this stream should shortly become a priority for WAMCO. Atoll/Islands should develop and carry out management protocols for this specific waste stream, in full compliance with the legislation and national directives.

The plan should suggest to:

- Establishing collection system (ensure that on the Islands to have at least one centre equipped for EEEW-collection).
- Apply economic instruments like take back bonus for returned cooling & freezing appliances, screens and gas discharge lamps when submitting a receipt for a newly bought appliance. The returned appliances have to be complete.
- Intensify inspections of businesses related to metal scrap that are not licensed for the collection and treatment of EEEW (shredder plants, sorting plants, traders)
- Inform and raise the awareness regarding EEEW through providing information about collection points, organizing EEEW collection campaigns, collection awards between municipalities etc.

Actual no data is available about the amount of EEEW in zone III. WAMCO has established a selling system of this fraction in Male' considered as valuable ("WAMCO shop") so that this waste stream is mainly derived out of the waste landing at Tilafushi dumpsite.

8.5.5. End-of Life Vehicle (ELV)

End of live vehicle has been considered as a priority stream by the Ministry of Environment and Energy. Based on the actual registered vehicles (which are very accurate) the ELV amount was estimated to 1% per year which equals to approx. 1 t/day of ELV for treatment. *Actual data have been provided for the years 2014-2016.*

Table 13: Actual ELV vehicle estimations (as 1% of registered vehicles)

Zone/Atoll	ELV (as 1% of total registered)	Year		
		2014	2015	2016
Kaafu Atoll	Motor cycle	435	462	490
	Car	31	33	35
	Bus	1	1	1
	Pick-Up	12	13	14
	Lorry	5	5	6
	Van	7	8	8
	Jeep	4	4	4
	Battery Scooter	3	3	3
	Other vehicles	11	11	12
	Kaafu Atoll	508	539	572
Vaavu Atoll	Motor cycle	0,85	0,85	0,86
	Car	0,06	0,06	0,06

Zone/Atoll	ELV (as 1% of total registered)	Year		
		2014	2015	2016
	Bus	0,00	0,00	0,00
	Pick-Up	0,06	0,06	0,06
	Lorry	0,02	0,02	0,02
	Van	0,04	0,04	0,04
	Jeep	0,01	0,01	0,01
	Battery Scooter	0,02	0,02	0,02
	Other vehicles	0,09	0,09	0,09
	Vaavu Atoll	1	1	1
Alifu Dhaalu Atoll	Motor cycle	4	4	5
	Car	0	0	0
	Bus	0	0	0
	Pick-Up	0	0	0
	Lorry	0	0	0
	Van	0	0	0
	Jeep	0	0	0
	Battery Scooter	0	0	0
	Other vehicles	0	0	0
	Alifu Dhaalu Atoll	6	6	6
Alifu Alifu Atoll	Motor cycle	3	3	3
	Car	0	0	0
	Bus	0	0	0
	Pick-Up	0	0	0
	Lorry	0	0	0
	Van	0	0	0
	Jeep	0	0	0
	Battery Scooter	0	0	0
	Other vehicles	0	0	0

Zone/Atoll	ELV (as 1% of total registered)	Year		
		2014	2015	2016
	Alifu Alifu Atoll	4	4	4
	Zone III	520	551	584

Type	kg/unit	Year		
		2014	2015	2016
Motor cycle	90	39.894	42.300	44.854
Car	1,150	36.440	38.638	40.969
Bus	2,000	1.724	1.827	1.936
Pick-Up	5,000	63.807	67.589	71.600
Lorry	5,000	26.813	28.409	30.101
Van	2,000	15.065	15.956	16.901
Jeep	2,400	9.518	10.093	10.704
Battery Scooter	90	241	255	270
Other vehicles	1,500	17.222	18.223	19.284
Input ton per day				
Motor cycle		0,10	0,11	0,12
Car		0,09	0,10	0,11
Bus		0,00	0,00	0,01
Pick-Up		0,17	0,18	0,19
Lorry		0,07	0,07	0,08
Van		0,04	0,04	0,04
Jeep		0,02	0,03	0,03
Battery Scooter		0,00	0,00	0,00
Other vehicles		0,04	0,05	0,05
Total		0,55	0,58	0,61

The projections are presented in the following chapter

8.5.6. Industrial waste from Tilafushi

An additional waste stream which was surveyed is the industrial waste from Tilafushi. The data provided from TLC (Tilafushi land corporation) shows that more that 200 out of 300 industries installed in Tilafushi are from the boat building or boat repairing industry. A questionnaire was prepared and shared with 10% of the industries. 50% of the industry were responsive. Additionally a site visit was held by Water solution team in July 2017. The combination of the site visits and the questionnaire has led to an evaluation of the waste amount by 6,0 t/day (approx.. 20 kg/industry) of residual mixed waste. The quality is:

Waste quality	Amount [%]
Food waste (food packaging and food rest)	50 %
Wood & Fibre	35 %
Paint bins, plastic barrels	10 %
Cement, inert waste	5%
Total	**100%**

Table 14: Waste quality of Industrial waste at Tilafusi

CHAPTER 3: PROJECTION AND PLANNING

1. Objective

The main objective of the projections and planning chapter is to develop adequate figures and design parameters (waste streams/Mass balances) for the upcoming preferred Waste management scenarios. It is important to point out that the objective is to include all important identified waste streams and to make realistic assumptions based on the available databases, the personnel interviews, observations and surveys conducted, to get as much realistic figures as possible.

Without an implemented monitoring and weighing system over a certain period, it will be difficult to get figures in the best accuracy. However, assumptions were made with enough buffers to be on the safe side.

Projections have been made for a period over 20 years. Starting year is 2017, milestones have been defined as:

- 2022 : start of the operation of the RSWMF in Tilafushi
- 2037: 15 years of operation of the RSWMF and probable start of a third line of the WTE facility

2. Population projection

Population projection was done based on the last three census 2000, 2006 and 2014:

Three trends have been developed with the following assumptions:

Minimum : Population growth rate of 2006-2014 Stabilization after approx. 10 years (at 1%) Negative growth rate considered as 0% After 20 years increasing by 1% (at 2%)
Maximum: Population growth rate of 2000-2006 Stabilization after approx. 10 years (at 2%) Negative growth rate considered as 0% After 20 years increasing by 1% (at 3%)
Average: Average of Maximum and Minimum Approx. 5,43% for zone III

For all trends, the negative growth rate of certain inhabited Islands was considered to be 0%.

Hulhumale is a new artificial island, which was created after the year 2000 with an important population development. Therefore, the growth rate is also important between 2006 and 2014. The trend will continue in the next years but was limited to 15%, which is still important.

In the following, the population trend is presented for selected years (5 years step). The detailed calculations is annexed.

Population Growth/year	2017	2018	2019	2020	2025	2030	2035
Minimum							
Kaafu Atoll	194.036	205.335	217.535	230.736	301.924	333.348	371.652
Vaavu Atoll	2.026	2.110	2.201	2.300	2.860	3.151	3.508
Alifu Dhaalu Atoll	10.237	10.656	11.095	11.553	13.877	15.322	17.082
Alifu Alifu Atoll	7.370	7.701	8.050	8.419	10.309	11.359	12.639
Total Zone III min	213.670	225.803	238.881	253.008	328.970	363.180	404.880
Maximum							
Kaafu Atoll	202.322	217.041	233.042	250.457	344.203	379.821	423.245
Vaavu Atoll	1.820	1.823	1.826	1.828	1.859	1.954	2.074
Alifu Dhaalu Atoll	9.395	9.501	9.608	9.718	10.273	11.062	12.037
Alifu Alifu Atoll	6.710	6.792	6.876	6.962	7.443	8.045	8.787
Total Zone III max	220.246	235.157	251.352	268.965	363.777	400.882	446.143
Average							
Kaafu Atoll	198.015	210.895	224.820	239.899	320.724	354.044	394.661
Vaavu Atoll	1.878	1.902	1.925	1.949	2.084	2.267	2.491
Alifu Dhaalu Atoll	9.784	10.030	10.283	10.544	11.896	13.107	14.584

Population Growth/year	2017	2018	2019	2020	2025	2030	2035
Alifu Alifu Atoll	6.956	7.127	7.304	7.488	8.445	9.277	10.293
Total Zone III average	216.633	229.953	244.332	259.879	343.149	378.694	422.029

Table 15: Population projection

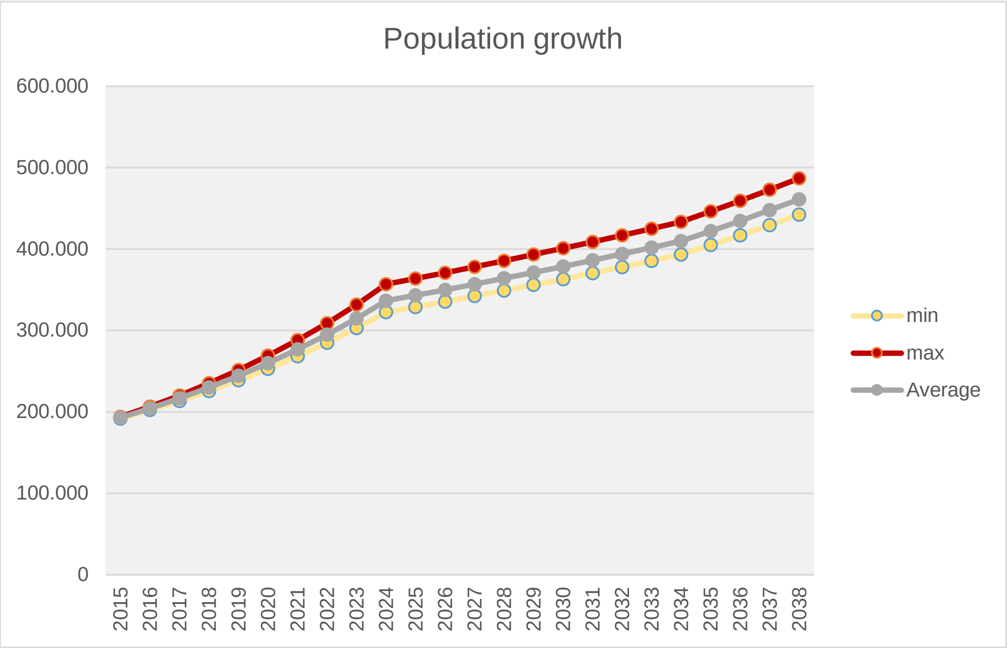


Figure 39: population projection for Zone III

3. Waste prognosis

3.1. Household waste

For the household waste based on the waste quantification assessment the following assumption and design parameters could be taken:

Inhabited Islands (except Male' and Hulhumale)

Household waste	kg/hab/day	Trend
Inhabited Island (rural character)	Start (2017): 0,55	increase of 2 % Service coverage starts by 84 % (2017), increase by 2% per year till 100% Commercial waste : 15% of HH waste

Male and Hulhumale

Household waste	kg/hab/day	Trend
Male & Hulhumale'	Start (2017):0,71	2017-2022: increase by 4% 2022-2027: increase by 2 % > 2027 : stabilisation by approx. 0,9 kg/hab/day Service coverage starts by 89% (2017): increase by 3% per year till 100% Commercial waste: 20% of HH waste

Service coverage is estimated around 89% actually with yearly increasing to reach the target of 100% in the next 5 years (realistic approach).

Waste for businesses and commercials have been estimated to 20% of the household waste which means that household waste and waste similar to household = 1,2 Household waste (factor 1,2 to be on the safe side) (same increasing as household waste).

With these assumptions, we have for Zone III the following waste quantity projections (5 years step, detailed provided in annexe):

Maximum range										
Item	Unit	Year								
		2017	2018	2019	2020	2025	2030	2035	2036	2037
Waste generated (households and commercial)										
Male'	Mg/ day	130	144	159	176	261	299	333	343	353
Consumption per head	kg/day	0,71	0,74	0,77	0,80	0,90	0,94	0,94	0,94	0,94
Hulhumale'	Mg/ day	20	24	29	35	71	81	90	93	96
Vilin'gili	Mg/ day	7	7	8	9	15	18	22	23	24
Consumption per head	kg/day	0,55	0,56	0,57	0,58	0,64	0,69	0,75	0,76	0,77
Other islands	Mg/ day	22	23	24	25	31	37	45	47	49
Total HH-waste generated	Mg/day	179	199	221	245	378	435	490	506	522
by households	Mg/ day	152	169	187	208	321	370	417	430	444
by commercial	Mg/ day	27	30	33	37	57	65	73	75	78
Waste generated and collected (households and commercial)										
Male'	Mg/ day	116	133	151	172	261	299	333	343	353
Service coverage ratio	%	89%	92%	95%	98%	100%	100%	100%	100%	100%

Maximum range										
Item	Unit	Year								
		2017	2018	2019	2020	2025	2030	2035	2036	2037
Hulhumale'	Mg/ day	18	22	28	34	71	81	90	93	96
Vilin'gili	Mg/ day	6	6	7	8	15	18	22	23	24
Service coverage ratio	%	84%	86%	88%	90%	100%	100%	100%	100%	100%
Other islands	Mg/ day	18	19	21	22	31	37	45	47	49
Total HH-waste collected	Mg/ day	158	181	207	237	378	435	490	506	522
from households	Mg/ day	134	154	176	201	321	370	417	430	444
from commercial	Mg/ day	24	27	31	36	57	65	73	75	78
Transport of collected waste										
Male' HH and market waste	Mg/ day	135,3	149,2	164,3	180,7	265,7	303,7	338,0	348,0	358,3
Hulhumale' HH waste	Mg/ day	18,2	22,5	27,7	34,1	70,5	80,8	90,1	92,8	95,6
Vilin'gili HH waste	Mg/ day	3,6	4,1	4,6	5,2	8,5	9,1	9,8	10,1	10,3
Other islands HH waste	Mg/ day	4,6	5,2	5,8	6,5	11,4	17,0	25,5	27,8	30,4

Average range										
Item	Unit	Year								
		2017	2018	2019	2020	2025	2030	2035	2036	2037
Waste generated (households and commercial)										
Male'	Mg/ day	127	140	153	167	240	275	307	316	325
Consumption per head	kg/day	0,71	0,74	0,77	0,80	0,90	0,94	0,94	0,94	0,94
Hulhumale'	Mg/ day	20	24	29	35	71	81	90	93	96
Vilin'gili	Mg/ day	6	6	7	7	10	12	15	16	16
Consumption per head	kg/day	0,55	0,56	0,57	0,58	0,64	0,69	0,75	0,76	0,77
Other islands	Mg/ day	22	23	24	25	31	37	45	47	49
Total HH-waste generated	Mg/ day	175	193	213	234	352	405	456	471	486
by households	Mg/ day	149	164	180	199	298	343	387	399	412
by commercial	Mg/ day	27	29	32	36	54	62	70	72	74
Waste generated and collected (households and commercial)										
Male'	Mg/ day	113	128	145	164	240	275	307	316	325
Service coverage ratio	%	89%	92%	95%	98%	100%	100%	100%	100%	100%

Average range										
Item	Unit	Year								
		2017	2018	2019	2020	2025	2030	2035	2036	2037
Hulhumale'	Mg/ day	18	22	28	34	71	81	90	93	96
Vilin'gili	Mg/ day	5	5	6	7	10	12	15	16	16
Service coverage ratio	%	84%	86%	88%	90%	100%	100%	100%	100%	100%
Other islands	Mg/ day	18	19	21	22	31	37	45	47	49
Total HH-waste collected	Mg/ day	154	176	200	227	352	405	456	471	486
from households	Mg/ day	131	149	169	192	298	343	387	399	412
from commercial	Mg/ day	24	27	31	35	54	62	70	72	74
Transport of collected waste										
Male' HH and market waste	Mg/ day	132,2	144,5	157,9	172,3	245,1	280,1	311,7	320,9	330,4
Hulhumale' HH waste	Mg/ day	18,2	22,5	27,7	34,1	70,5	80,8	90,1	92,8	95,6
Vilin'gili HH waste	Mg/ day	4,3	4,7	5,1	5,5	7,9	8,8	9,7	10,0	10,3
Other islands HH waste	Mg/ day	4,6	5,2	5,8	6,5	11,4	17,0	25,5	27,8	30,4

Minimum range										
Item	Unit	Year								
		2017	2018	2019	2020	2025	2030	2035	2036	2037
Waste generated (households and commercial)										
Male'	Mg/ day	124	135	147	159	221	253	282	291	299
Consumption per head	kg/day	0,71	0,74	0,77	0,80	0,90	0,94	0,94	0,94	0,94
Hulhumale'	Mg/ day	20	24	29	35	71	81	90	93	96
Vilin'gili	Mg/ day	5	5	6	6	7	8	10	10	11
Consumption per head	kg/day	0,55	0,56	0,57	0,58	0,64	0,69	0,75	0,76	0,77
Other islands	Mg/ day	22	23	24	25	31	37	45	47	49
Total HH-waste generated	Mg/ day	171	187	205	225	329	379	427	440	454
by households	Mg/ day	145	159	174	190	278	320	360	372	384
by commercial	Mg/ day	26	29	32	35	52	59	66	68	71
Waste generated and collected (households and commercial)										
Male'	Mg/ day	110	124	139	156	221	253	282	291	299
Service coverage ratio	%	89%	92%	95%	98%	100%	100%	100%	100%	100%

Minimum range										
Item	Unit	Year								
		2017	2018	2019	2020	2025	2030	2035	2036	2037
Hulhumale'	Mg/ day	18	22	28	34	71	81	90	93	96
Vilin'gili	Mg/ day	4	5	5	5	7	8	10	10	11
Service coverage ratio	%	84%	86%	88%	90%	100%	100%	100%	100%	100%
Other islands	Mg/ day	18	19	21	22	31	37	45	47	49
Total HH-waste collected	Mg/ day	151	171	193	218	329	379	427	440	454
from households	Mg/ day	128	144	163	184	278	320	360	372	384
from commercial	Mg/ day	23	26	30	34	52	59	66	68	71
Transport of collected waste										
Male' HH and market waste	Mg/ day	129,0	140,0	151,6	164,1	225,9	258,1	287,2	295,7	304,4
Hulhumale' HH waste	Mg/ day	18,2	22,5	27,7	34,1	70,5	80,8	90,1	92,8	95,6
Vilin'gili HH waste	Mg/ day	5,1	5,4	5,7	5,9	7,4	8,5	9,6	10,0	10,3
Other islands HH waste	Mg/ day	4,6	5,2	5,8	6,5	11,4	17,0	25,5	27,8	30,4

Table 16: HH waste quantity projection in t/day for zone III

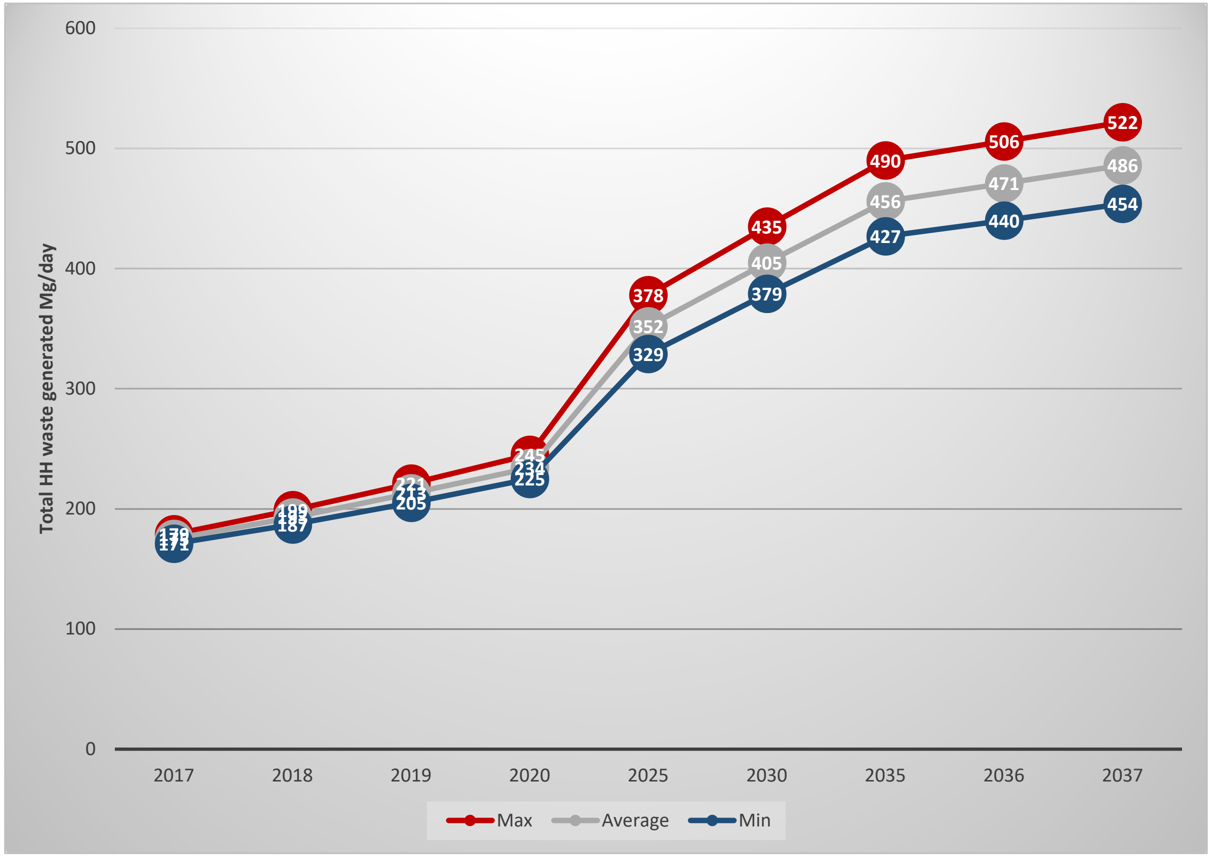


Figure 40: HH waste quantity projection in t/day for zone III

3.2. Resort waste

Main parameter and assumption for the resort waste quantity projection are the average bed occupation (existing figures 2010-2014 from Tourist Yearbook 2015)

Month/year	2010	2011	2012	2013	2014	Average
January	83,5	87,2	90,3	82,1	87,5	
February	92,5	94,4	87,3	93,6	94,9	
March	82,6	85,8	78	86,4	85	
April	74,2	83,8	77,2	79	84,8	
May	64,5	65,5	63,1	71,3	73,4	
June	50,2	55	53,7	59	64,1	
July	63,5	68,9	65,9	70,4	73,6	
August	73,1	72,8	71,6	80,5	81,6	
September	67,6	69,3	63,7	72	72,6	
October	79,8	83,4	80,2	86,8	86,4	
November	81,4	83,9	74,5	78,2	73,6	
December	77,7	79,9	76,7	81,3	78,9	
Total	74,22	77,49	73,52	78,38	79,70	76,66

Table 17: Average bed occupation (2010-2014)

The actual projections of new hotel, resort and guesthouse development and the average waste quantity from the waste survey of *3 kg/bed/night*. The waste quantity development for Hotels and guesthouses might be less than this figure but to be on the safe side the average below will be used.

Another limiting factor for this calculation was that the only available figures for future resort, Hotels and guesthouse development were limited to 2021. Beyond that year there are no reliable figures. While the number of Islands are limited, while the amount of resorts is comparing to the other streams not so important and while the resorts are bound to practice waste segregation and waste avoidance, the projections over 2021 could be considered as constant.

Waste quantity 3kg/bed/night		2017			2018			2019			2020			2021		
Atoll		**Nos.**	**Beds**	**average t/day**	**Nos.**	**Beds**	**average t/day**	**Nos.**	**Beds**	**average t/day**	**Nos.**	**Beds**	**average t/day**	**Nos.**	**Beds**	**average t/day**
Kaafu Atoll	Resorts	47	9.924	22,82	49	10.194	23,44	49	10.194	23,44	49	10.194	23,44	49	10.194	23,44
	Hotels	15	1.416	3,26	15	1.416	3,26	15	1.416	3,26	15	1.416	3,26	15	1.416	3,26
	Guest Houses	137	2.417	5,56	137	2.417	5,56	137	2.417	5,56	137	2.417	5,56	137	2.417	5,56
Kaafu Atoll		199	13.757	32	201	14.027	32	201	14.027	32	201	14.027	32	201	14.027	32
Alifu Alifu Atoll	Resorts	13	2.216	5,10	13	2.216	5,10	13	2.216	5,10	13	2.216	5,10	13	2.216	5,10
	Hotels			0,00			0,00			0,00			0,00			0,00
	Guest Houses	20	182	0,42	20	182	0,42	20	182	0,42	20	182	0,42	20	182	0,42
Alifu Alifu Atoll		33	2.398	6	33	2.398	6	33	2.398	6	33	2.398	6	33	2.398	6
Alifu Dhaalu Atoll	Resorts	16	3.862	8,88	16	3.862	8,88	16	3.862	8,88	16	3.862	8,88	16	3.862	8,88
	Hotels			0,00			0,00			0,00			0,00			0,00
	Guest Houses	10	111	0,26	10	111	0,26	10	111	0,26	10	111	0,26	10	111	0,26
Alifu Dhaalu Atoll		26	3.973	9	26	3.973	9	26	3.973	9	26	3.973	9	26	3.973	9
Vaavu Atoll	Resorts	3	552	1,27	3	552	1,27	3	552	1,27	3	552	1,27	3	552	1,27
	Hotels			0,00			0,00			0,00			0,00			0,00

Waste quantity 3kg/bed/night		2017			2018			2019			2020			2021		
Atoll		**Nos.**	**Beds**	**average t/day**	**Nos.**	**Beds**	**average t/day**	**Nos.**	**Beds**	**average t/day**	**Nos.**	**Beds**	**average t/day**	**Nos.**	**Beds**	**average t/day**
	Guest houses	10	76	0,17	10	76	0,17	10	76	0,17	10	76	0,17	10	76	0,17
Vaavu Atoll		13	628	1	13	628	1	13	628	1	13	628	1	13	628	1
Zone III		**271**	**20.756**	**48**	**273**	**21.026**	**48**	**273**	**21.026**	**48**	**273**	**21.026**	**48**	**273**	**21.026**	**48**

Table 18: Resort, Hotel, Guesthouse waste projection

3.3. Other waste streams

3.3.1. Construction and Demolition waste

Construction and demolition waste “means the waste comprising of building materials, debris and rubble resulting from construction, remodelling, repair and demolition of any civil structure.

C&D waste includes bricks, tiles, stone, soil, rubble, plaster, drywall or gypsum board, wood, plumbing fixtures, non-hazardous insulating material, plastics, wallpaper, glass, metal (e.g., steel, aluminium), asphalt, etc. However, C&D waste does not include any hazardous waste

C&D wastes are heavy (due to high density), often bulky, and occupy considerable storage space. C&D wastes stored outside construction sites and along roadsides are a cause of both traffic congestion and mishaps. These wastes are quite often given away for filling in low-lying areas or plots to private agencies, or disposed at open spaces or on the roadside illegally. Waste from small generators quite often finds its way into the nearest municipal bin, vat, waste storage depots, making the municipal waste heavy and degrading its quality for further treatment like composting or energy recovery. C&D waste is also often dumped in surface drains obstructing the flow of wastewater leading to urban flooding.

Benefits of processing construction and demolition waste

- C&D waste can be put to a profitable use, given the scarcity of sand and stone for construction, thereby saving natural resources.
- It prevents public nuisance and traffic congestion issues arising from indiscriminate dumping of C&D waste.
- It saves valuable space at landfill sites.
- It reduces cost of bulk transportation if recycled close to source of generation.

The following table indicates some use potential of different components of recycled C&D waste material. However, care has to be taken in keeping durability and structural considerations in mind while planning such use.

Table 19: C&D Wastes and Their Reuse Potential

MATERIAL	PROCESS	END USE
Demolition waste	Crushed and sorted	Recycled aggregate
Construction waste	Washed to remove cement and recover aggregate	Recycled aggregate
Reinforced concrete	Crushed, sorted and steel bars removed Steel recycled	Recycled concrete aggregate For recycling
Clay bricks and roof tiles	Cleaned Crushed and sorted Pulverised	Reused for masonry Aggregate Mixed with lime to produce mortar

MATERIAL	PROCESS	END USE
Calcium silicate bricks	Cleaned Crushed Pulverised	Reused for masonry Aggregate Recycled into new calcium silicate bricks
Natural stone masonry	Cleaned Crushed	Reused for masonry Aggregate
Natural stone slabs	Cleaned Crushed	Flooring, cladding Aggregate
Ceramic tiles	Cleaned Crushed	Flooring, cladding Aggregate
Asphalt paving	Crushed and cold mixed	Road construction excluding wearing course
Mixed demolition waste (ABC i.e. asphalt, bricks, concrete)	Crushed	Fill material
Steel	Cleaned Recycled	Reused steel components New steel components
Aluminium	Cleaned Recycled	Aluminium recycling streams
Timber beams, doors etc.	Cleaned	Reused as beams, doors etc. (if free of hazardous preservatives).
Timber boards	Cleaned	Reused as shuttering and other products Feedback for engineered woods
Plastics	Recycled	Plastic recycling streams
Gypsum plasterboard	Cleaned Crushed Recycled	Reuse as boards Soil conditioner New gypsum products
Glass	Cleaned Crushed Recycled	Glass recycling streams

Assumptions and planning parameter for C&D waste (based on the latest C&D survey):

Island	Average C&D waste in Mg/day	Yearly growth rate (20 years)	Yearly growth rate (after 20 years)	Comments
Male'	330	1%	Constant	Probably most of the amount comes from the bridge construction which will be closed in 2018 and some of the multi-storey building project. The consultant's opinion is that these figures are still high.
Hulhumale'	200	2%	1%	Hulhumale is probably the island which will have the most significant construction development in the next 20 years and above

According to the waste survey, 91% of the C&D waste could be processed for further use and 9% is for incineration.

Item	unit	Year							
		2017	2020	2025	2030	2035	2040	2045	2047
C&D waste Male'	Mg/day	330	340	357	376	395	403	403	403
C&D waste Hulhumale	Mg/day	200	212	234	259	286	306	322	328
Total C&D waste	Mg/day	530	552	592	634	680	709	724	731
Amount for reuse	Mg/day	482	503	538	577	619	645	659	665
Amount for incineration	Mg/day	48	50	53	57	61	64	65	66

Table 20: C&D waste forecast for planning

3.3.2. Market waste

Market waste has been considered for future projection as constant

3.3.3. Clinical waste

Clinical waste has been considered for future projection as constant

3.3.4. Industrial waste

The industrial waste flow is coming mainly from the Island of Tilafushi itself. This waste streams could be characterized as similar to HH waste. It is coming more or less from the boat builders and boat maintenance on Tilafushi. As far as the waste quantities are, still, not reliable and considering any other industrial development in the region the industrial waste should be considered as increasing with 2% per year.

3.3.5. Lube oil waste

Procedures related to prevention, collection, transport, recovering or controlled destruction of motoric and industrial waste oil should be defined in a special legislation. Environmental Protection Agency should be the authority who should handle and maintain used oil registers, where the data on generated, collected, processed and destroyed amounts of used oil are recorded. Within the first trimester of the year and based on registered data, EPA should develop the annual report on used oil amounts at the region level, which should provide;

- Annual data on types and generated amounts of used oil by each business activity, as well as at the region level;
- Data on the amounts of used oil sent for processing or destruction;
- Encountered problems and derived suggestions for future aimed at improving destruction process of waste oil.

EPA should identify private companies interested on collection and recycling of this specific stream to possibly extend their operations outside the territory of the respective unit. They should also promote segregated collection of this specific waste stream.

Producers and distributors and/or local government units render on individual bases or in a joint cooperation partnership awareness raising campaigns to inform final users about:

- hazardous substances contained in waste oil and the potential effects posed to health and environment;
- rules and procedures for segregated collection of waste oil aimed at providing incentives for treatment and recycling;
- available collection and recycling methods/schemes;

Based on the actual date, lube oil waste projection were made considering an increase of 2% per year

Atoll & Island	Total Lube oil consumption (l/year)	2017	2018	2019	2020	2025	2030	2035
K. Dhiffushi	1.334	1.361	1.388	1.416	1.444	1.594	1.760	1.943
K. Gaafaru	1.133	1.156	1.179	1.202	1.226	1.354	1.495	1.651
K. Gulhi	1.276	1.302	1.328	1.354	1.381	1.525	1.684	1.859
K. Guraidhoo	1.550	1.581	1.613	1.645	1.678	1.852	2.045	2.258
K. Himmafushi	3.339	3.406	3.474	3.543	3.614	3.990	4.406	4.864
K. Hulhumale'	30.311	30.917	31.536	32.166	32.810	36.224	39.995	44.157
K. Huraa	2.642	2.695	2.749	2.804	2.860	3.157	3.486	3.849
K. Kaashidhoo	3.282	3.348	3.415	3.483	3.553	3.922	4.331	4.781
K. Maafushi	5.060	5.161	5.264	5.370	5.477	6.047	6.677	7.371
K. Male' City	283.990	289.670	295.463	301.372	307.400	339.394	374.719	413.720
K. Thulusdhoo	1.404	1.432	1.461	1.490	1.520	1.678	1.853	2.045
K. Villimale'	10.020	10.220	10.425	10.633	10.846	11.975	13.221	14.597
AA. Bodufolhudhoo	813	829	846	863	880	972	1.073	1.184
AA. Feridhoo	612	624	637	649	662	731	808	892
AA. Himandhoo	778	794	809	826	842	930	1.027	1.133

Atoll & Island	Total Lube oil consumption (l/year)	2017	2018	2019	2020	2025	2030	2035
AA. Maalhos	870	887	905	923	942	1.040	1.148	1.267
AA. Mathiveri	1.079	1.100	1.122	1.145	1.167	1.289	1.423	1.571
AA. Rasdhoo	1.969	2.009	2.049	2.090	2.132	2.353	2.598	2.869
AA. Thoddoo	400	408	416	424	433	478	528	583
AA. Ukulhas	1.310	1.336	1.363	1.390	1.418	1.566	1.729	1.908
Adh. Dhan' gethi	1.332	1.359	1.386	1.414	1.442	1.592	1.758	1.940
Adh. Dhidhdhoo	333	340	346	353	360	398	439	485
Adh. Dhigurah	791	806	822	839	856	945	1.043	1.152
Adh. Fenfushi	1.188	1.211	1.235	1.260	1.285	1.419	1.567	1.730
Adh. Hangnameedhoo	926	945	963	983	1.002	1.107	1.222	1.349
Adh. Kun'burudhoo	351	358	365	372	380	419	463	511
Adh. Maamigili	4.314	4.400	4.488	4.578	4.670	5.156	5.692	6.285
Adh. Mahibadhoo	2.086	2.128	2.170	2.214	2.258	2.493	2.752	3.039
Adh. Mandhoo	180	184	187	191	195	215	238	262
Adh. Omadhoo	986	1.006	1.026	1.046	1.067	1.178	1.301	1.436

Atoll & Island	Total Lube oil consumption (l/year)	2017	2018	2019	2020	2025	2030	2035
V.Felidhoo	1.156	1.179	1.203	1.227	1.251	1.382	1.525	1.684
V. Fulidhoo	1.480	1.509	1.539	1.570	1.601	1.768	1.952	2.155
V. Keyodhoo	634	647	660	673	686	758	837	924
V. Rakeedhoo	580	592	604	616	628	693	766	845
V. Thinadhoo	678	692	705	719	734	810	895	988
Total l/year	370.186	377.589	385.141	392.844	400.701	442.406	488.452	539.290
Total l/day	1.014	1.034	1.055	1.076	1.098	1.212	1.338	1.478
Total barrel/day (200l)	5	5	5	5	5	6	7	7
Total kg/day	862	879	897	915	933	1.030	1.137	1.256
Total t/day	0,86	0,88	0,90	0,91	0,93	1,03	1,14	1,26

Table 21: Lube oil waste quantity projections

3.3.6. ELV

End-of life vehicles have been estimated with 1% of the registered vehicles in Zone III. For Male and Hulumale the exact number of registered vehicles for 2011-2014 are known so the projection could be done with these figures. With the population census for all Islands we could do an interpolation and assume that for the other atolls in Zone III the registered vehicles are approximatively 16% of the registered vehicles the zone. With these assumptions and population development of Zone III the following projections for end of life vehicles could be done (5 year step, for detail see annex). The percentage of different components have been calculated based on *“End-of-Life Vehicle Waste Disposal Site EASR” from Ontario Ministry of the Environment and Climate Change (Canada).*

Breakdown of material per weight	
Ferrous metal	68%
Non-ferrous metal	8%
Electrical parts	1%
Fluids	2%
Plastics	9%
Carpets	1%
Battery	1%
Glass	3%
Rubber	2%
Tyres	3%
Process polymer	1%
others	1%
Total	100%

Table 22: ELV material breakdown for processing

ELV	1%	Of registered vehicles

Atoll	Year	2017	2018	2019	2020	2025	2030	2035
Kaafu Atoll	Motor cycle	520	551	585	621	835	1.123	1.511
	Car	37	39	42	44	60	80	108
	Bus	1	1	1	1	2	2	3
	Pick-Up	15	15	16	17	23	31	42
	Lorry	6	7	7	7	10	13	18
	Van	9	9	10	10	14	19	25
	Jeep	5	5	5	6	7	10	14
	Battery Scooter	3	3	3	4	5	7	9
	Other vehicles	13	13	14	15	20	27	37
Kaafu Atoll		607	645	684	726	976	1.313	1.766
Vaavu Atoll	Motor cycle	0,86	0,86	0,87	0,87	0,89	0,91	0,93
	Car	0,06	0,06	0,06	0,06	0,07	0,07	0,07
	Bus	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Atoll	Year	2017	2018	2019	2020	2025	2030	2035
	Pick-Up	0,06	0,06	0,06	0,06	0,06	0,06	0,06
	Lorry	0,02	0,02	0,02	0,02	0,02	0,02	0,02
	Van	0,04	0,04	0,04	0,04	0,04	0,04	0,04
	Jeep	0,01	0,01	0,01	0,01	0,01	0,01	0,01
	Battery Scooter	0,02	0,02	0,02	0,02	0,02	0,02	0,02
	Other vehicles	0,09	0,09	0,09	0,09	0,09	0,09	0,09
Vaavu Atoll		1	1	1	1	1	1	1
Alifu Dhaalu Atoll	Motor cycle	5	5	5	5	6	6	7
	Car	0	0	0	0	0	0	1
	Bus	0	0	0	0	0	0	0
	Pick-Up	0	0	0	0	0	0	0
	Lorry	0	0	0	0	0	0	0
	Van	0	0	0	0	0	0	0
	Jeep	0	0	0	0	0	0	0
	Battery Scooter	0	0	0	0	0	0	0

Atoll	Year	2017	2018	2019	2020	2025	2030	2035
	Other vehicles	0	0	0	1	1	1	1
Alifu Dhaalu Atoll		6	6	7	7	8	9	10
Alifu Alifu Atoll	Motor cycle	3	3	3	4	4	4	5
	Car	0	0	0	0	0	0	0
	Bus	0	0	0	0	0	0	0
	Pick-Up	0	0	0	0	0	0	0
	Lorry	0	0	0	0	0	0	0
	Van	0	0	0	0	0	0	0
	Jeep	0	0	0	0	0	0	0
	Battery Scooter	0	0	0	0	0	0	0
	Other vehicles	0	0	0	0	0	0	0
Alifu Alifu Atoll		4	5	5	5	5	6	7
Zone III		619	657	696	738	990	1.328	1.783
By vehicle								
Motor cycle		528	560	594	630	845	1.135	1.524

Atoll	Year	2017	2018	2019	2020	2025	2030	2035
Car		38	40	42	45	60	81	109
Bus		1	1	1	1	2	2	3
Pick-Up		15	16	17	18	24	32	43
Lorry		6	7	7	8	10	14	18
Van		9	9	10	11	14	19	25
Jeep		5	5	5	6	8	10	14
Battery Scooter		3	3	4	4	5	7	9
Other vehicles		14	14	15	16	21	29	38
By weight	kg/unit							
Motor cycle	90	47.562	50.436	53.484	56.718	76.090	102.126	137.122
Car	1.150	43.441	46.065	48.848	51.800	69.485	93.254	125.200
Bus	2.000	2.052	2.175	2.305	2.444	3.271	4.383	5.876
Pick-Up	5.000	75.854	80.365	85.149	90.223	120.594	161.363	216.108
Lorry	5.000	31.896	33.800	35.819	37.960	50.781	67.996	91.117
Van	2.000	17.904	18.966	20.094	21.289	28.443	38.046	50.938

Atoll	Year	2017	2018	2019	2020	2025	2030	2035
Jeep	2.400	11.352	12.039	12.769	13.542	18.177	24.407	32.783
Battery Scooter	90	286	303	321	340	454	606	811
Other vehicles	1.500	20.410	21.602	22.867	24.208	32.225	42.973	57.389
ELV Input ton per day								
Motor cycle		0,12	0,13	0,14	0,15	0,20	0,27	0,36
Car		0,11	0,12	0,13	0,13	0,18	0,24	0,33
Bus		0,01	0,01	0,01	0,01	0,01	0,01	0,02
Pick-Up		0,20	0,21	0,22	0,23	0,31	0,42	0,56
Lorry		0,08	0,09	0,09	0,10	0,13	0,18	0,24
Van		0,05	0,05	0,05	0,06	0,07	0,10	0,13
Jeep		0,03	0,03	0,03	0,04	0,05	0,06	0,09
Battery Scooter		0,00	0,00	0,00	0,00	0,00	0,00	0,00
Other vehicles		0,05	0,06	0,06	0,06	0,08	0,11	0,15
Total		0,65	0,69	0,73	0,78	1,04	1,39	1,86

Atoll	Year	2017	2018	2019	2020	2025	2030	2035
Breakdown of material per weight								
Ferrous metal	68%	0,44	0,47	0,50	0,53	0,71	0,95	1,27
Non-ferrous metal	8%	0,05	0,06	0,06	0,06	0,08	0,11	0,15
Electrical parts	1%	0,01	0,01	0,01	0,01	0,01	0,01	0,02
Fluids	2%	0,01	0,01	0,01	0,02	0,02	0,03	0,04
Plastics	9%	0,06	0,06	0,07	0,07	0,09	0,13	0,17
Carpets	1%	0,01	0,01	0,01	0,01	0,01	0,01	0,02
Battery	1%	0,01	0,01	0,01	0,01	0,01	0,01	0,02
Glass	3%	0,02	0,02	0,02	0,02	0,03	0,04	0,06
Rubber	2%	0,01	0,01	0,01	0,02	0,02	0,03	0,04
Tyres	3%	0,02	0,02	0,02	0,02	0,03	0,04	0,06
Process polymer	1%	0,01	0,01	0,01	0,01	0,01	0,01	0,02
others	1%	0,01	0,01	0,01	0,01	0,01	0,01	0,02

Table 23: ELV waste quantity projections

3.3.7. Velana Airport Island waste

The data provided from Velana airport management in Male gives an amount of 9,4 t/day of Commercial waste similar to Household waste in 2016. With the growth rate for tourist arrivals from the tourism yearbook for 2013-2017 and the information about the airport development, the following figures have been calculated for the waste generation:

Item	Unit	Year									
		2016	average	2017	2020	2025	2030	2035	2040	2045	2047
Tourist flow	per year	1.286.135	1.123.300	1.199.772	1.461.863	2.031.982	2.824.446	3.925.966	5.457.074	7.585.308	8.653.236
average tourist flow	per day	3.524	3.078								
% change over previous year	%	4,20%	6,81%								
HH waste airport	t/day	9,40		10,04	12,23	17,00	23,64	32,85	45,67	63,48	72,41

Table 24: Waste generation forecast at Velana airport

4. ISWMCs

The main objective of the GOM is to establish at least one ISWMC per Island by the end of 2018. This ambitious program is part of the national strategy and policy for improving the inner island waste management and development. ISWMCs should promote segregation and composting on Island level in order to reduce the amount of residual waste for treatment. ISWMC are consisted mainly by:

- A fenced area
- A platform for composting
- Some storage facilities (concrete/bricks walls with a roof shed on top) for valuable fraction such as plastics, metal cans, paper and cardboard
- And some equipment for crushing and baling the material.

After some failed attempts and lessons learn period since 2005 the new ISWMCs have been developed with more accuracy in terms of space availability and dimensioning.

Figure 41: example of an ISWMC of the 3rd generation

Figure 42: Example of an ISWMC of the 3rd generation

Best practice case : Ukulhas (alifu Alifu atoll)

IWMC are considered as politically high priority in terms of awareness and community participation. Ukulhas was considered as best practice case by MEE. The sorting and composting rates are acceptable and site management is done properly.

Main challenge is the lack of income while no customer could be found for recyclables.

Further information :

Source : "study of nationally recognized good practices of WASTE MANAGEMENT -Case-study of AA.Ukulhas and B.Maalhos- UNDP- Prepared by Aisha Niyaz 2016"

http://www.mv.undp.org/content/maldives/en/home/ourwork/environmentandenergy/successstories/Ukulhas-an-example-of-excellent-waste-management-practices.html

In zone III most of the ISWMC are still not planned, or not constructed. To include the waste streams of the ISWMC in the feasibility assessment an Excel based tool was developed for the waste prognosis of the residual waste quantities coming from the Islands to Tilafushi (future location of the RSWMF).

Name - Administrative Status			N° of inhabitants 2017	Waste estimation 2017	waste estimation 2017	ISWMC	Composting Composting rate %	Sorting plastics	 metal can	 Paper & Cardboard	Residual waste
				kg/day	t/year		30% in t/day	50% in t/day	60% in t/day	30% in t/day	in t/day
Kaafu Atoll	Dhihffushi	rural	1.079	553	202	planned	0,00	0,00	0,00	0,00	0,55
	Gaafaru	rural	1.115	571	208	planned	0,00	0,00	0,00	0,00	0,57
	Himmafushi	rural	2.019	1.034	378	planned	0,00	0,00	0,00	0,00	1,03
	Hulhumale'	urban	23.983	18.668	6.814	planned	0,00	0,00	0,00	0,00	18,67
	Huraa	rural	1.508	772	282	planned	0,00	0,00	0,00	0,00	0,77
	Kaashidhoo	rural	1.947	998	364	planned	0,00	0,00	0,00	0,00	1,00
	Male'	urban	145.560	116.170	42.402	planned	0,00	0,00	0,00	0,00	116,17
	Thulusdhoo	rural	1.618	829	303	planned	0,00	0,00	0,00	0,00	0,83
	Vilin'gili	rural	9.248	4.739	1.730	planned	0,00	0,00	0,00	0,00	4,74
	Gulhi	rural	995	510	186	planned	0,00	0,00	0,00	0,00	0,51
	Guraidhoo	rural	1.874	960	351	planned	0,00	0,00	0,00	0,00	0,96
	Maafushi	rural	3.382	1.733	632	planned	0,00	0,00	0,00	0,00	1,73
Kaafu Atoll			194.328	147.537	53.851		0	0	0	0	148
Vaavu Atoll	Felidhoo	rural	512	263	96	under construction	0,00	0,00	0,00	0,00	0,26
	Fulidhoo	rural	384	197	72	under construction	0,00	0,00	0,00	0,00	0,20
	Keyodhoo	rural	719	368	134	under construction	0,00	0,00	0,00	0,00	0,37
	Rakeedhoo	rural	106	54	20	under construction	0,00	0,00	0,00	0,00	0,05
	Thinadhoo	rural	157	80	29	under construction	0,00	0,00	0,00	0,00	0,08
Vaavu Atoll			1.878	962	351		0	0	0	0	1
Alifu Dhaalu Atoll	Dhan'gethi	rural	885	454	166	operated	0,10	0,01	0,01	0,01	0,33
	Dhigurah	rural	690	354	129	planned	0,00	0,00	0,00	0,00	0,35
	Dhihdhoo	rural	164	84	31	under construction	0,00	0,00	0,00	0,00	0,08
	Fenfushi	rural	924	473	173	under construction	0,00	0,00	0,00	0,00	0,47
	Hangnaameed	rural	537	275	101	under construction	0,00	0,00	0,00	0,00	0,28
	Kun'burudhoo	rural	475	243	89	under construction	0,00	0,00	0,00	0,00	0,24
	Maamigili	rural	2.598	1.331	486	under construction	0,00	0,00	0,00	0,00	1,33
	Mahibadhoo	rural	2.168	1.111	405	under construction	0,00	0,00	0,00	0,00	1,11
	Mandhoo	rural	391	200	73	under construction	0,00	0,00	0,00	0,00	0,20
	Omadhoo	rural	952	488	178	under construction	0,00	0,00	0,00	0,00	0,49
Alifu Dhaalu Atoll			9.784	5.013	1.830		0	0	0	0	5
Alifu Alifu Atoll	Bodufolhudho	rural	646	331	121	under construction	0,00	0,00	0,00	0,00	0,33
	Feridhoo	rural	441	226	82	under construction	0,00	0,00	0,00	0,00	0,23
	Himandhoo	rural	800	410	150	under construction	0,00	0,00	0,00	0,00	0,41
	Maalhos	rural	434	222	81	under construction	0,00	0,00	0,00	0,00	0,22
	Mathiveri	rural	697	357	130	under construction	0,00	0,00	0,00	0,00	0,36
	Rasdhoo	rural	1.099	563	206	under construction	0,00	0,00	0,00	0,00	0,56
	Thoddoo	rural	1.673	857	313	under construction	0,00	0,00	0,00	0,00	0,86
	Ukulhas	rural	1.165	597	218	under construction	0,00	0,00	0,00	0,00	0,60
Alifu Alifu Atoll			6.956	3.564	1.301		0	0	0	0	4
Zone III			**212.946**	**157.076**	**57.333**		**0**	**0**	**0**	**0**	**157**

Figure 43: screenshot of the ISWMC waste quantity prognosis tool

The variable parameters[1] are:

[1] Due to the complexity of the calculations we assumed that all ISWMCs will have the same composting and sorting rates

- the composting rate
- the sorting rate for plastics, metals and P&C

It has been assumed that at the start (2017) the composting rate is at 20%, sorting rate for plastics, metals and P&C respectively 10%, 10%, and 20% while at the start only a few ISWMC are under operation. For the year 2022 the assumption was that all ISWMCs are under operation and that the composting and sorting rates increased respectively to 30 %, 20%, 20%, 30% and that increase will continue by 10% every 5 years to reach 50% of composting rate in 2037 and 40%,40%,50% respective sorting rates for plastics, metals and P&C.

It should also be noted that due to the particularity of this region (only 33 Inhabited islands, Male' and Hulhumale' are not considered in this ISWMC program) the influence of this waste streams comparing to the waste streams from Male and Hulhumale' are not so important.

5. Transfer stations

Actual three transfer stations are planned as part of the ISWM in zone III:

- Male TS at industrial village (new reclaimed area in Male')
- Hulhumale TS (at the south of Hulhumale)
- Vilingili TS (at the location of the actual IWMC)

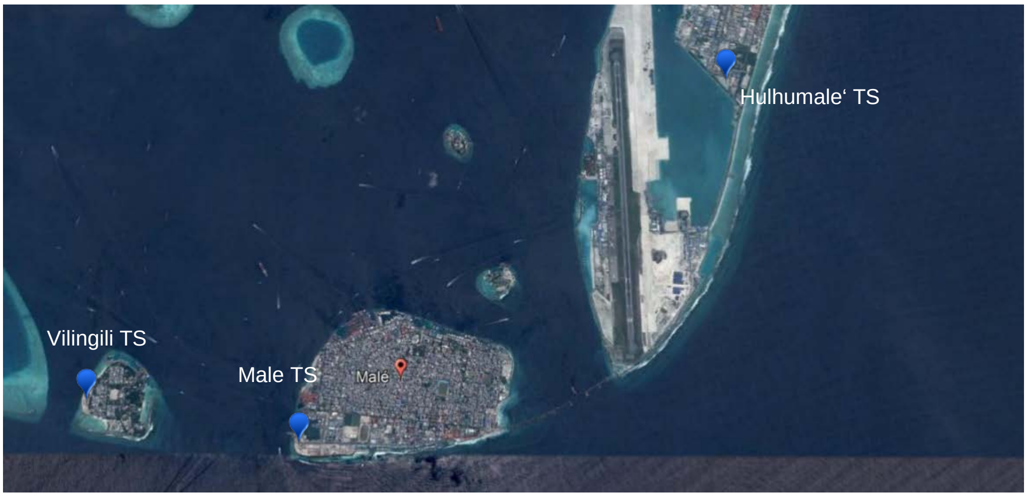


Figure 44: TS locations Greater Male'

The transfer station in Male was designed for the sole transferring purposes rather than sorting and selling of recyclables and valuable fractions. Main requirement is to guarantee that at least C&D waste is collected and transported separately from the other Households. Some containers could be dedicated for mono-loading (for example P&C from administration, or recyclables from Hulhumale, etc.) allowing a better organisation of different waste streams.

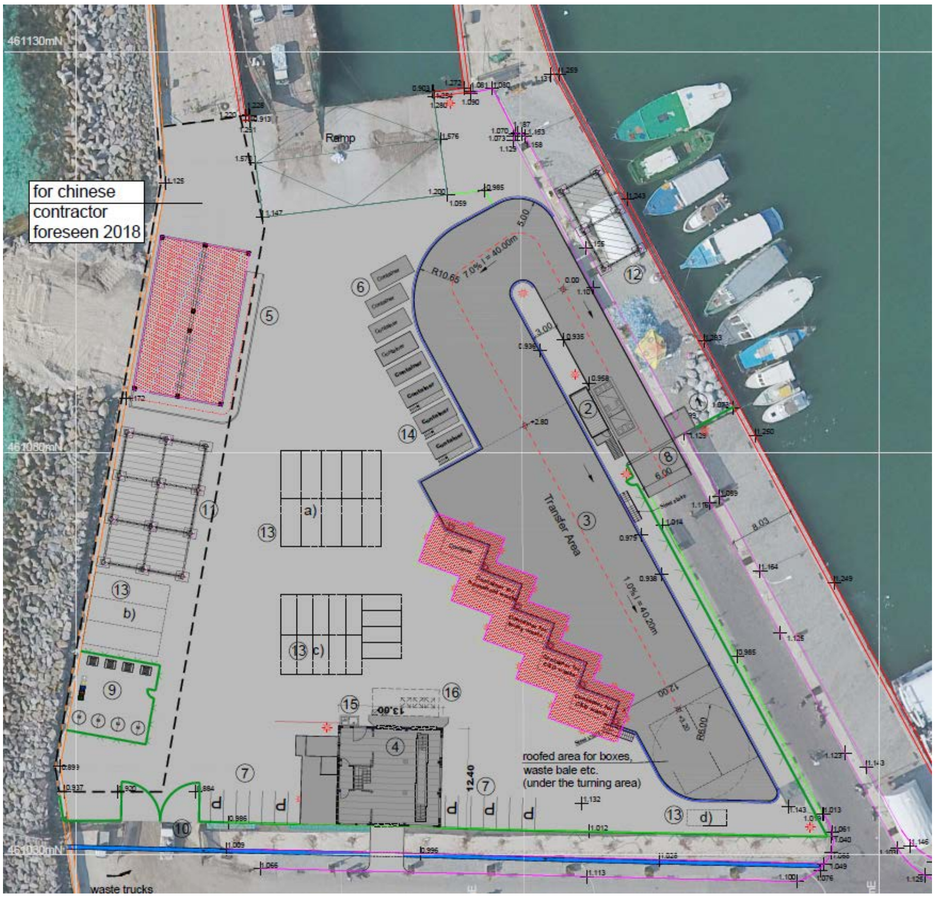


Figure 45: Planned TS in Male‘ (Industrial village)

A new area was allocated for the Transfer facility in Hulhumale’. Actually three options are under consideration and discussion at MEE. One option is to build a civic amenity and to foresee this area for storage and maintenance. The second and third option is to build a transfer station (of different size).

Figure 46: designated area for Hulhumale TS or civic amenity

Vilingili has actually an ISWMC. Upon request of the Ministry and due to the further development of Vilingili it was suggested to rehabilitate and upgrade this site to a waste transfer station. On long term, the waste should be transferred to Male transfer station via a bridge between Vilingili and Hulumale.

Figure 47: ISWMC in Vilingili

Figure 48: ISWMC in Vilingili

6. Mass balances

Main objective is to have an overview about the main waste streams arriving at Tilafushi in order to design the future RSWMF including the WTE infrastructure.

The following waste streams have been considered:

- Household and commercial waste from Hulhumale and Male
- Household and commercial waste from the other inhabited islands after processing through the ISWMCs
- Commercial waste from Velana airport Hulhule’
- Resort waste (similar to HH waste)

- Clinical waste (autoclaved waste) from the two main hospitals of the zone
- Lube oil waste quantification based on oil consumption data received from MEE
- Industrial waste similar to HH waste from Tilafushi itself
- ELV projections based on the number of registered vehicles in the region
- C&D waste based on assumption and observation

Additionally considering that the start of the RSWMF will be only at 2022 a certain amount of waste is delivered and processed (baling) during the next years. This amount was estimated to 200.000 t. At the start of the facility in 2022 an amount of approx. 495 t/day is expected at the gate. After processing of C & D, ELV and sorting of small valuable fractions an input of 395 t/day for the waste incinerator was estimated. In case of less or more input there is a possibility to monitor the process and the efficiency through the baled waste stored between 2018 and 2022.

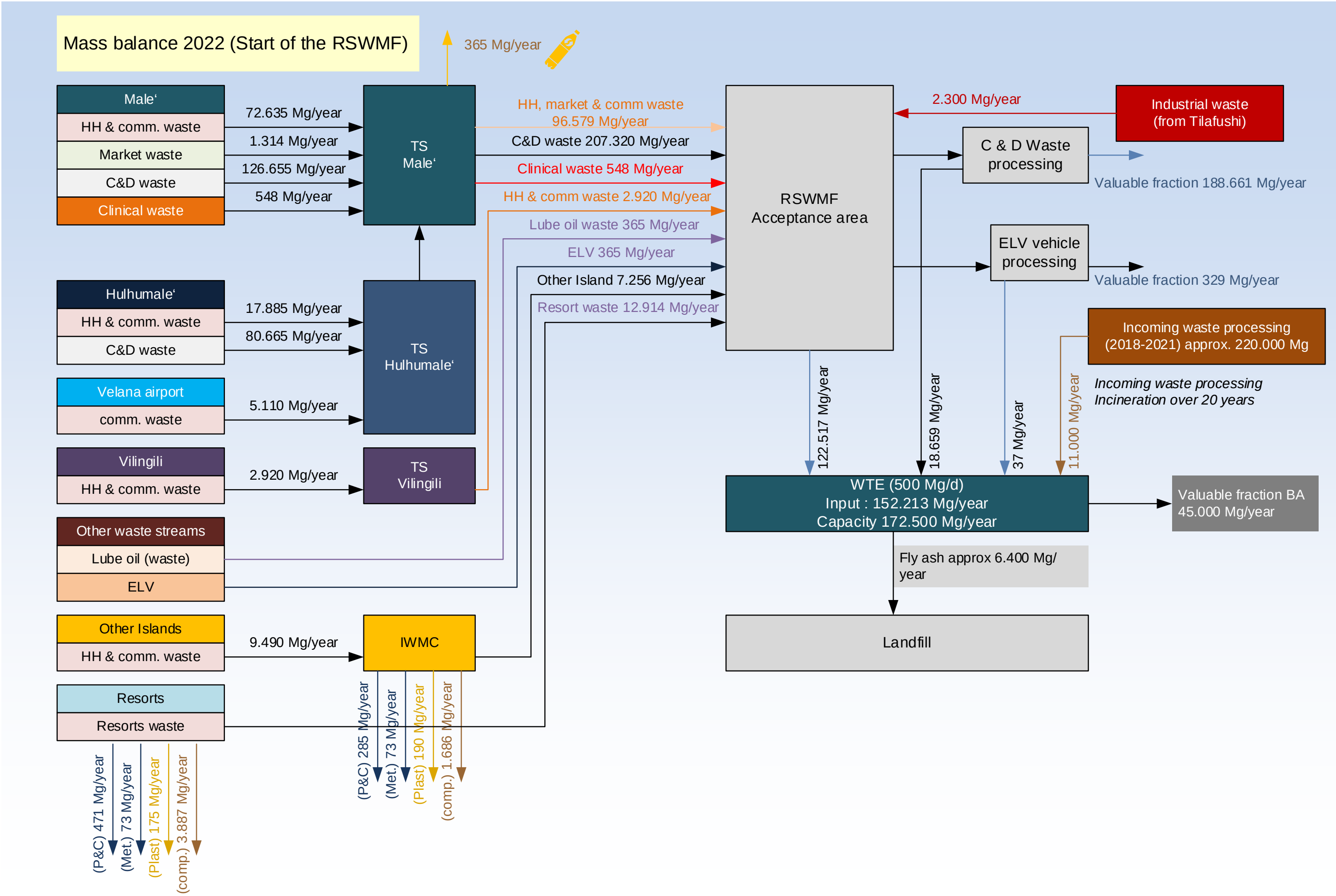


Figure 49: Mass balance for the starting year of the RSWMF in 2022

Consequently the WTE facility will be dimensioned in the first stage for an input of 500 t/day (two lines of 250 t/day)

The tentative mass balance[2] for 2037 (after 15 years of operation) shows that the capacity of the WTE plant is not enough for the incoming waste. Two scenarios are possible:

- Increasing the sorting rates for valuable fractions: Particularly the GM region has still an important potential.
- Or increasing the capacity of the WTE by a third line of 250 t/day

it should be noted the scenario development should start after a few years of the facility operation in order to include also the return of experience from the WTE.

The following figure shows the tentative mass balance for 2037 considering that segregation and sorting in the greater Male' region is still poor.

[2] These mass balances have been made based on the scenario of a centralized Regional waste management facility in Tilafushi which was identified as the Best Environmental and Practical Options in the following chapter.

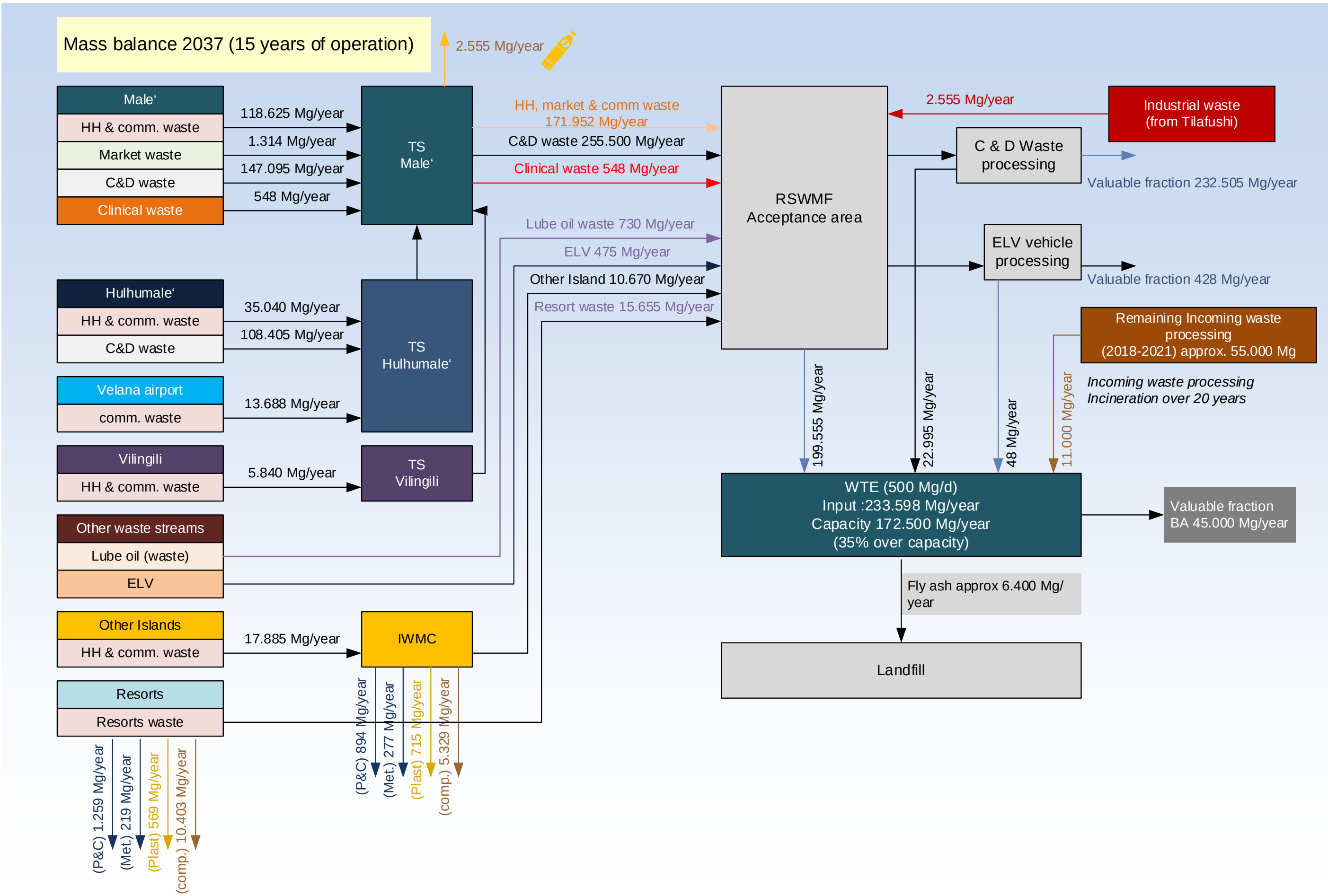


Figure 50: Mass balance for 2037 (15 years of operation of the RSWMF)

CHAPTER 4: SCENARIOS AND BPEO

1. Waste management options

The study for selection of most appropriate waste management option has been conducted using a screening and selection process known as the Best Practicable Environmental Option (BPEO). BPEO entails a systematic and balanced assessment of different waste disposal options, to identify the option which provides maximum environment, economic and social benefit.

A BPEO process involves a process of identifying viable scenarios for waste management, followed by a process of performance assessing against a number of decision criteria such as technical, environment, social and financial/economic to determine which scenario is the preferred option. The BPEO concept has been outlined in the "National Solid Waste Management Policy for the Republic of Maldives" and has been identified as "*one of the strategic principles for development of waste management systems in the country"*.

BPEO is a strategic rather than site-specific tool, hence it does not address the site-specific issues associated with individual locations and it cannot justify the selection of particular site for individual facilities. The BPEO approach implicitly recognizes that the preferred option may differ from location to location because of variation in the local needs, resources and impact and in relative significance of criteria. Nevertheless, because of the nature of analysis required, the concept is not sufficiently precise to be used to justify the selection of specific sites, but is appropriate to use in conjunction with the broad area of research.

The geographical, social and cultural context in the Maldives makes the search for options and scenarios more complex while due to its unicity there is not similar cases which could be transferred from other countries in the region.

BPEO processes involves the implication of a maximum of stakeholders and needs an extensive technical expertise to come out with reliable results. Normally such processes needs a certain time in order to conduct necessary workshops and discussion loops.

Due to the time constraints and constraints in the ToR, this iterative approach couldn't be done during the elaboration of this study.

However, In order to have a quite realistic output it was suggested to apply the BPEO process on 3 levels:

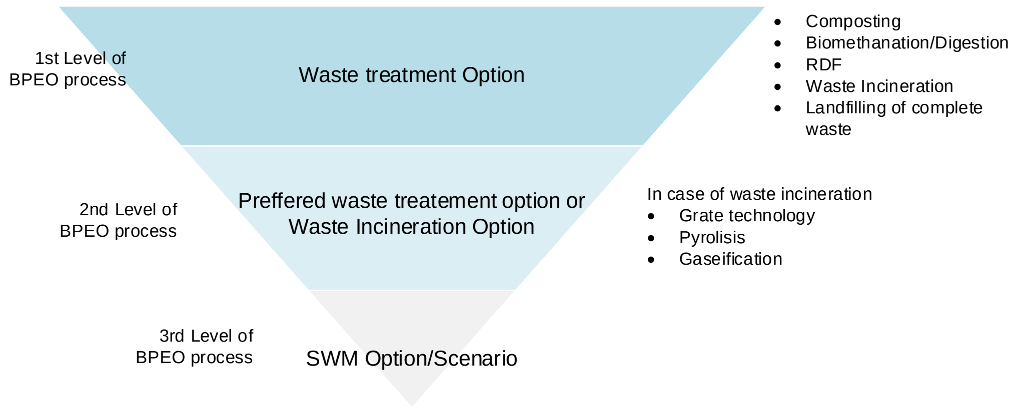


Figure 51: Levels of BPEO processes

2. Technology assessment (1st level of BPEO)

The first level is focussed on the different treatment technologies in the SWM. Objective is to reduce the number of technologies to a reasonable level in order to develop a minimum amount of scenarios through the BPEO process (3rd level). The following pre-screening table shows already a the recommended treatment technologies which needs to be asset in the further chapter as a function of :

- The annual waste quantity in the region
- The waste composition and typology
- The time frame strategy : short, medium or long term

In a second step, the different waste treatment will be presented and compared with the following methodology.

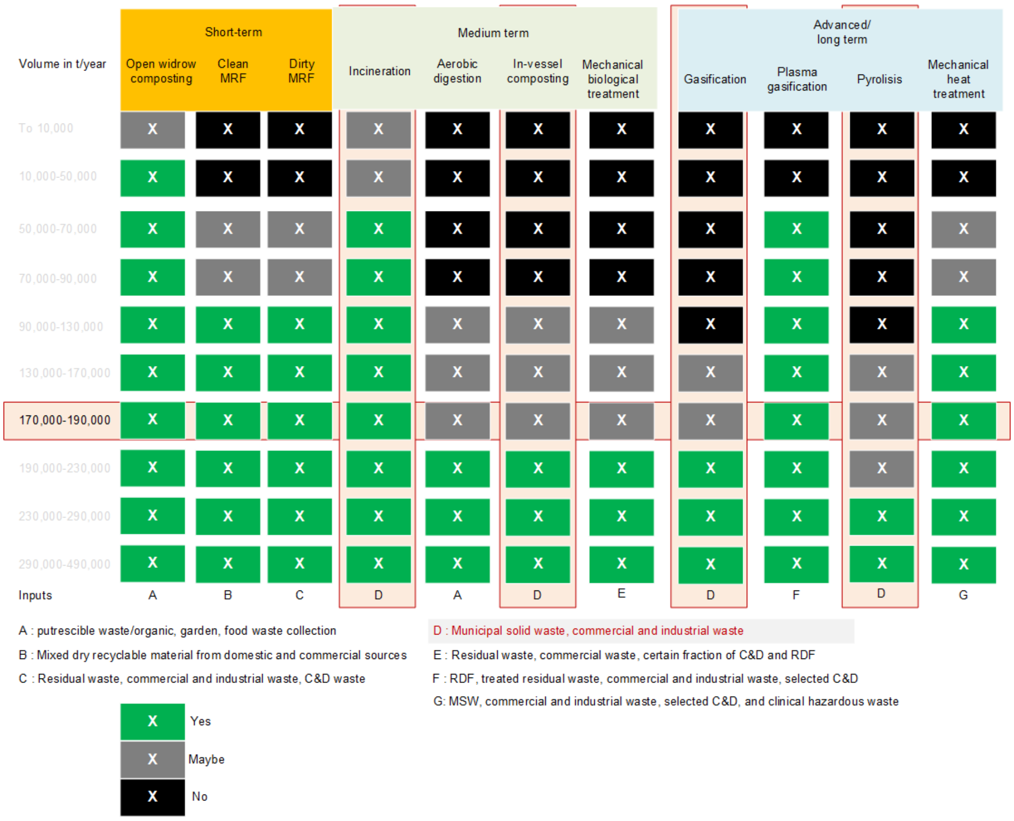


Figure 52: technology assessment depending on input and volume of waste

2.1. Waste treatment

2.1.1. Composting

Municipal solid waste (MSW) primarily consists of organic, inorganic, and inert fractions. Under natural conditions, the organic fraction of waste continually decomposes, accompanied by a strong foul odour and production of gases, which are predominantly CH_4 or CO_2 depending on the aerobic condition of the decomposing mass. Vector infestation during the natural decomposition is a common phenomenon.

Composting is a process of controlled decomposition of the organic waste, typically in aerobic conditions, resulting in the production of stable humus-like product, i.e., compost.

The third preferred choice in the ISWM strategy (3 R strategy), i.e., adoption of resource recovery strategies and composting, ensures that waste is processed appropriately to facilitate further use of the material. Composting is a biological process of stabilising biomass either in the presence or absence of free oxygen, carried out by a host of microbes. Aerobic composting, which is carried out in the presence of air, is far more popular because it is much faster compared with the "trench" composting where direct access to air is denied. Processing of MSW by this process yields humus rich compost (organic manure) along with macronutrients and micronutrients for plants.

Given the propensity of organic waste to contribute to environmental pollution in many ways, composting and other biological stabilisation processes, which would mitigate the impact of uncontrolled decomposition of organic MSW, should be adopted by urban areas. Composting is an environmentally beneficial waste recycling mechanism and not a waste disposal mechanism.

Benefits of composting

- The real economic benefits of compost use include improved soil quality, enhanced water retention capacity of soil, increased biological activity, micronutrient content, and improved pest resistance of crops
- Composting minimises or avoids GHG emissions from anaerobic decomposition of organic waste (such as in a large unturned heap).
- Composting increases the design life of other waste management facilities.
- Stringent design requirements and associated costs for catering to management of leachate from organic waste decomposition may be reduced in those landfills that do not receive organic waste.
- Compost is particularly useful as organic manure; it contains macronutrients (nitrogen, phosphorous, and potassium) as well as micronutrients. When used in conjunction with chemical fertilisers, optimum results are obtained.
- The use of compost reduces the dependency on chemical fertilisers for agricultural operations. When used as a soil amendment, compost reduces the need for water, fertilisers, and pesticides. Compost acts as a soil conditioner, therefore supporting the long-term fertility of soil.
- Compost may be used to revitalise vegetation habitats and add life to marginal, impoverished soils and wastelands.
- Compost may also be used as a bio matrix in remediation of chemical contaminants and as a remediated soil in contaminated sites; compost helps in binding heavy metals and other contaminants, reducing leachate and bio-absorption.

The financial viability of compost plants is primarily dependent on the marketability of the compost at a reasonable price. For the low carbon soil (soil organic carbon) in the Maldives, there is a requirement of good quality compost for agriculture. Yet the present demand for compost is very low. An analysis of the available markets and potential demand for compost is essential to decide the required size of the compost plant. An assessment of end user requirements of compost quality, as defined by the final use, is essential to arrive at the final design of the compost plant.

Composting technologies

Technologies for composting can be classified into the following general categories:

- windrow composting;
- aerated static pile composting;
- in-vessel composting;
- decentralised composting (bin and box composting); and
- vermicomposting.

Windrow composting

Windrow composting process consists of placing the pre-sorted feedstock in long narrow piles called windrows that are turned on a regular basis for boosting passive aeration. The turning operation mixes the composting materials and enhances passive aeration. Compost yield of 10-15% is more common from mixed municipal solid waste.

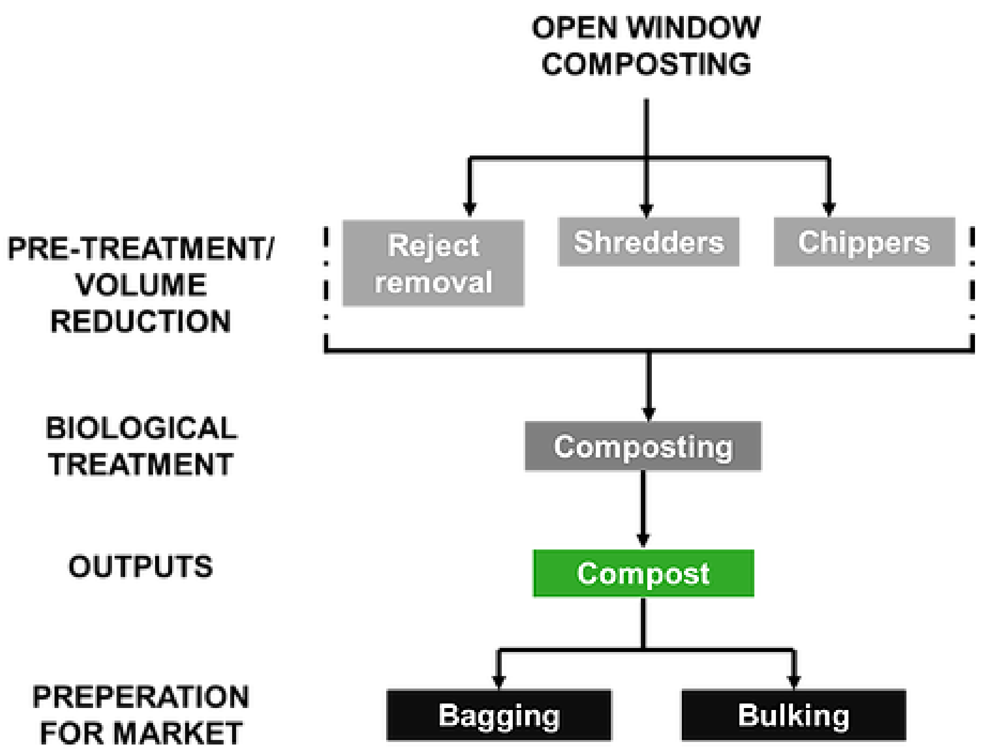


Figure 53: technology description windrow composting

Configuration	
Waste streams accepted:	Putrescible / organic waste, garden / food waste collections
Input capacity ranges	5,000-500,000 tonnes per year
Typical outputs	Compost
Purposes	To recycle biodegradable waste into compost for land application / soil improvement

Indicative capital cost	Upwards of 600,000 USD for small scale simple windrow system
Indicative operational cost	Low
Life span	15-20 years
Skills requirements	Low
Job creation opportunity	High
Technology restrictions	OWC is a process that can take up to 12 weeks The technology requires mechanical treatment to remove contaminants Compost turned by mechanical means should not be practised in close proximity to settlements in case of odour / bio aerosol issues

key performance indicators for windrow compost production

for a 500 t/day plant, 20% of process efficiency is possible under good operational conditions, the typical efficiency of a windrow compost plant receiving *segregated organic solid waste* is around 18%–20%, i.e., for an input feedstock of 100 t/day of segregated waste, it should be able to produce 18–20 tonnes of finished compost. Where mixed waste is received as input feedstock, compost yield of 10%–15% is expected.

Advantages:	Disadvantages
Open windrow composting is a relatively low capital waste treatment process Saleable product Land application when convenient Improves nutrient qualities	Green waste dependent on the weather conditions Collection infrastructure impacts waste types received There can be respiratory / health issues associated with bio aerosols from turning compost, and some odour issues High use of water

In-Vessel composting

In-vessel composting (IVC) is a way of accelerating the composting process within an enclosed environment. Waste will be screened and any oversize items are removed. The waste will then be shredded or chipped to increase the surface area and reduce the average material size. Source segregated of organic wastes will often require a limited amount of treatment prior to composting.

The composting process takes place under controlled conditions in an enclosed environment, either within buildings (bays, beds) or in composting vessels (tunnels, drums, towers).

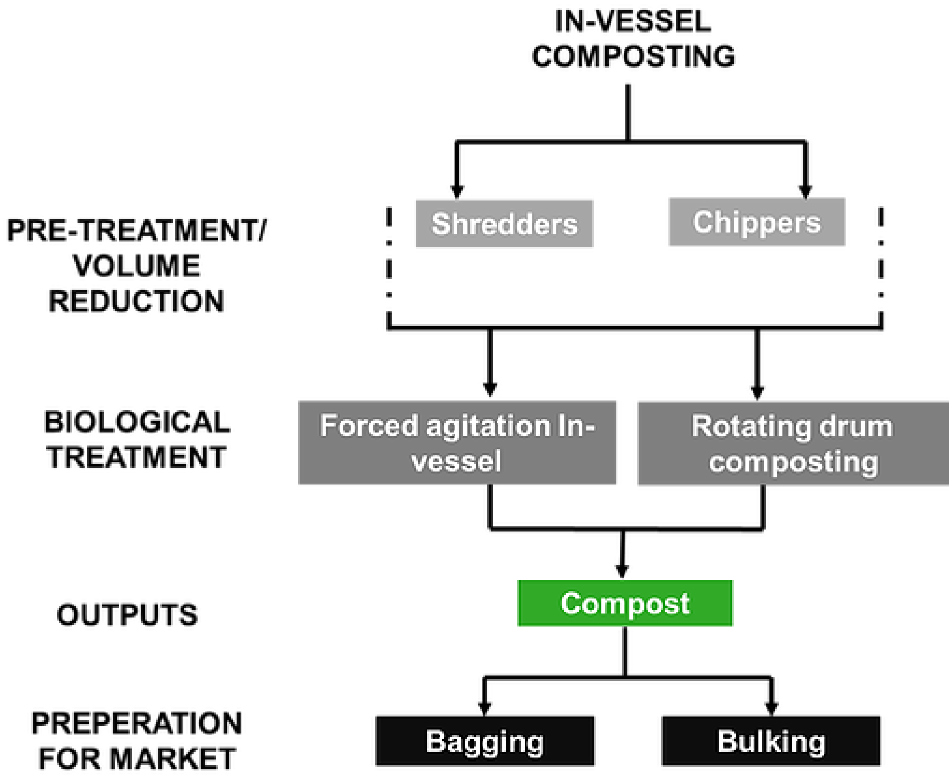


Figure 54: technology description In vessel composting

Configuration	
Waste streams accepted:	Putrescible / organic waste, garden / food waste collections
Input capacity ranges	5,000-500,000 tonnes per year
Typical outputs	Compost
Purposes	To recycle biodegradable waste into compost for land application / soil improvement
Indicative capital cost	25,000-50,000 USD/(capacity ton/day), (for ex : 50 t/day of input = 1,25 Mio -2,5 Mio USD investment)
Indicative operational cost	High
Life span	20-30 years
Skills requirements	High
Job creation opportunity	Low
Technology restrictions	Require several weeks to decompose and stabilise materials Requires mechanical agitation techniques Moisture content must be controlled through blending with co-substrates or dry feedstock

Advantages:	Disadvantages
Completed rapidly, resulting in product stabilisation / sanitation in 3 to 4 days Relatively small footprint allows entire process to take place within a controlled environment (inside a building) Maintain a rapid decomposition process year-round regardless of external ambient condition	Requires active management to ensure a good mix of materials is processed, in order to develop and maintain good quality compost outputs Potential for odour issues High use of water

2.1.2. Mechanical Biological treatment

Mechanical biological treatment (MBT) combines both mechanical and biological treatment methods (open windrow composting, materials recycling facilities, anaerobic digestion and in-vessel composting). These are supported by a combination of pre-treatment and sorting techniques at the beginning of the process, and a selection of emissions control and quality control techniques at the end of the process.

The mechanical and biological processes can be arranged in either order, with mechanical treatment preceding biological treatment or vice versa. Typical mechanical treatments will include a range of sorting technologies, from simple sieve/trommel separation techniques through to more advanced positive selection techniques like near infrared segregation.

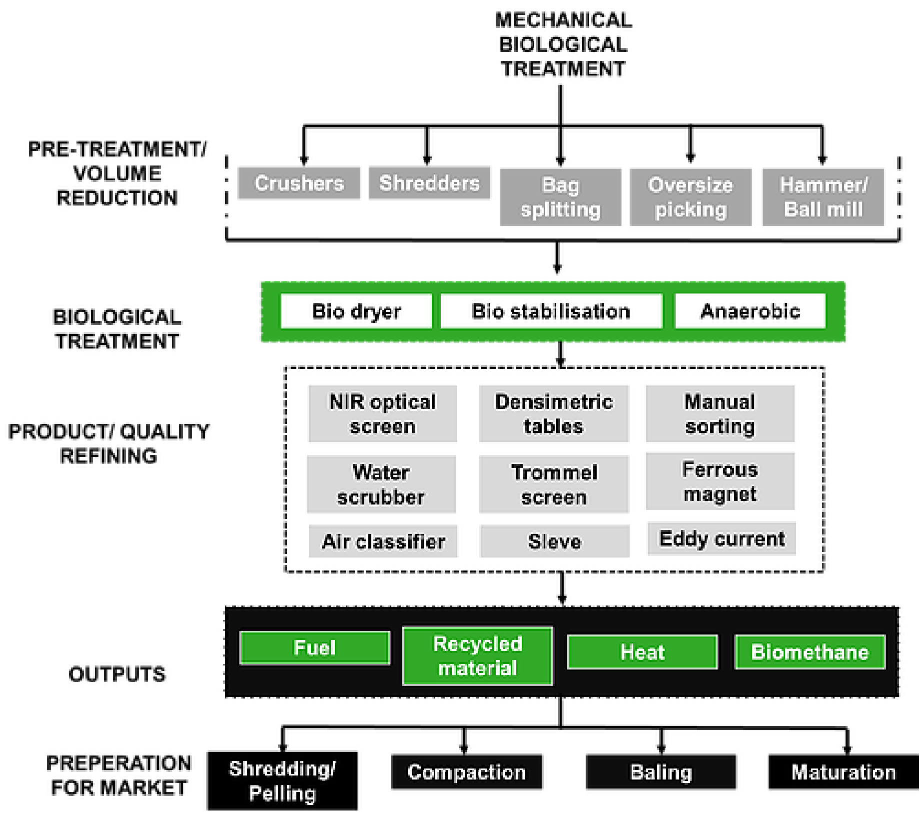


Figure 55: technology description MBT

Configuration	
Waste streams accepted:	MSW, commercial and industrial waste, wet type
Input capacity ranges	50,000-500,000 tonnes per year
Typical outputs	Energy, recyclables, fines, stabilised material
Purposes	Stabilise waste, producing useable recyclable and organic products in the process
Indicative capital cost	240-325 USD/(ton/year capacity) (f. ex: 100,000 t/year capacity = 24-35 Mio USD)
Indicative operational cost	High
Life span	20-30 years
Skills requirements	High
Job creation opportunity	Low
Technology restrictions	Not suitable for hazardous materials. Not suitable for bulky or large waste streams. Will only recover a small amount of relatively low-grade recyclables.

Advantages:	Disadvantages
Conserving resources and reducing emissions harmful to the environment Reduce volume and more rapid waste stabilisation Stabilisation of the waste reduces side-effects at the landfill site Hazardous waste contaminants will not reach municipal landfill sites due to the sorting of the waste prior to treatment	Potential for odour issues A variety of occupational health and safety issues Dry recyclables separated out during the process will be of poor quality Demand fixed tonnages of waste

2.1.3. Waste to Energy

Waste to energy (WtE) refers to the process of generating energy in the form of heat or electricity from MSW. Energy from MSW can be achieved through:

a. thermal processes like incineration or combustion of refuse derived fuel (RDF); and
b. biological processes like biomethanation and further conversion into electrical power or automotive fuel (compressed biogas).

The integrated solid waste management (ISWM) hierarchy indicates that recovery of energy from waste is preferable only after considering the potential for recovery of material. Valuable energy is sought to be recovered after ensuring that all possible reduce, recycle, and recover mechanisms have been adopted.

Proven WtE technologies include incineration of MSW with recovery of energy, either as heat or converted to electricity and production of high calorific value RDF, which is fast gaining acceptance. However, stringent norms specifying quality standards and conditions for its utilisation must be developed by concerning authorities. There are various other technologies under discussion, such as pyrolysis and gasification, which will be discussed only if the Incineration was identified as the BPEO for waste treatment technology in this context

Combustion technologies in the Maldives have to cope with the comparably high moisture and inert content, as is common in the local HH waste. However, doorstep segregation of waste, segregated management of inert wastes, and pre-treatment to separate the high calorific fraction (RDF) can enable efficient thermal processes.

WTE plants are an expensive option for managing MSW, requiring skilled staffing and adoption of high-level technologies. They also have the potential to cause significant environmental impacts through emissions and fly ashes if plants are not operated efficiently and if appropriate emission control mechanisms are not adopted.

Incineration

Incineration is a waste treatment process that involves combustion of waste at very high temperatures in the presence of oxygen and results in the production of ash, flue gas, and heat. Incineration is a feasible technology for combustion of unprocessed or minimum processed refuse and for the segregated fraction of high calorific value waste.

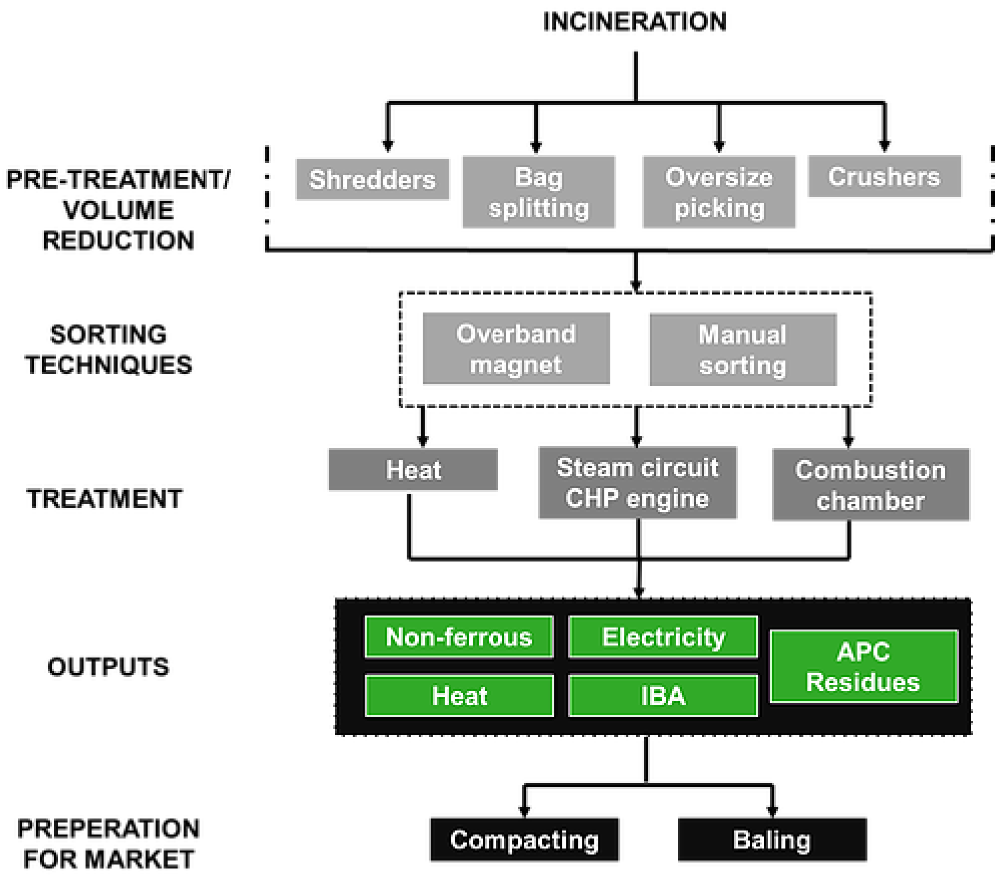


Figure 56: technology description incineration

The potential for energy generation depends on the composition, density, moisture content, and presence of inert in the waste. In practice, about 65%–80 % of the energy content of the organic matter can be recovered as heat energy, which can be utilised either for direct thermal applications or for producing power via steam turbine generators.

Besides the potential for energy use, incineration of MSW helps to reduce landfill volumes. Incineration is an option especially where other better options of processing of waste are not feasible and land for landfilling and other waste processing methods is scarce.

MSW incineration projects are appropriate only if the following overall criteria are fulfilled:

- a mature and well-functioning waste management system has been in place for a number of years;
- Incineration is especially relevant for the dry bin content in a two-bin system. For unsegregated waste, pre-treatment is necessary;
- the lower calorific value (LCV) of waste must be at least 1,450 kcal/kg (6 MJ/kg) throughout all seasons. The annual average LCV must not be less than 1,700 kcal/kg (7 MJ/ kg)
- the furnace must be designed in line with best available technologies to ensure stable and continuous operation and complete burnout of the waste and flue gases. MSW is usually incinerated in a grate incinerator. Uniform combustion of waste is dependent on the grate design.

- the supply of waste should be stable and amount to at least 500 TPD of segregated waste;
- produced electricity or steam can be sold on a sustainable basis (e.g., feeding into the general grid at adequate tariffs).
- it is possible to absorb the increased treatment cost through management charges and tipping fees.
- skilled staff can be recruited and maintained.
- since the capital investment is very high, the planning framework of the community should be stable enough to allow a planning horizon of 25 years or more.
- strict monitoring systems are proposed and followed.

Configuration	
Waste streams accepted:	Residual waste, commercial and industrial waste, certain fractions of C&D waste, RDF
Input capacity ranges	10,000-500,000 tonnes per year
Typical outputs	Electricity, heat, incinerator bottom ash, air pollution control residues
Purposes	Recover energy from non-recyclable mixed waste streams
Indicative capital cost	60-70 Mio USD for 100,000 tpa facility
Indicative operational cost	Low
Life span	20-30 years
Skills requirements	High
Job creation opportunity	Low
Technology restrictions	Not suitable for bulky or large items Will destroy all non-metal recyclable materials Requires a specialist grate to handle higher temperatures generated by refuse derived fuel (RDF) Energy recovery efficiencies are lower for electricity than heat

Advantages:	Disadvantages
Incineration is a robust technology than can be used to treat a variety of waste streams Revenue from both gate fees and energy generation can make the technology competitive	Incineration is capital intensive Large quantities of waste to incinerate can alter plans for recycling and reuse of waste Flue gases can pollute the environment Requires feedstock to be pre-treated to a RDF, or a local producer of RDF

Biomethanation/Digestion

Biomethanation is the anaerobic (in the absence of free oxygen) fermentation of biodegradable matter in an enclosed space under controlled conditions of temperature, moisture, pH, etc. The waste mass undergoes decomposition due to microbial activity, thereby generating biogas comprising mainly of methane and carbon dioxide (CO_2), and digested sludge, which is almost stabilised but may contain some pathogen. Due to the anaerobic environment, hydrogen sulfide (HS) is generated with varying percentage depending on the sulphur content in the system (in the form of protein, sulphate, etc.). Like composting, biomethanation is one of the most technically viable options is an “option for the organic fraction of MSW due to the presence of high organic and moisture content.

Generally, the overall process can be divided into four stages:

- pre-treatment
- anaerobic fermentation
- collection of biogas and its usage
- residue treatment

Pre-treatment: Most digestion systems require pre-treatment of waste to obtain a homogeneous feedstock. For anaerobic fermentation, pre-processing involves separation of non-digestible material either through source segregation or through mechanical sorting at the biogas plant facility. Source segregation results in less contaminated sludge compost. The separation ensures the removal of undesirable or recyclable material such as glass, metals, stones, etc. The waste is shredded before it is fed into the digester for better fermentation especially when the incoming material has large pieces or whole items.

Anaerobic Fermentation (Digestion): Anaerobic fermentation happens in three steps brought about by different groups of microbes: hydrolysis (hydrolytic bacteria), acidogenesis (acidogenic bacteria), and finally biomethanation (methanogenic bacteria). Normally the digesters (fermenters) are designed as single stage or single phase, where all the three processes take place in microenvironments within the single vessel. Later, the concept of biphasic fermenters were developed where the process up to acidogenesis happens in the first phase in a slightly lower pH range and the methanogenesis happens in the second phase at near neutral pH range. This mode is supposed to be more efficient from the point of pH as well as time management because of the flexibility to optimise each of these reactions.

However, for MSW, the normal practice is to use suspended particulate fermenter configuration in one digester or two digesters in tandem. In the latter case, the efficiency as well as effluent quality improves. The size of the fermenter (digester) depends on the input volume of the substrate (feed material for microbial action) in suspension and the HRT. Inside the digester, the feed is diluted to achieve the desired solids content and remains in the digester for a designated retention time. For dilution, a varying range of water sources can be used such as clean water, sewage, or re-circulated liquid from the digester effluent. Usually, the solids concentration is around 6%–10%, but some of the well-known systems have more than 20% total solids; such systems are called dry fermentation or digestion. In batch mode, solids concentration of even 40% can be used.

A heat exchanger can be fitted for better utilisation of heat in the whole system, especially for maintaining the desired temperature range in the digesting vessel.

Gas Recovery: The biogas obtained may be scrubbed to ensure automotive quality CNG-like gas (CO_2 less than 4% and H S less than 10 ppm). Biogas may also be used for generating electricity.

Residue Treatment: The digested sludge from the digester is dewatered and the liquid recycled for use in the dilution of incoming feed. The biosolids are dewatered to 50%–55% total solids with a screw press, filter press, or other types of dewatering systems and aerobically cured to obtain a compost product.

Utility of biogas produced in biomethanation plants

The percentage of methane (CH_4) varies with the efficiency of the anaerobic digestion and the composition of the substrate. With cattle manure, about 55%–60% methane is obtained; whereas with food waste, 70% methane is obtained. Biogas is also water saturated (100% humidity). The calorific value of biogas is 5,000–6,000 kilocalories per cubic meter (kcal/m^3) depending on the methane percentage. The biogas, by virtue of its high calorific value, has tremendous potential to be used as fuel for power generation through either internal combustion engines or gas turbines.

Broadly, biogas can be used for the following purposes:

- cooking or heating fuel;
- motive power (e.g., biogas pump);
- electrical power; and
- Gaseous automotive fuel, after stripping carbon dioxide (CO), hydrogen sulphide (H S), and moisture called compressed biogas(CBG).

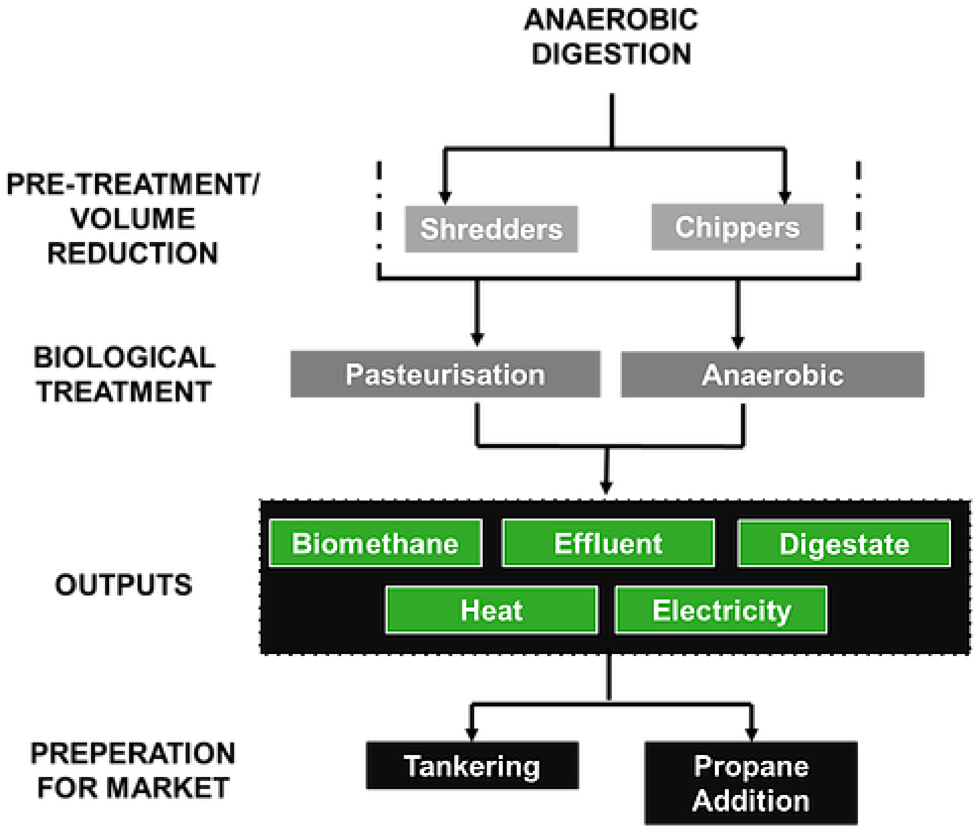


Figure 57: technology description anaerobic digestion

Configuration	
Waste streams accepted:	Putrescible / organic waste, garden / food waste collections, slurries, energy crops
Input capacity ranges	5,000-150,000 tonnes per year
Typical outputs	Biomethane, heat and electricity, nutrient rich digestate
Purposes	Recover biodegradable waste into a digestate for land application / soil improvement and recover energy as either gas or heat and power
Indicative capital cost	440 USD/(t/year input capacity) wet AD process
Indicative operational cost	High
Life span	20-30 years
Skills requirements	High
Job creation opportunity	Low
Technology restrictions	Requires an intensive monitoring and control over conditions to maintain the digestion process Can be sensitive to imbalances in feedstock (e.g. high quantities of food versus garden waste or vice versa)

Advantages:	Inconvenient
AD has potential for treating a variety of organic waste streams Greenhouse gas and harmful gases are prevented AD has the potential for energy production	Requires on-going management and monitoring Health and safety issues can arise at AD plants Significant odour issues Quality is often insufficient for the digestate to be used as soil enhancer

Merits of biomethanation process

- Energy generation, the produced biogas can be used for cooking or for the production of electricity and heat.
- Biogas may also be cleaned by removing CO_2 and HS. The resulting methane enriched biogas containing more than 90% methane (CH_4) is somewhat like compressed natural gas (CNG). However, for this gas to be used as automotive fuel, the percentage of CO_2 has to be less than 5%, which corresponds to methane percentage of 95% or more. H S has to be less than 10 parts per million (ppm) for use in automobiles. Use of this fuel is more benign for the environment than using petroleum-based automotive fuels.

- Like composting, biomethanation also leads to reduced landfill requirement, thus extending the life of existing landfills.
- Biomethanation of biodegradable organic material would result in stabilised sludge (maturation time (post rotting) after the biomethanisaton which is much more than 2 to 3 days but something around 4 weeks) which can be used as a soil conditioner and fertiliser. However, pathogen kill or inactivation may not be complete during anaerobic digestion with the relatively short hydraulic retention time (HRT) designed for optimisation of biogas production. Therefore, aerobic composting of the sludge is recommended to pass the material through temperature cycle of above 60°C–70°C for at least 2 days.
- Although the total system of biomethanation is more cost intensive than the total system of open aerobic composting, biomethanation has certain advantages with respect to much less odour and bird menace. The time frame (cycle time) is also less, so that less land is required for the same capacity. These two can be a big advantage where the only available sites are close to habitation.

Applicability of biomethanation

- Biomethanation is ideal for wet organic wastes, e.g., cooked food. Biomethanation plants require a consistent source of degradable organic matter, free from inert and toxic material. Slaughterhouse waste is eminently suitable for biomethanation.
- Odour problems are also considerably reduced by adopting biomethanation. If the proposed waste processing site is in close proximity to residential areas, biomethanation is a preferred treatment option, especially considering odour issues.
- Anaerobic digestion technology can be adopted in both
    - decentralised systems—up to 5 TPD (much smaller quantities can be processed where O&M is not outsourced); and
    - centralised systems—in modules of up to 50 TPD digesters (for higher capacity in one digester, the size may become unwieldy and difficult to maintain).
- The design of the plant has to be done according to the substrate (feed material) for smooth functioning. The next most important challenge is to make the digester leak-proof. Proper O&M is a critical factor for ensuring the success of the biogas plant which can be achieved through a well-defined standard operating procedure (SOP). Economic viability of the plants is ensured when there is a sustainable and viable market for the generated biogas in the vicinity of the plant and the sludge manure produced during the process.

Refuse derived fuel

Refuse derived fuel (RDF) as fuel is derived from combustible waste fraction of solid waste like plastic, wood, pulp or organic waste, other than chlorinated materials, in the form of pellets or fluff produced by drying, shredding, dehydrating and compacting of solid waste. It is used as a fuel for either steam or electricity generation or as alternate fuel in industrial furnaces or boilers (co-processing or co-incineration of waste in cement, lime, and steel industry and for power generation). The composition of RDF is a mixture that has higher concentrations of combustible materials than those in the parent mixed MSW.

Production and combustion of RDF for energy recovery is not only an economically viable option for municipal solid waste management (MSWM), but it also greatly reduces the requirement for landfill space. The techno-economic feasibility of producing high calorific value RDF from mixed MSW has to be seen in the context of the concrete framework conditions of a particular region.

RDF typically consists of the residual dry combustible fraction of the MSW including paper, textile, rags, leather, rubber, non-recyclable plastic, jute, multi-layered packaging and other compound packaging, cellophane, thermocol, melamine, coconut shells, and other high calorific fractions of MSW. However from the ISWM hierarchy perspective, separately recycling relevant components (e.g., paper, plastics, jute, metal, glass, multi-layered packaging used for liquid food items, etc.) should be prioritise. The composition and resultant energy content of RDF varies according to the origin of waste material and the sorting, separation, and processing being adopted in the facility.

The suitability of RDF for use as a fuel is dependent on certain critical parameters of the constituent waste:

- calorific value
- water content;
- ash content;
- sulphur content; and
- chlorine content.

The required specific composition and characteristics of RDF for co- processing will be determined by the kind of furnace, temperatures achieved in the furnace, and the associated flue gas management systems.

Potential use of refuse derived fuel in industry

In keeping with the present state of technology, RDF is fired in a moving grate furnace or a boiler equipped with some form of grate. RDF can also serve as a feedstock for other types of thermal systems, e.g., pyrolysis and fluidised bed systems. The relative uniformity of properties and higher quality of RDF as compared with mixed MSW has led, in the past, to a preference for RDF in some applications.

> RDF is to be seen in combination with the incineration and not as a stand-alone technology

2.1.4. BPEO for Waste treatment technology

The following methodology and approach was chosen for the BPEO process for waste treatment technology.

- Choosing of the decision criteria and weighing
- Identifying the most known and practicable waste treatment technologies
- Evaluation of waste treatment technology as a function of the weighted decision criteria
- Option scoring : The option having the lowest score is the most suitable option

The decision criteria (sub-criteria) have been chosen among the 4 main criteria of the BPEO process:

BPEO criteria	Decision criteria
Technical	Facility location : need of a buffer zone from residential area Feedstock : need of pre-treatment processes Technical capacity: Waste quantity, which can be managed by a single facility. Land intake: land requirement Residual waste: Residual waste production which needs to be brought on a sanitary landfill Energy recovery: potential for direct energy Technical complexity: Maturity of the technology
Environmental	Air quality Toxicity of products Leachate pollution Other pollution and safety measures
Social	Employment Level of skills Health Effects Landscaping Business opportunity
Economical	CAPEX OPEX Ability to finance Return on investment

These sub-criteria have been weighted and compare again each other in order to have an overall weighing of the main BPEO decision criteria. With the consultants own excel based BPEO tool the following results was achieved:

N°	Key Criteria	Weighting	Percentage Distribution	Rank
1	Technical	3,29	33,49%	1
2	Environmental	2,00	20,39%	4
3	Social	2,40	24,46%	2
4	Economic	2,13	21,66%	3
Total			100,00%	

Figure 58: result from the decision criteria-weighing tool

N°	Technical		Environmental		Social		Economic	
1	Facility location	1	Air Quality	1,5	Employement	2,0	CAPEX	2,5
2	Technical capacity	4	Toxicity of products	3,0	Labour level of skills	1,0	OPEX	2,5
3	Feedstock	3	Leachate pollution	2,5	Health effects	2,5	Ability to finance	1,0
4	Land intake	5	Other pollution	1,0	Landscaping	2,5	Return on Investment	2,5
5	Residual w aste	5			Business opportunity	4,0		
6	Energy recovery	2,5						
7	Technical complexity	2,5						
	Weighing	3,29		2,00		2,40		2,13

Figure 59: Decision criteria weighing

N°	Technical		% distr.	rank	Environmental		% distr.	rank	Social		% distr.	rank	Economic		% distr.	rank
1	Facility location	1,0	4,3%	7	Air Quality	1,5	18,8%	3	Employement	2,0	16,7%	4	CAPEX	2,5	29,4%	1
2	Technical feasibility	4,0	17,4%	3	Toxicity of products	3,0	37,5%	1	Labour level of skills	1,0	8,3%	5	OPEX	2,5	29,4%	1
3	Feed stock	3,0	13,0%	4	Leachate pollution	2,5	31,3%	2	Health effects	2,5	20,8%	2	Ability to finance	1,0	11,8%	4
4	Land intake	5,0	21,7%	1	other pollution	1,0	12,5%	4	Landscaping	2,5	20,8%	2	Return on Investment	2,5	29,4%	1
5	Residual w aste	5,0	21,7%	1					Business opportunity	4,0	33,3%	1		0,0	0,0%	5
7	Energy recovery	2,5	10,9%	5												
6	Technical complexity	2,5	10,9%	5												
			100,00%				100,00%				100,00%				100,00%	

Figure 60: Decision weighing criteria details

The second step was to evaluate each technology against each criterion. In the following is presented the technology comparison:

Criteria	Windrow composting	In-vessel composting	MBT	Biomethanation	RDF	Incineration	Integrated system (composting + RDF)	Sanitary landfill (of complete MSW)
Technical criteria								
Facility location	To be located as per the buffer zone criteria mentioned below.	To be located as per the buffer zone criteria mentioned below.	To be located as per the buffer zone criteria mentioned below.	To be located as per the buffer zone criteria mentioned below.	To be locate as per the buffer zone criteria mentioned below.	To be located as per the buffer zone criteria mentioned below.	To be located as per the buffer zone criteria mentioned below.	Landfill sites must be located at least 500 m away from residential areas.
Buffer zone (no Housing/residential Development zone)	500 m for facilities dealing with 100 t/day or more of msw 400 m for facilities dealing with 75–100 t/day of msw 300 m for facilities dealing with 50–75 t/day of msw 200 m for facilities dealing with 10–50 t/day of msw No buffer zone for facilities dealing up to 5 t/day of msw No buffer zone for decentralised plants handling less than 1 t/day of msw (but adequate environmental controls are required)							
Natural environment	Composting in coastal/high rain-fall areas should have a shed to prevent waste from becoming excessively wet and thereby to control leachate generation.							Should be avoided in marshy land and in conditions where the ground water table is 2 m from the base of the liner. In marshy land, apart from ground and

Criteria	Windrow composting	In-vessel composting	MBT	Biomethanation	RDF	Incineration	Integrated system (composting + RDF)	Sanitary landfill (of complete MSW)
								surface water contamination potential, there could be huge risks due to structural safety of the landfill (slippage and complete break-down)
Land requirement	For 300 t/day of segregated/pre-sorted msw: 5 ha of land including buffer zone is required.	For 300 t/day of segregated/pre-sorted msw: 1 ha of land including buffer zone is required.	For 300 t/day of segregated/pre-sorted msw: 5 ha of land including buffer zone is required.	For 300 t/day of segregated/pre-sorted msw: 2.5 ha of land is required.	For 300 t/day of segregated/ pre-sorted msw: 2 ha of land is required.	For 500 t/day of mixed waste: 2,5 ha of land including buffer zone	For 300 t/day of segregated/ pre-sorted msw: 6 ha of land (note: many of the processing units are shared).	For 300 t/day of msw: 30 ha of land is required for 20 years.
Waste quantity which can be managed by a single facility.	Max. 500 t/day	Max. 500 t/day	Max. 500 t/day	1 t/day at small scale to 500 t/day at larger scale	100 t/day of segregated waste and above	500 t/day and above of mixed waste (smaller plants are not techno economically viable, given the cost of required environ- mental control	500t/day and above (economically sustainable above 500 t/day plant size)	100 t/day and above. Smaller landfills are not techno economically viable

Criteria	Windrow composting	In-vessel composting	MBT	Biomethanation	RDF	Incineration	Integrated system (composting + RDF)	Sanitary landfill (of complete MSW)
						equipment and boiler technology		
Requirement for segregation prior to technology	High	High	low	Very high	High	High – feed stock should be free from inerts and low on moisture content	Moderate be-cause both dry and wet fractions are utilized	low
Rejects	About 30% including inerts if only composting is done 15%* rejects with RDF, if located in the same plant	About 30% including inerts if only composting is done 15%* rejects with RDF, if located in the same plant	About 30% from mixed waste*	About 30% from mixed waste*	Around 30% from mixed waste**	Around 15%	Approximately 15-20%	No rejects
Potential for direct energy recovery	No	No	No	Yes	No (feed stock for energy recovery)	Yes	Yes	No
Technology maturity	Windrow composting technique is well established	In-vessel composting is still not considered as well established	Feasibility for mixed MSW waste is proven	Feasibility for biodegradable waste is proven. In case of mixed waste, appropriate pre-sorting has to be carried out.	Quality of RDF should be based on end use, no clear consensus on quality requirements. Burning of RDF below 850°c for less than 2	Technology is available. However constraints of low calorific value, high moisture content and high proportion of	Composting and RDF combined facility is an upcoming phenomenon. Utilisation of rejects from compost	Sanitary landfill is a proven method for safe disposal of waste, practiced world over. However it has environmental implications and

Criteria	Windrow composting	In-vessel composting	MBT	Biomethanation	RDF	Incineration	Integrated system (composting + RDF)	Sanitary landfill (of complete MSW)
					seconds residence time can pose serious problems of health and environment. Rules regulating Characteristics of RDF and guidelines for appropriate use not prescribed by concerned authority.	inert waste should be considered while undertaking the project commercially.	plants as input material for RDF production and sale. Rejects from integrated system are 15-20% as opposed to 30-40% from individual system.	efforts have to be made to minimize waste going to landfills.
Financial criteria								
Indicative capital investment	Typically 2,5-3 Mio USD for 500 t/day plant	25,000-50,000 USD/(capacity ton/day),	240-325 USD/(ton/year capacity)	Typically 11-15 Mio USD for 500 t/day plant	Typically 2,5-3 Mio USD for 500 t/day plant	Very high capital, operating and maintenance costs.2,2 Mio USD per Mw power production	Typically 3,5-4,5 Mio USD for 500 t/day plant) without a mechanical hot air generator (hag) for drying however, moisture can be reduced by bio-drying with much less cost	High

Criteria	Windrow composting	In-vessel composting	MBT	Biomethanation	RDF	Incineration	Integrated system (composting + RDF)	Sanitary landfill (of complete MSW)
							but slightly reduced efficiency.	
Social criteria								
Labour requirement	Labour intensive	Labour intensive	Labour intensive	Less labour intensive	Labour intensive (based on current practice).	Non labour intensive but requires considerable technical capacity,	Labour intensive but requires considerable technical capacity.	Labour intensive but Requires considerable technical expertise as well.
Predominant skills for operation and management	Technically qualified and experienced, and semi-skilled staff..	Technically qualified and experienced staff.	Technically qualified and experienced staff.	Technically qualified and experienced staff.	Technically qualified and experienced staff.	Technically qualified and experienced staff.	Technically qualified and experienced staff and semi-skilled.	Technically qualified and experienced, and semi- skilled staff.
Environmental criteria								
Concerns for toxicity of product	The final product is generally applied to soil and used as manure. Can contaminate the food chain if compost is not meeting norms.	The final product is generally applied to soil and used as manure. Can contaminate the food chain if compost is not meeting norms.		The final product is generally applied to soil as a soil conditioner. Can contaminate the food chain if compost is not meeting norms.	-	-	The final product is generally applied to soil and used as manure. Can contaminate the food chain if compost is	-

Criteria	Windrow composting	In-vessel composting	MBT	Biomethanation	RDF	Incineration	Integrated system (composting + RDF)	Sanitary landfill (of complete MSW)
							not meeting norms.	
Leachate pollution	Potential exists. Varies with the climate of area and seasonal variation. In relatively dry seasons, leachate can be recirculated into the windrow to contain loss of nutrients and also pollution potential. In high rainfall areas, the windrows need to be covered either temporarily or permanently to control leachate generation. However, the design of the shed should be such that good			High if not treated appropriately	Low	High potential of leachate at the receiving pit.	Potential exists for compost varies with the climate of area and seasonal variation. In relatively dry seasons, leachate can be recirculated into the wind-row to contain loss of nutrients and also pollution potential. In high rainfall areas, the wind- rows need to be covered either temporarily or permanently to control leachate generation. However, the	Polluted surface runoff during wet weather, groundwater contamination due to leachate infiltration Moderate to high depending upon the leachate recycling and control systems. Leachate management during monsoons requires special attention

Criteria	Windrow composting	In-vessel composting	MBT	Biomethanation	RDF	Incineration	Integrated system (composting + RDF)	Sanitary landfill (of complete MSW)
	natural ventilation is maintained.						de- sign of the shed should be such that good natural ventilation is maintained.	
Atmospheric pollution	Low (dust, aerosol etc.). Odour issues.	Low	Low to moderate	Low. Leakage of biogas. Odour issues.	Low to moderate (dust, aerosols). Very high if RDF is not burnt at required temperature. Odour issues.	Very high if emissions not managed properly. Fly ash should be disposed safely in an engineered landfill. (emissions due to incomplete combustion of municipal refuse contain a number of toxic compounds, dioxins and furans, requiring appropriate emissions control systems)	Moderate, require appropriate emission control systems (air emission include acid gases, dioxins and furans).	Air pollution and problems of odour and methane emissions if not managed properly.
Other	Fire and safety	Fire and safety	Fire and safety	Fire and safety	Presence of	Disposal of	Presence of	Spontaneous

Criteria	Windrow composting	In-vessel composting	MBT	Biomethanation	RDF	Incineration	Integrated system (composting + RDF)	Sanitary landfill (of complete MSW)
	issues to be taken care of	issues to be taken care of	issues to be taken care of	issues to be taken care of	inappropriate material in the RDF (chlorinated plastics). Fire and safety issues to be taken care of.	bottom ash/ slag. Fire and safety issues to be taken care of.	inappropriate material in the RDF (chlorinated plastics). Fire and safety is- sues to be taken care of.	ignition due to possible methane concentration. Fire and safety issues to be taken care of.

This comparison leads to the following waste treatment technology option scoring:

- The technology with the *highest risks and impacts* have the *lowest points* attribution
- The technology with the *highest amount of points* is the *preferred technology* for the area

Impact	Windrow composting	In-vessel composting	MBT	Biomethanation	RDF	Incineration	Integrated system (composting + RDF)	Sanitary landfill (of complete MSW)
Technical								
Facility location	Medium-High	Medium-High	Medium-High	Medium-High	Medium-High	Medium-High	Medium-High	Medium-High
1	2	2	2	2	2	2	2	2
Technical feasibility	Low -Medium	Medium	Medium-High	Medium	Medium-High	Low	Low	Medium
4	16	12	8	12	8	20	20	12
Feed stock	Medium-High	Medium-High	Medium-High	High	Medium-High	Medium-High	Low -Medium	Low
3	6	6	6	3	6	6	12	15
Land intake	Medium-High	Medium	Medium-High	Medium	Medium-High	Low	Medium-High	High
5	10	15	10	15	10	25	10	5
Residual w aste	Medium-High	Medium-High	Medium-High	Medium-High	Medium-High	Low -Medium	Medium	Low
5	10	10	10	10	10	20	15	25
Energy recovery	High	Medium-High	High	Low	High	Low	Low	High
2,5	2,5	5	2,5	12,5	2,5	12,5	12,5	2,5
Technical complexity	Low -Medium	Medium-High	Medium-High	Medium	Medium	Medium	Medium	Low
2,5	10	5	5	7,5	7,5	7,5	7,5	12,5
Environmental								
Air Quality	Low	Low -Medium	Medium	Low	Low	Medium	Low -Medium	Medium
1,5	7,5	6	4,5	7,5	7,5	4,5	6	4,5
Toxicity of products	Low -Medium	Low -Medium	Low -Medium	Low -Medium	Low	Low	Low -Medium	Low
3	12	12	12	12	15	15	12	15
Leachate pollution	Low -Medium	Low -Medium	Low -Medium	Low -Medium	Low	Medium	Low -Medium	Medium-High
2,5	10	10	10	10	12,5	7,5	10	5
other pollution	Medium-High	Medium-High	Medium-High	Medium-High	Medium-High	Medium-High	Medium-High	Medium-High
1	2	2	2	2	2	2	2	2
Social								
Employement	Medium-High	Medium-High	Medium-High	Low -Medium	Medium	Low	High	High
2	4	4	4	8	6	10	2	2
Labour level of skills	Medium-High	High	Medium	Medium-High	Medium-High	Medium-High	Medium-High	Medium-High
1	2	1	3	2	2	2	2	2
Health effects	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High
2,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	2,5
Landscaping	Medium-High	Medium	Medium-High	Medium-High	Medium-High	Low -Medium	Medium-High	High
2,5	5	7,5	5	5	5	10	5	2,5
Business opportunity	High	High	High	Medium	Medium	Low -Medium	Medium	High
4	4	4	4	12	12	16	12	4
Economic								
CAPEX	Low -Medium	Medium	Medium-High	High	Low -Medium	High	Medium	Medium-High
2,5	10	7,5	5	2,5	10	2,5	7,5	5
OPEX	Medium	Medium	Medium-High	Medium	Medium-High	Medium-High	Medium	Medium-High
2,5	7,5	7,5	5	7,5	5	5	7,5	5
Ability to finance	Low -Medium	Medium	Medium-High	Low -Medium	Low -Medium	Low -Medium	Low -Medium	Low -Medium
1	4	3	2	4	4	4	4	4
Return on Investment	Medium-High	Medium-High	Medium-High	Low	Medium-High	Low	Medium	Medium-High
2,5	5	5	5	12,5	5	12,5	7,5	5
Total score	137,00	132,00	112,50	154,50	139,50	191,50	164,00	132,50

Figure 61: results of the option scoring

Which means that the waste incineration was the Best Practicable and Environmental waste treatment technology under the specific conditions in the Maldives for this zone.

2.2. Waste incineration

2.2.1. Grate technology

Grate incinerators are widely applied for the incineration of mixed municipal wastes and can be used for untreated, non- homogenous, and low calorific municipal waste. An overhead crane feeds waste into the hopper, where it is transported via the chute to the grate in the furnace. On the grate, the waste is dried and then burned at high temperature with supply of air. The ash, including non-combustible fractions of waste, leaves the grate as slag or bottom ash through the ash chute.

Different grate systems can be distinguished by the way the waste is conveyed through the different zones in the combustion chamber. The type of grate system determines the efficacy of primary air feeding, conveying velocity and raking, as well as mixing of the waste.

Reciprocating grates: Many modern MSWM incinerator facilities use reciprocating grates. The quality of burnout achieved is generally good. Reciprocating grates consist of sections that span the width of the furnace but are stacked above each other. Alternate grate sections slide back and forth, while the adjacent sections remain fixed. Waste tumbles off the fixed portion and is agitated and mixed as it moves along the grate.

There are essentially two main reciprocating grate variations:

1. Reverse reciprocating grate: The grate bars oscillate back and forth in the reverse direction to the flow of the waste. The grate is sloped from the feed end to the ash discharge end and is comprised of fixed and moving grate steps.

2. Push forward grate: The grate bars form a series of many steps that oscillate horizontally and push the waste in the direction of the ash discharge.

Other grate types that have been in use include rocking grates, travelling grates, roller grates, and cooled grates.

Grate incinerators are of two types:

- Moving grate furnace system: waste enters from one end while ash is discharged at other

- Fixed grates: series of steps with drying stage and initial combustion phase, complete combustion and final carbon burn- out

Advantages of Grate Incinerators:

- o There is no need for prior sorting or shredding.
- o Technology is widely tested and meets the standards of technical performance.
- o It accommodates large variations in waste composition and calorific value.
- o It allows for an overall thermal efficiency of up to 85%.

Disadvantage of grate incinerators:

- o Capital and maintenance costs are relatively high.

2.2.2. Pyrolysis

Pyrolysis involves an irreversible chemical change brought about by the action of heat in an atmosphere devoid of oxygen. Synonymous terms are thermal decomposition, destructive distillation, and carbonisation. Pyrolysis, unlike incineration, is an endothermic reaction and heat must be applied to waste to distil volatile components. Process of converting plastic to fuels through pyrolysis is possible, but it is yet to be proven to be a commercially viable venture.

Pyrolysis is carried out at 500°C–1,000°C and produces three component streams:

1. Gas: It is a mixture of combustible gases such as hydrogen, carbon monoxide, methane, carbon dioxide, and some hydrocarbons.

2. Liquid: It consists of tar, pitch, light oil, and low boiling organic chemicals like acetic acid, acetone, methanol, etc.

3. Char: It consists of elemental carbon along with the inert material in the waste feed.

Gas, liquid, char are useful because of their high calorific value. Part of the heat obtained by combustion of either char or gas is often used as process heat for the endothermic pyrolysis reaction. It has been observed that even after utilising the heat necessary for pyrolysis, extra heat still remains which can be commercially exploited.

Although a number of laboratory and pilot investigations have been made, only a few have led to full scale plants. German experience also indicates that while several small scale pyrolysis and gasification plants for MSW were set up a few decades ago, almost all have been shut down due to operational and commercial issues.

Feed stock for pyrolysis

Feedstock for pyrolysis should have high calorific value with very less moisture content and should be homogenous in nature. Many plastics, particularly the polyolefins, which have high calorific values and simple chemical constitutions of primarily carbon and hydrogen, are usually used as a feedstock in pyrolysis. More recently, pyrolysis plants are being tested to degrade carbon-rich organic material such as MSW. For mixed MSW pre-processing is necessary to bring homogeneity to increase efficiency.

Municipal solid waste pyrolysis

Sorted and pre-treated feedstock is supplied to pyrolysis reactor-rotary kilns, rotary hearth furnaces, and fluidised bed furnaces are commonly used as MSW pyrolysis reactors-where partial combustion of material occurs at 500°C-800°C.

As a result of combustion of organic matter in an oxygen-deficient environment, various products such as char (ash), pyrolysis oil, and syngas are produced. Production of these is dependent on the organic component of MSW, temperature, pressure, and time of retention in the reactor. Char or solid residue is a combination of non-combustible material and carbon. The syngas is a mixture of gases (combustible constituents include carbon monoxide, hydrogen, methane, and a broad range of other volatile organic compounds). Syngas is further refined to remove particulates, hydrocarbons, and soluble matter, and is then combusted to generate electricity. The syngas typically has a net calorific value (NCV) of 2,800-4,800 kilocalorie per normal cubic meter (kcal/Nm^3) or 10–20 megajoule per normal cubic meter (MJ/Nm^3). If required, the condensable fraction can be collected by cooling the syngas, potentially for use as a liquid fuel (oils, waxes, and tars).

One key issue for use of syngas in energy recovery is tarring. The deposition of tars can cause blockages and other operational challenges and has been associated with plant failures and inefficiencies at some pilot and commercial scale facilities. Tarring issues may be overcome by higher temperature secondary processing.

In order to recover the energy content of syngas, it should be further processed in the following ways:

1. Syngas can be burned in a boiler to generate steam, which may be used for power generation or industrial heating;
2. Syngas can be used as a fuel in a dedicated gas engine;
3. Syngas, after reforming, may be suitable for use in a gas turbine;
4. Syngas can also be used as a chemical feedstock.

For plasma pyrolysis of MSW, it should be noted that-along with pre- sorted MSW as feedstock-additional inputs, such as flux material and carbonaceous material (e.g., coke) are required.

Plasma pyrolysis vitrification

This is a modified pyrolysis technology aiming at energy or resource recovery from organic waste. The system uses a plasma reactor, which generates, by application of high voltage between two electrodes, an extremely high temperature (5,000°C-14,000°C). This hot plasma zone dissociates the molecules in any organic material into the individual elemental atoms, while all the inorganic material are simultaneously melted into a molten lava. This process is still far away from any proven practical and sustainable application in MSWM.

Gasification

Gasification is a partial combustion of organic or fossil based carbonaceous material, plastics, etc. into carbon monoxide, hydrogen, carbon dioxide, and methane. This is achieved at high temperature (650°C and above), with a controlled amount of air, oxygen, or steam. The process is largely exothermic, but some heat may be required to initialise and sustain the gasification process. The main product is syngas, which contains carbon monoxide, hydrogen, and methane. Typically, the gas generated from gasification will have an NCV of 4–10 MJ/Nm^3. The other main product produced by gasification is a solid residue of non-combustible material (ash), which contains a relatively low level of carbon.

Gasification of municipal solid waste

Feedstock Preparation: MSW should be pre-processed before it can be used as feedstock for the gasification process. The pre-processing comprises of manual and mechanical sorting, grinding, blending with other material, drying, and pelletization. The purpose of pre-processing is to produce a feed material with consistent physical characteristics and chemical properties. Carbonaceous material of municipal waste stream is most important feedstock for gasification.

Gasifiers for municipal solid waste treatment

Gasification technology is selected on the basis of available fuel quality, capacity range, and gas quality conditions. The main reactors used for gasification of MSW are fixed beds and fluidised beds. Larger capacity gasifiers are preferable for treatment of MSW because they allow for variable fuel feed, uniform process temperatures due to highly turbulent flow through the bed, good interaction between gases and solids, and high levels of carbon conversion.

(1) Fixed Beds

Fixed bed gasifiers typically have a grate to support the feed material and maintain a stationary reaction zone. They are relatively easy to design and operate, and are therefore useful for small and medium scale power and thermal energy uses. The two primary types of fixed bed gasifiers are updraft and downdraft.

In an updraft gasifier, the fuel is also fed at the top of the gasifier but the airflow is in the upward direction. As the fuel flows downward through the vessel, it dries, pyrolyzes, gasifies, and combusts. The main use of updraft gasifiers has been with direct use of the gas in a closely coupled boiler or furnace. Because the gas leaves this gasifier at relatively low temperatures, the process has a high thermal efficiency and, as a result, wet MSW containing 50% moisture can be gasified without any pre- drying of the waste.

In a downdraft gasifier, air is introduced into a downward flowing packed bed or solid fuel stream and gas is drawn off at the bottom. The air or oxygen and fuel enter the reaction zone from the top, decomposing the combustion gases and burning most of the tars. Downdraft gasifiers are not ideal for waste treatment because they typically require a low ash fuel such as wood to avoid clogging.

(2) Fluidised Beds

Fluidised beds are an attractive proposition for the gasification of MSW. In a fluidised bed boiler, a stream of gas (typically air or steam) is passed upward through a bed of solid fuel and material (such as coarse sand or limestone). The gas acts as the fluidising medium and also provides the oxidant for combustion and tar cracking. Waste is introduced either on top of the bed through a feed chute or into the bed through an auger. Fluidised beds have the advantage of extremely good mixing and high heat transfer, resulting in very uniform bed conditions and efficient reactions. Fluidised bed technology is more suitable for generators with capacities greater than 10 MW because it can be used with different fuels, requires relatively compact combustion chambers, and allows for good operational control. The two main types of fluidised beds for power generation are bubbling and circulating fluidised beds.

In a bubbling fluidised bed (BFB), the gas velocity must be high enough so that the solid particles, comprising the bed material, are lifted, thus expanding the bed and causing it to bubble like liquid. A bubbling fluidised bed reactor typically has a cylindrical or rectangular chamber designed so that contact between the gas and solids facilitates drying and size reduction (attrition). As waste is introduced into the bed, most of the organics vaporise pyrolytically and are partially combusted in the bed. Typical desired operating temperatures range from 900°C to 1,000°C.

A circulating fluidised bed (CFB) is differentiated from a bubbling fluid bed in that there is no distinct separation between the dense solids zone and the dilute solids zone. The capacity to process different feedstock with varying compositions and moisture contents is a major advantage in such systems.

Integrated gasification with power generating equipment

MSW gasification can be integrated with power turbines, steam cycle, and other power generating equipment to provide thermal energy. Combination of MSW gasification with power turbines and fuel cells increases overall efficiency of the system. Development is happening on the following lines:

1. Integrated gasification combined cycle (IGCC) is based on the concept of integrating MSW gasification with gas turbines and steam cycle.

2. Fuel cells are integrated with MSW gasifier. Tubular solid oxide fuel cells have been found to be most effective for these applications.

General challenges of operating gasification plants

Gasification takes place in low oxygen environment that limits the emission of pollutants. It also generates fuel gas that can be further used in a number of ways, as suggested in the section on pyrolysis. During gasification, tars, heavy metals, halogens, and alkaline compounds are released within the product gas and can cause environmental and operational problems. Tars are high molecular weight organic gases that ruin reforming catalysts, sulfur removal systems, and ceramic filters and increase the occurrence of slagging in boilers, on other metal and refractory surfaces. Alkalis can increase agglomeration in fluidised beds that are used in some gasification systems and can also ruin gas turbines during combustion. Heavy metals are toxic and accumulate, if released into the environment. Halogens are corrosive and a cause of acid rain, if emitted to the environment. The key to achieving cost efficient, clean energy recovery from MSW gasification will be overcoming problems associated with the release and formation of these contaminants.

Challenges of utilising pyrolysis and gasification in the Maldivian context

High calorific value waste, which may otherwise be processed in more sustainable processes, is required as feedstock. Organics can be converted into compost in a much more cost-effective and environmentally safe process, as against using them as feedstock for these processes.

Pyrolysis and gasification processes require specific feedstock quality, which has a direct impact on the efficiency and commercial viability of the product. Pre-treatment of waste is a must. Specified size and consistency of solid waste should be achieved before MSW can be used as feed.

3. Waste incineration technology assessment

Using the same approach as previously for the waste treatment options the 4 main criteria (Technical, environmental, social and economic) and their sub-criteria have been again re-weighted against each other. Environmental and social criteria have been considered as mainly equal so that the focus was held on the technical and economic criteria.

N°	Key Criteria	Weighting	Percentage Distribution	Rank
1	Technical	3,93	40,59%	2
2	Environmental	0,65	6,72%	3
3	Social	0,10	1,03%	4
4	Economic	5,00	51,66%	1
Total			100,00%	

Figure 62: Weighing of the key criteria for waste incineration

The 3 waste incineration technologies:

- Grate incineration
- Pyrolysis
- Gasification

Have been evaluated against each other with the following results:

Impact	Grate technology	Pyrolisys	Gaseification
Technical			
Facility location	Medium-High	Medium-High	Medium-High
0,1	0,2	0,2	0,2
Technical capacity	Low -Medium	Medium	Medium-High
4	20	12	12
Feedstock	Medium-High	High	Medium-High
5	20	10	10
Land intake	Medium-High	Medium	Medium-High
3,4	10,2	10,2	10,2
Residual w aste	Medium-High	Medium-High	Medium-High
5	10	10	10
Energy recovery	High	Low	High
5	25	25	25
Technical complexity	Low -Medium	Medium	Medium
5	20	10	10
Environmental			
Air Quality	Low	Low	Low
0,6	0,6	0,6	0,6
Toxicity of products	Low -Medium	Low -Medium	Low
0,1	0,2	0,1	0,1
Leachate pollution	Low -Medium	Low -Medium	Low
0,1	0,4	0,4	0,4
Other pollution	Medium-High	Medium-High	Medium-High
1,8	3,6	1,8	1,8
Social			
Employement	Medium-High	Low -Medium	Medium
0,1	0,3	0,3	0,3
Labour level of skills	Medium-High	Medium-High	Medium-High
0,1	0,3	0,2	0,2
Health effects	Medium	Medium	Medium
0,1	0,3	0,3	0,3
Landscaping	Medium-High	Medium-High	Medium-High
0,1	0,2	0,2	0,2
Business opportunity	High	Medium	High
0,1	0,3	0,3	0,3
Economic			
CAPEX	Low -Medium	High	Low -Medium
5	10	5	5
OPEX	Medium	Medium	Medium-High
5	10	5	5
Ability to finance	Low -Medium	Low -Medium	Low -Medium
5	10	5	5
Return on Investment	Medium-High	Low	Medium-High
5	10	5	5
Total score	151,60	101,60	101,60

Figure 63: option scoring for waste incineration technology

It appears that the grate incineration technology is the most suitable waste incineration method for the context of the Maldives and the zone III.

4. BPEO for overall scenarios (3rd level of BPEO)

4.1. Scenario analysis

Designing and implementing new waste management systems and optimising existing ones should consider aspects of resource recovery, environmental soundness, financial sustainability, and institutional capabilities, in addition to technical and technological appropriateness of systems for handling and disposing waste. This implies that the selection of best MSWM options and scenarios goes far beyond a technology selection.

After the first step of waste treatment technology assessment, five outstanding scenarios have been identified for further consideration.

Scenario 1 : business as usual (baseline)

The first scenario is the baseline scenario, which describes the actual situation without any improvement. This scenario is characterized by a non-standardized and state of the art waste collection and transport system, no proper waste transfer or intermediate storage facilities and uncontrolled waste dumping and burning. The actual system do not need important investment but leads to important environmental and social damages.

Advantages	Inconvenient
Technical: *Simple technology*	Technical: *Not state of the art* *Not standardised*
Environmental: -	Environmental: *Marine pollution* *Atmospheric pollution* *Groundwater pollution*
Social: -	Social: Reduction of living quality (dumpsite, dust, smog, sanitary risks)
Financial: *Low CAPEX* *Low OPEX*	Financial: *Marketability of valuable products* *No additional revenues from technology (electricity, heat, compost etc.)*

Scenario 2 : Improved SWM + transfer station (GM) + RSWMF Tilafushi

The second identified scenario considered a centralized system for the entire zone III with a Regional Waste Management Facility (WTE facility) at Tilafushi. Additional Transfer facilities have been foreseen for the Greater Male' region which is the main area in terms of waste quantity production. Outer Islands will implement a improved collection and transport system with open trucks and small compaction trucks in atoll capital. Collection bins and receptacles should be standardised with a mix of door-2-door collection and collection points. Outer-island and Resort waste are collected by an Outer-island vessel system passing through or nearby each island. Temporary storage and sorting recyclables done on ISWMCs. Valuable fractions collected through outer island collection tours and centralized marketability on Tilafushi.

Advantages	Inconvenient
Technical: Standardised system Improvement of collection rate	Technical: Fragile system in the perspective of weather conditions (storage facilities should be provided on Outer-islands) High Logistical (transport system) efforts
Environmental: Reduction of illegal dumping and burning and all environmental aspects related to these practices	Environmental: Specific environmental aspects based on the technology have to be considered, monitored and mitigate
Social: Improvement of living standards on inhabited areas Job creation opportunities	Social:
Financial: Market potential of sorted fractions Market potential of WTE output (electricity heat)	Financial: High CAPEX High OPEX (Outer Island transport costs)

Scenario 3: Advanced ISWM + transfer station (GM) + RSWMF Tilafushi

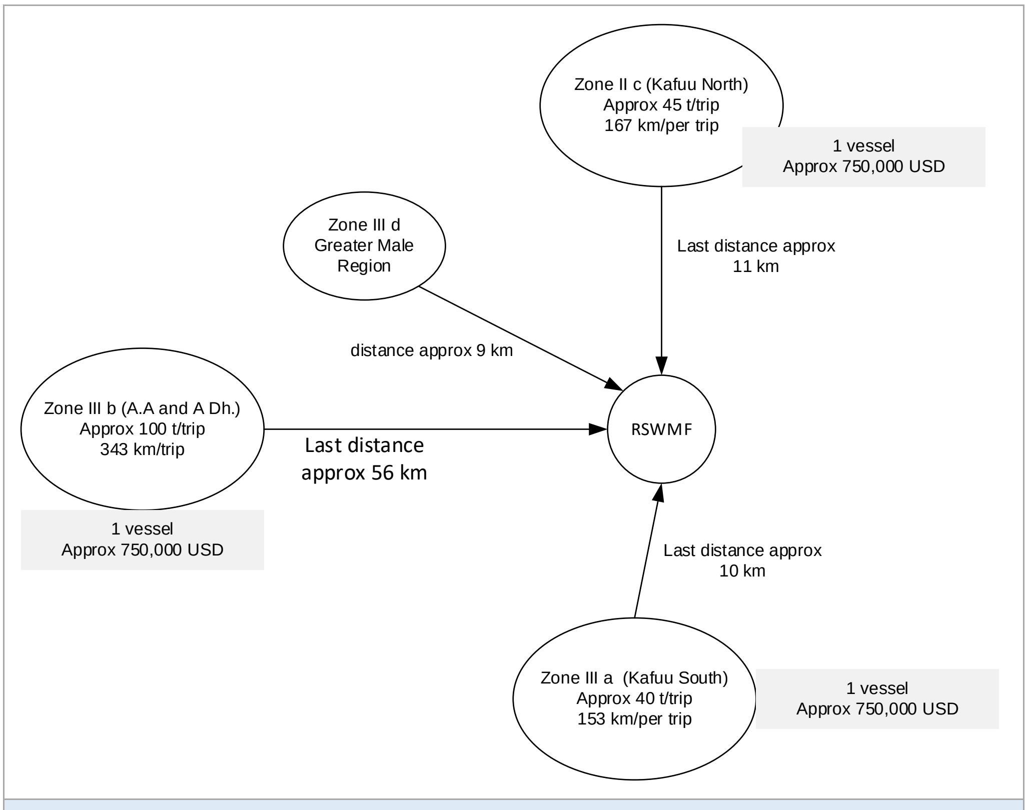
This scenario is a long-term development of scenario 2. It is characterized by the development of a state of the art collection system with focus on sorting at Household level (multi-bin system), the collection with standardised compaction trucks. The improvement of sorting and composting of the ISWMCs and the development of the sorting, recycling, C&D waste processing, ELV and EEW at the Facility in Tilafushi.

Advantages	Inconvenient
Technical: Advanced technical improvements Optimisation of all waste streams System is more robust against weather conditions	Technical: Needs advanced skills and technicity
Environmental: Reduction of illegal dumping and burning and all environmental aspects related to these practices	Environmental:
Social: Improvement of living standards on inhabited areas Job creation opportunities	Social:

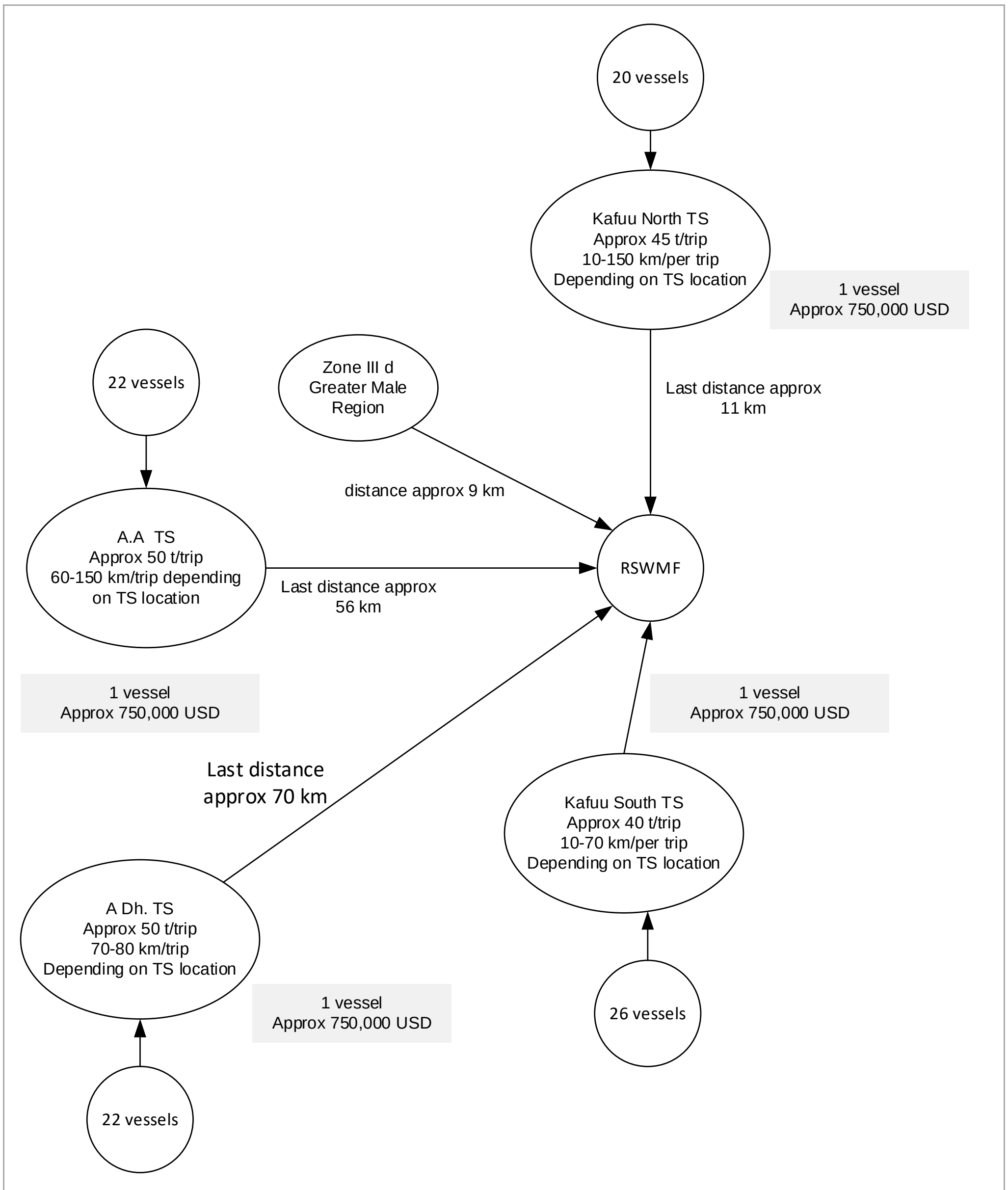
Financial: Improvement of market potential of sorted fractions	Financial: Highest CAPEX and OPEX

Scenario 4: additional TS in other atolls

The consideration of additional Transfer facilities in the other atolls of the Zone (except Greater Male) present the advantage to have a more robust system in terms of waste transport to Tilafushi during harsh weather conditions. On the other side, there is a need of additional land availability (and all inherent costs). The transport costs could not be reduced significally while the Outer Islands, which are already poor, should transport their waste to this facility on their own effort.



Scenario with direct haul



Scenario with TS on each atoll

Advantages	Inconvenient
Technical: Increasing the storage capacity on Atoll in case of harsh weather conditions	Technical:
Environmental:	Environmental: Higher logistical effort and transport cost while each island and each resort needs to bring their waste to the TS
Social:	Social:

	Difficulties in providing adequate and motivated staff to work on uninhabited island
Financial:	Financial: Higher CAPEX and OPEX (land acquisition, additional facilities, additional vessels

Scenario 5: Additional RSWMF in other atolls

Another option is to consider a decentralised system with an additional Regional solid waste management facility in the other atolls of the region (for example in the Alifu Alifu and the Alifu Dhalu Atoll). This could be advantageous in a long-term perspective while actually and on mid-term basis the actual waste quantities in this atoll might not be sufficient for a WTE. On a long term perspective the construction of a RSWMF with focus on composting, sorting and recycling could be an advantage in :

- Reducing the transport costs to Tilafushi
- Optimising the waste flows
- Optimising the capacity of the WTE in Tilafushi (400 t/day instead of the creation of an additional third line of 200 t/day)

Advantages	Inconvenient
Technical: Long term scenario Additional affordable technology (composting)	Technical:
Environmental: Reducing transport logistics, reducing diesel consumption	Environmental: Additional land acquisition
Social:	Social:
Financial: Reduction of logistics and transport costs	Financial: Additional CAPEX and OPEX

Considering the same weighing for all criteria (technical, environmental, social and financial) as same (all 25%), we have the following results:

Impact	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Technical					
Facility location	Medium-High	Medium-High	High	Medium-High	Medium-High
1	5	2	2	1	2
Technical feasibility	Low -Medium	Low -Medium	Low -Medium	Low -Medium	Medium-High
1	5	4	4	4	4
Feed stock	Low -Medium	Low	Low -Medium	Low	Medium-High
1	1	4	5	4	5
Land intake	Medium	Medium	Medium-High	Medium-High	Medium-High
1	1	3	3	2	2
Residual w aste	Low -Medium	Low	Low -Medium	Low -Medium	Medium-High
1	1	4	5	4	4
Energy recovery	Low -Medium	Low -Medium	Low -Medium	Low -Medium	High
1	1	4	4	4	4
Technical complexity	Medium-High	Medium-High	Medium-High	Medium-High	Medium
1	5	2	2	2	2
Environmental					
Air Quality	Medium	Medium	Medium	Medium	Low
1	1	3	3	3	3
Toxicity of products	Low -Medium	Low -Medium	Low -Medium	Low -Medium	Low
1	1	4	4	4	4
Leachate pollution	Low -Medium	Low -Medium	Low -Medium	Low -Medium	Low
1	1	4	4	4	4
Marine pollution	Low -Medium	Low -Medium	Medium	Low -Medium	Medium-High
1	1	4	4	3	4
Groundw ater pollution	Low -Medium	Low -Medium	Medium	Low -Medium	Medium-High
1	1	4	4	3	4
Social					
Employement	High	Medium	Medium	Medium	Medium
1	1	3	3	3	3
Labour level of skills	Low	Medium-High	Medium-High	Medium-High	Medium-High
1	5	2	2	2	2
Health effects	High	Low -Medium	Low -Medium	Low -Medium	Low -Medium
1	1	4	4	4	4
Landscaping	High	Medium	Low -Medium	Medium-High	Medium-High
1	1	3	4	2	2
Business opportunity	High	Low -Medium	Low	Medium	Low -Medium
1	1	4	5	3	4
Economic					
CAPEX	Medium-High	High	High	Medium-High	Low -Medium
1	5	2	1	1	2
OPEX	Medium-High	High	Medium-High	Medium-High	Medium-High
1	5	2	1	2	2
Ability to finance	Medium	High	Medium-High	Medium	Low -Medium
1	5	3	1	2	3
Return on Investment	Medium	Low -Medium	Medium	Medium	Medium-High
1	1	3	4	3	3
Total score	49,00	68,00	69,00	60,00	67,00

The scenario 2 (upgraded SWM + RSWMF at Tilafushi), 3 (advanced SWM + RSWMF at Tilafushi) and 5 (decentralised system with additional RSWMF on a atoll) seems to be the preferred options. A sensitivity analysis is necessary to determine the recommended option in a short, medium and long term

4.2. Sensitivity analysis

The following changes in the weighing criteria have been considered for the further analysis:

- Increasing of technical weighing by 20% (other stays equal)
- Increasing of environmental criteria weighing by 20% (other stays equal)
- Increasing of social criteria weighing by 20% (other stays equal)

- Increasing of financial criteria weighing by 20% (other stays equal)

With the following results:

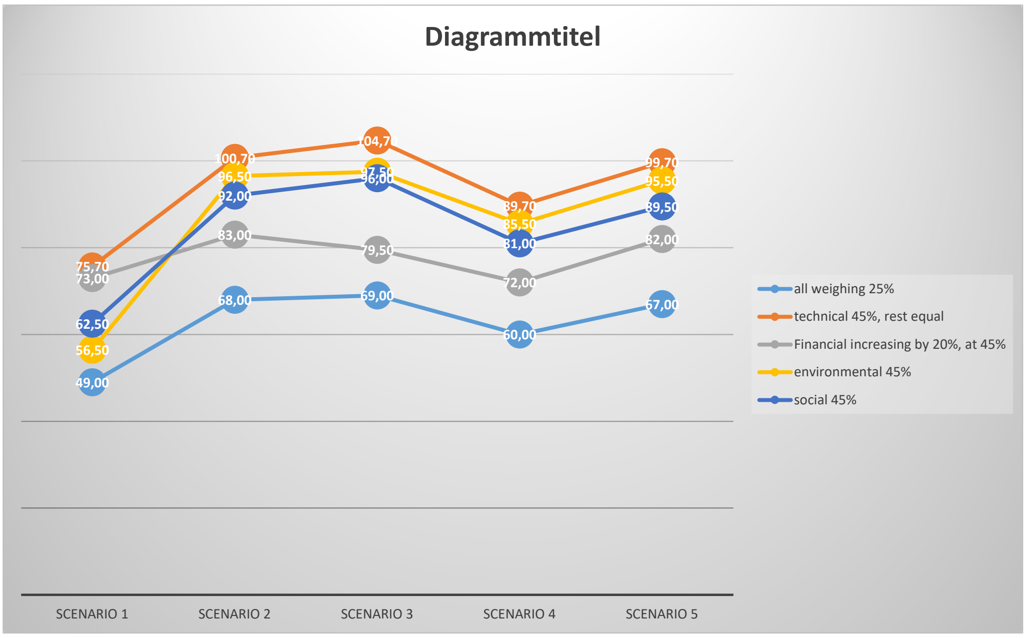


Figure 64: Sensitivity analysis

Interpretation of the results:

Scenario 2 and 3 are the most robust in the view of changings of the four weighing criteria (technical, environmental, social and financial criteria), while scenario 2 seems to be the preferred one on short and mid-term basis (financial aspect is more important than the others are). Scenario 3 is to be considered on long-term basis while scenario 5 is actually not robust enough considering the actual set of criteria.

CHAPTER 5: SCENARIO DEVELOPMENT

1. Waste collection and Inner-island transport

In the following are presented the advantages and inconvenient of the different collection systems which could be used

System	Description	Advantages	Inconvenient
SHARED: Residents can bring out waste at any time			
Dumping at designated location	Residents and other generators are required to dump their waste at a specified location or in a masonry enclosure.	Low capital costs	Loading the waste into trucks is slow and unhygienic. Waste is scattered around the collection point. Adjacent residents and shopkeepers protest about the smell and appearance.
Shared container	Residents and other generators put their waste inside a container which is emptied or removed.	Low operating costs	If containers are not maintained they quickly corrode or are damaged. Adjacent residents complain about the smell and appearance.
INDIVIDUAL: The generators need a suitable container and must store the waste on their property until it is collected.			
Block collection	Collector sounds horn or rings bell and waits at specified locations for residents to bring waste to the collection vehicle.	Economical. Less waste on streets. No permanent container or storage to cause complaints.	If all family members are out when collector comes, waste must be left outside for collection. It may be scattered by wind, animals and waste pickers.
Kerbside collection	Waste is left outside property in a container and picked up by passing vehicle, or swept up and collected by sweeper.	Convenient, No permanent public storage.	Waste that is left out may be scattered by wind, animals, children or waste pickers.
Door to door collection	Waste collector knocks on each door or rings doorbell and waits for waste to be brought out by resident.	Convenient for resident. Little waste on street.	Residents must be available to hand waste over. Not suitable for apartment buildings because of the amount of walking required.
Yard collection	Collection labourer enters property to remove waste.	Very convenient for residents. No waste in street.	The most expensive system, because of the walking involved. Cultural beliefs, security considerations or architectural styles may prevent labourers from entering properties.

Table 25: Advantages and inconvenient of different collection systems

1.1. Small and middle sized islands

Small Islands, less than 1000 inhabitants are characterized by a high level of awareness. The roads are wide so that a door-to-door collection could be foreseen. Due to the relative small demography and population growth an advanced collection system with waste compaction trucks *is not needed*. The actual transport system via small trucks could be maintained. In order to improve the sorting rate and to be in line with the establishment of ISWMC; each household could be tipped with small bins of different colours (10-20 l). The waste is transferred from the household's bins into bigger bins (120 l) put on the truck. These bins of different colours will be brought to the ISWMC for the different purposes (Composting, plastics, P&C, residual waste).

HH bins (colour and type only for information and as example purposes) for small islands			
			
20 l bin for residual waste	10 l bins for sorted fractions (plastics, P&C, etc..)		

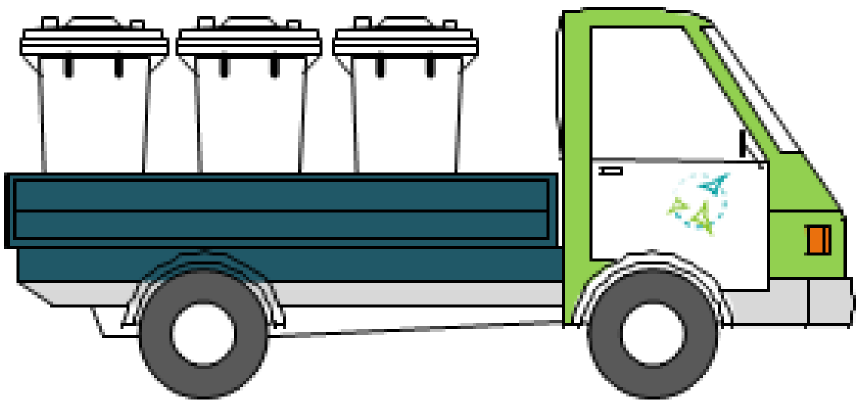


Figure 65 : Waste collection truck small island

For Islands bigger than 1000 inhabitants the same approach can be adapted but with medium scale trucks.

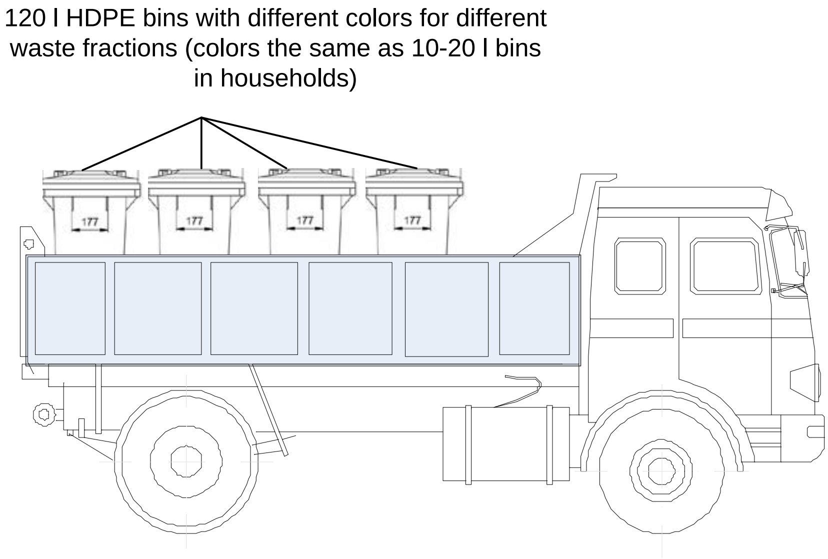


Figure 66: waste collection truck bigger islands

Frequency of collection:

Some communities are accustomed to a collection seven days a week, whilst other collection tendencies are striving for just once each week. If fly breeding is to be controlled, the waste should be collected twice a week in hot climates. Other factors to consider are the odours caused by decomposition and the accumulated quantities. If residents are accustomed to daily collection it may not be politically feasible to reduce the frequency to twice a week. In some cities waste is collected on the day of rest (Friday). Some collect waste at night, perhaps for cultural reasons or because of the weather or traffic congestion.

1.2. Atoll capitals

For the Atoll capitals due to the important amount of waste, the level of “urbanisation” and the demography evolution, a collection with compaction trucks is recommended. The collections system with standardised bins could also be implemented.

HH bins (colour and type only for information and as example purposes) for Atoll capitals		
		
120 l bins of different colors		

Figure 67: waste compaction truck for urbanized islands

In order to meet the objectives of the National Strategy for Waste and to attain substantial deflection of waste from the landfill, towards achievement of recycling and composting objectives, it is recommended to start immediately with a waste segregation system in the atoll capital.

To guarantee a harmonization of the system, the colour code for the bin or bag system should be *developed and fixed on the national level as soon as possible*:

Type of waste	Colour	Actually based on WAMCOs 2 stream strategy
Rest fraction/dry material	Anthracite/grey/Black	Black
Recyclables/dry material	Yellow/Pink	Green
Paper and Cardboard	Green/Blue	Green
Organic waste/wet material	Green/Brown	Black (while not part of the recyclable)

Table 26: Suggested waste color codification for collection bags or bins

The introduction of a sustainable recycling system is, of course, very ambitious, particularly the lack of adequate structures for reusing and reutilization of valuable waste fraction present an important risk not to achieved the targets sets in the national law.

Therefore, it is recommended to improve not only the inter-Island cooperation in the region but for this specific field of the waste management to evaluate the possibility of an interregional networking.

1.3. Resorts Islands

The resorts are responsible to implement a sustainable ISWM on their own expenses. Therefore the presented methods could only be seen as suggestions and recommendations:

Coloured bins could be provided for the differentiated collections of the waste. The bins have to be brought to a fixed transfer point nearby the resorts (resort berth/docking, or on sea transfer). The procurement of the bins are under the own expenses of the resorts.

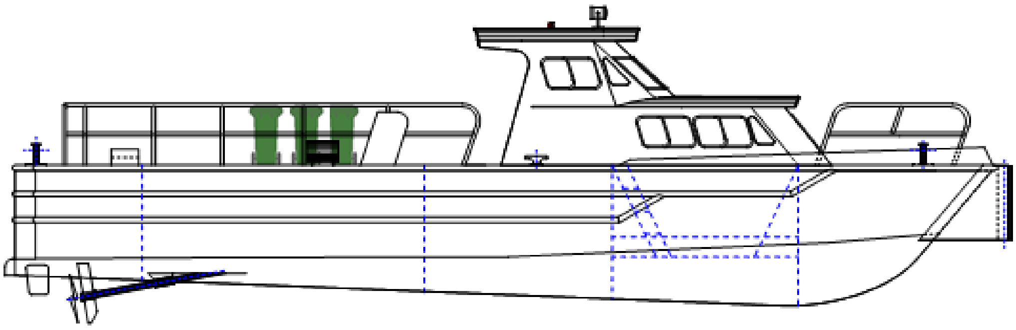


Figure 68: Small vessels for Resort waste transport (design and procurement on resorts expenses)

Resorts bin should be 120 l or maximum 240 l in order to facilitate the handling and uploading by hand.

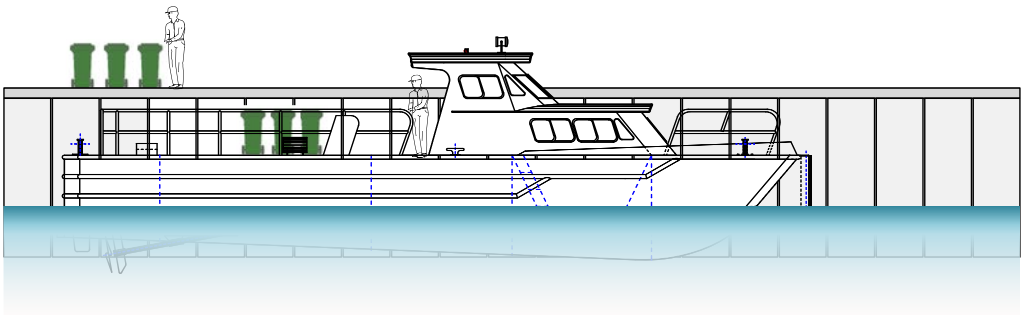
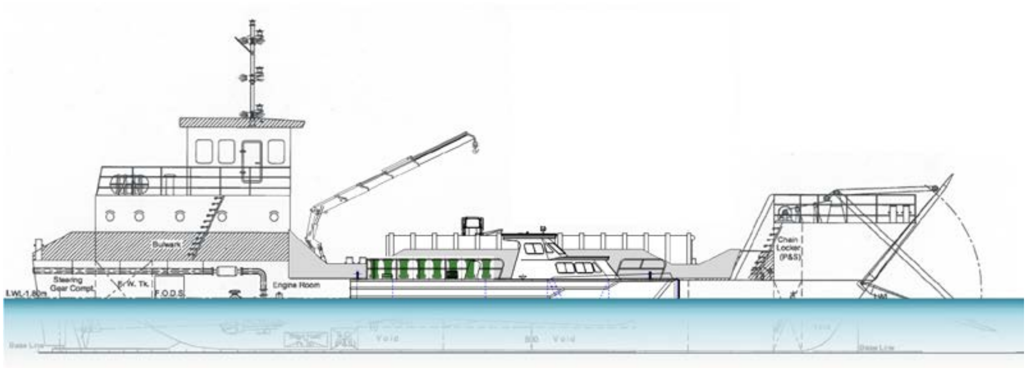


Figure 69: -Step 1- Waste bin transfer on resort jetty (small jetty)



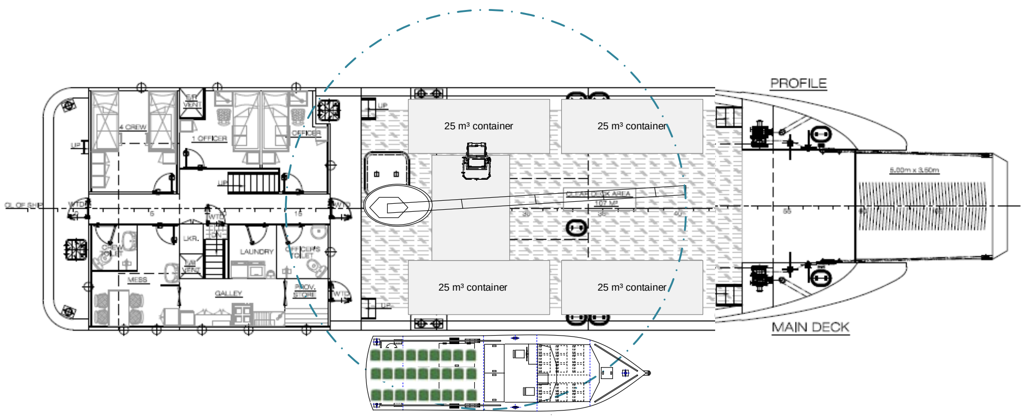


Figure 70: -Step 2- waste bin unloading on outer-Island vessel

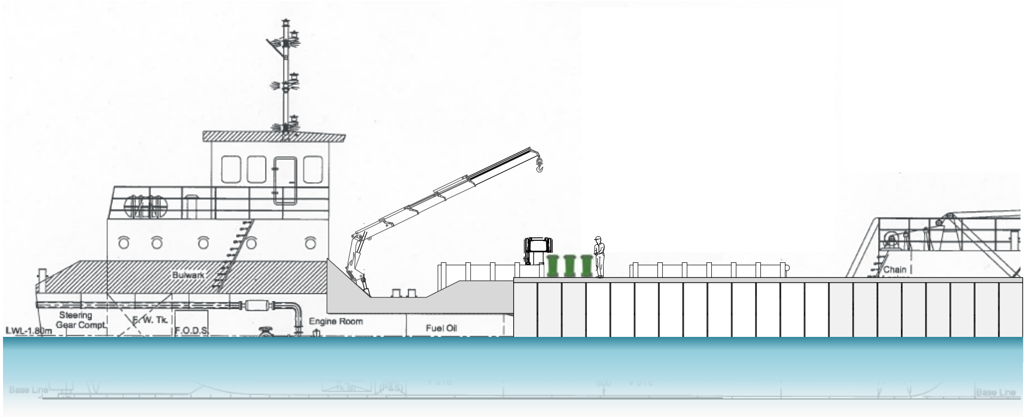


Figure 71: -Alternative- direct unload on resort's jetty/berth (in case of bigger berth)

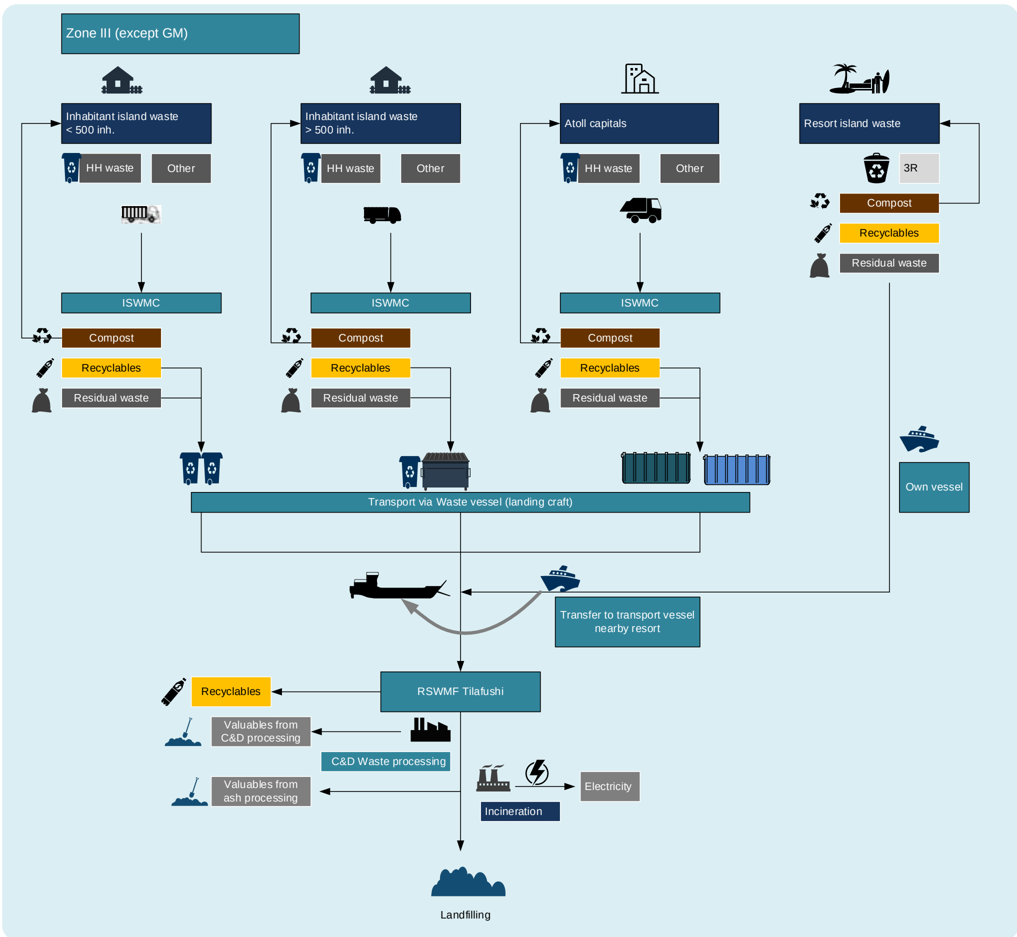


Figure 72: schematic overview of collection and transport system for Islands & resorts (except GM)

1.4. Special case 1: Hulumale

Hulumale is a particular case in the region. As a newly reclaimed island, many efforts were made in terms of modern urban and infrastructure planning. The roads are wider and followed strict organized planning rules. Buildings are organised in square shapes, which allows a state of the art SWM planning. The most convenient collection method for citizen will be the implementation of a D2D system while a combination of D2D and collection points might be also technically feasible. Due to the important number of multi-storey buildings in Hulhumale a kerbside or yard collection could also be implemented. Collection receptacles should be similar to Atoll capital and should be consisted of standardised container of 120 l, 240 l or 660 l containers (depending on collection type in the different districts).

Figure 73: Example of a standardized 660 l bin

Collection trucks should be standardised compaction trucks. From economical point of view and due to the wide roads, bigger trucks with a capacity of 14 m³ or bigger are recommended.

1.5. Special case 2: Male' City

Option 1: Door 2 door strategy (WAMCOs preferred approach)

For Male there is an urgent need to define a clear, harmonized and integrated strategy in waste collection. The actual system should be optimised by a:

- A uniformed system of bag collection system which is most economical and effective way on short term basis
- By a combination of a door 2 door collection with a first optimisation of the collection frequency (6/7 or 7/7 for wet waste and once a week for dry waste which should be tested even due to the space issue)
- The realisation of small collection points *for certain areas as pilot project in order to see the technical feasibility*
- And the realisation of a transfer facility (station and equipment) for Male'

On very short-term basis (2-3 years) it is recommended to start with a one bag system collecting all unsorted household waste at the same time (grey/black one bag system).

After a successful implementation phase with the optimisation of the collection logistics and with increasing awareness of the population, the segregation of valuable fraction can start. The implementation of the bag system with different colours for wet and dry waste should be done smoothly starting with 1 zone per district (total of 4 zones) or starting with one district and after successfully implementation spreading the system to district 2,3 and 4.

The bag size for wet waste should be in the beginning between 20-40 l, preferably reinforced (1,2 Mil/30 µm), the colour could be chosen according to adopted norms and should be kept definitely an fixed . All bags should be printed with the Logo of WAMCO, with “Safuu Rajje” brand or both.

The advantage of such branded system is that the bags could be distributed during the registration process or to the citizens who are registered in order to identify them during the collection. “unbranded” bags means the citizen is not registered and therefore the bag will not be collected.

For the residual/dry waste and due to the lower collection frequency a bigger volume with a min. of 60 l-120 l bags in black colour are suggested. This waste is mainly “lighter” so a conventional thickness of 18 µm could be foreseen.

All bags should be uniformed with the WAMCO brand print or the “Saffu Rajje” logo or both. Household should be informed with a small brochure in Dhivehi (the use of Pictogram is recommended) which waste is considered as wet waste and which is the residual/dry waste

			
			
Recommended	Recommend	In Europe used for plastic waste	In Europe used for paper and Cardboard

The use of biodegradable waste bags (for wet waste) is actually not recommended due to the high production costs. If the separation is well done on the citizen level than the bags could be easily separated during the waste treatment stage.

According to the actual waste generation, calculated realistic waste densities for wet and dry waste and the waste collection frequency a quantity for the complete city of Male of maximum

- 9 Million bags/year for residual waste (equals approx. 1 bag/household/day) at the start

In case of implementing a sorting system:

- 9 Million bags/year for wet waste (equals approx. 1 bag/household/day) at the start
- 1,3 Mio bags/year for dry waste (equals approx. 1 bag/household/week)

needs to be foreseen. This can be readapted after implementation of test districts/phases.

Dimensioning parameter for collection strategy (demand)
Dimensioning method : Households (based on census), frequency Wet waste : 6/7 Dry waste: 1/7 Preliminary segregation: Wet waste/Dry waste
Bags (Wet waste): Coloured, 20-40 l, reinforced plastic bag : approx. 1 /Household/day Bags (dry waste): Black, 60-120l, standard plastic bag: approx. 1/Household/week

In the following figure is presented the waste management strategy for Household waste in Male if Option 1 (door 2 door collection) is the prefered option.

Most of the collection has been foreseen by WAMCO on a door to door basis. This of course the most advantageous and customer friendly approach. The main risk is that without a clear organisation and strategy household could be easily forget. Additional variation of the door 2 door system is the building collection service. This service can be opted by building owners with available/designated spaces for waste bins in the buildings.

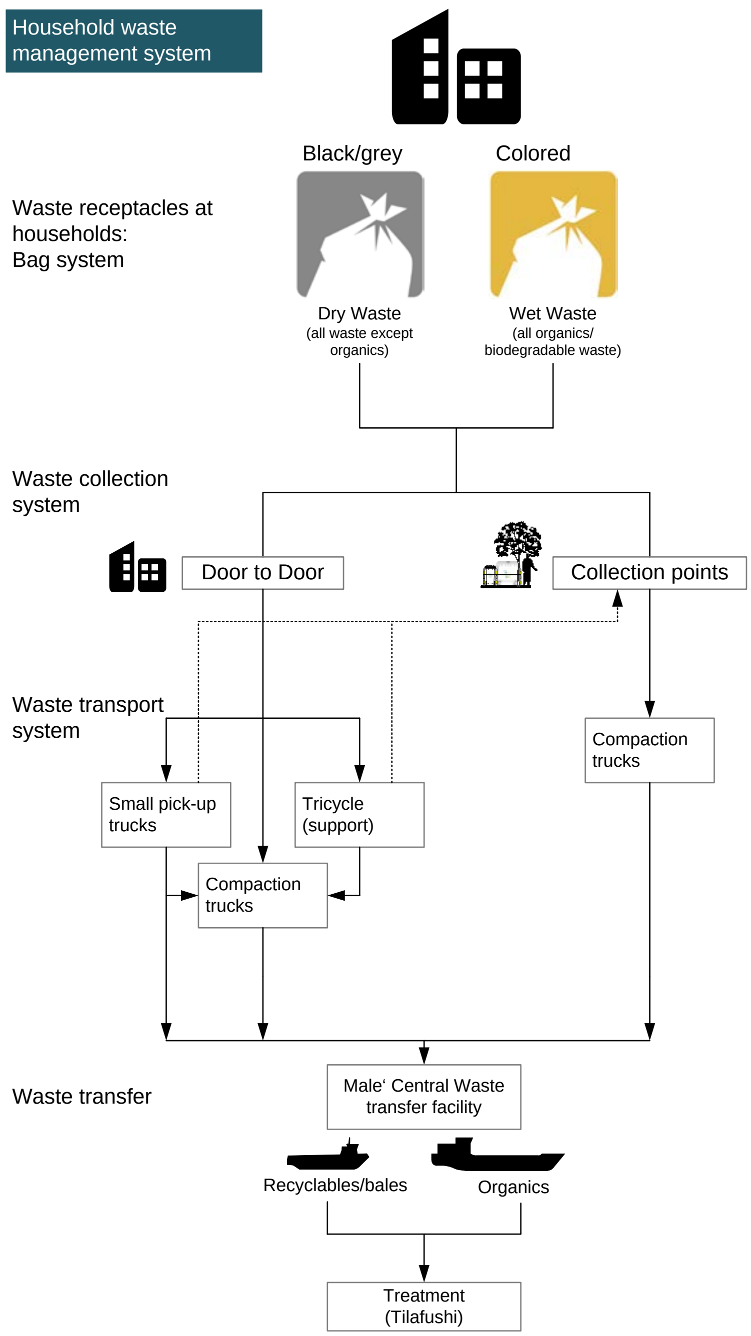


Figure 74: Waste strategy Household waste short term

The establishment and realisation of collection points (tariff can be developed throughout the vicinity of the point) could bring additional support and collection help.

Main advantages are:

- Improve the waste collection and transport system through centralized spots
- Optimization of waste collection frequency
- Improving of the hygienic conditions by dumping into cleared areas with sufficient dimensioned, closed receptacles (bins) (despite the fact that

previous experiences have not been successful, probably due to technical lacks)

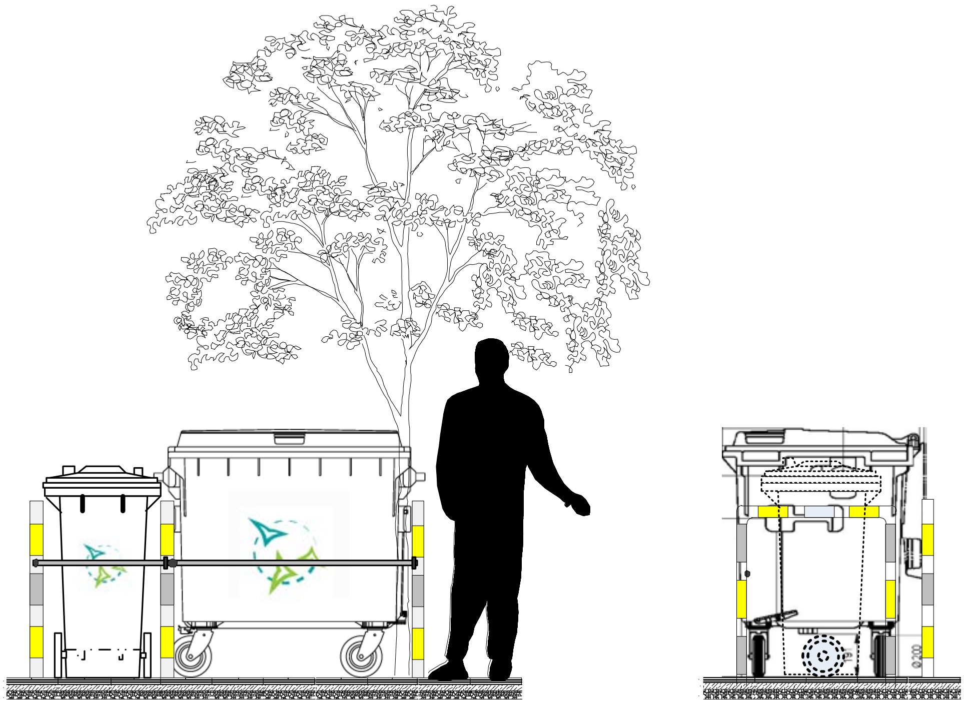


Figure 75: example of an open collection point

Figure 76: example of a closed/secured collection point

The collection points should be manned by normalized bins. Due to the limited space availability, the number of collection points will be limited in the beginning to approx. 10% of the collected waste. This collection point should also be considered as a pilot. The number could be increased depending on public space availability.

Dimensioning parameter for collection strategy/Collection points
Dimensioning method : 10 % of generated household waste, Dry/Wet waste separation, frequency Wet waste : 5/7, dry waste: 1/14
Bins (Wet waste): Coloured (same as bag), 240 l-360 l, standard HDPE bin : approx. 1-2 bins/collection point Bins (dry waste): Black, 770-1100l, standard HDPE bin : min 1 bin/collection point

For the collection points (pilot phase/market area) an amount of:

- 20 bins of 360 l (min 14 bins + reserve)
- 10 bins of 770 l or 1100 l (7+reserve)
- And a space availability of min 8 m²/collection point
- And adapted collection vehicle (compaction truck with lifting device)

Option 2: decoupling primary and secondary collection[3]

Decoupling primary from secondary collection is a system applied in many congested cities of the world. While the primary collection in a city like Male might be a mix of D2D collection and a self-carry system to collection points, the secondary collection, i.e. picking up the waste from these collection points and bringing it to its final destination can be scheduled during off-peak traffic hours. Therefore, collection points using (nicely designed) larger containers are installed across the city. In the beginning, Male citizens might abstain from using these containers but gradually most of the citizens are expected to adopt it. To overcome the reluctance in the beginning, WAMCO can offer both a D2D and a curbside collection service and charge different rates. Both D2D collectors and the citizens who pay less for the waste services then can place waste in those curb side collection points.

To facilitate smooth operation of the D2D collection (or self-carry system), curb side containers or collection points have to be distributed across the entire city at a certain distance which poses a significant challenge because of the narrow streets, the vast number of scooters and motorbikes and an almost complete lack of dedicated all off-street parking opportunities and finally the overall limited space.

[3] Lyndsay Chapple, Jürgen v. Kories, Preliminary Concept Design Report Collection System Male, Technical Assistance Consultants Report, 14.08.2017

Comparison between 2 options	
Door 2 door and collection point support (WAMCO's preferred option and consultants 1st approach	Decoupling primary and secondary collection (ADB's PPTA preferred option and consultants 2nd suggestion)
Advantages Customer/citizen friendly Actual system (no big changes)/short term implementation easier Reliable for the polluter-payer principle	***Advantages*** More efficient Less sensitive to the traffic and congestion situation in Male'
Inconvenient Important logistical effort Important manpower Less efficient and more sensitive to the traffic conditions in Male'	***Inconvenient*** Mid-term approach Needs a change in the approach of the operator Lobbying and convincing work is important on all level Implementation of approx. 400 collection points in Male' is challenging Polluter payer principle is more difficult to apply Risk of illegal dropout, flytips etc. nearby the collection points

Table 27: Comparison table option 1 vs option 2

Commercial waste (bins & container dimensioning)

For commercial waste similar to household waste, a bag or a bin system could be introduced. For commercial similar to household waste as well as the waste from hotels, guesthouse and restaurants special waste tours should be planned. This can be done in a first step in close cooperation with free capacities of foreign workers and the city.

In a first step, similar to the HH-waste strategy, an unsegregated waste collection system should be implemented with standardised bins (same colour as the HH-waste bags, preferably in black/grey).

Waste collection should be done by small pick-up trucks or similar with a transfer into the compaction truck or via direct haul to the TS.

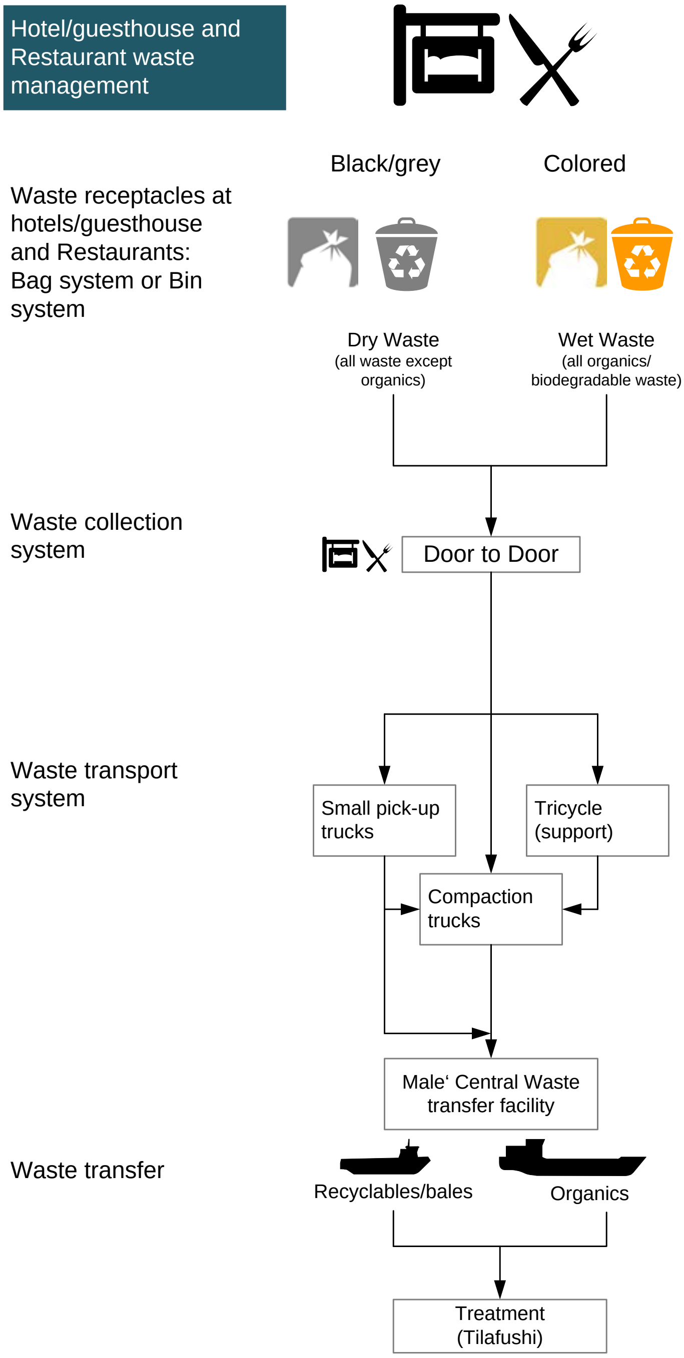


Figure 77 : Hotel and Restaurant waste management system

Actually more than 400 food related commercial shops and stores (restaurant, Café, bars etc.) and around 30 Hotels and guestrooms have been identified.

Similar to the HH waste collection, the second step could be the implementation of 2 two stream strategy with separate collection of a wet and dry fraction.

Each of the commercials should be included in the dry/wet waste collection system (second step) and be manned with a 120 l bin for wet waste and a 120 l plastic bag for dry waste.

Figure 78: Standardized bin for commercial waste collection

Dimensioning parameter for collection strategy : Commercial waste
Dimensioning method : List of restaurants, food related shops, hotel and Guesthouses, Dry/Wet waste separation, frequency Wet waste : 6/7, dry waste: to be determined through optimization process
Bins (Wet waste): Coloured (same as bag), 120 l, standard HDPE bin : 1 per restaurant/shop/Hotel/Guesthouse Bag (dry waste): Black, 120 l, standard plastic bag : 1 per restaurant/shop/Hotel/Guesthouse

Special pick-up service: Male Central Market

The particularity of Market waste is the important amount and very clear fractions of wet and dry waste (composed most of the time of packaging waste like plastics, wood boxes, etc.). Actually, the amount was estimated to 2-3 t/day but to be in line with the transfer facilities and the collection trucks a special pick-up service should be foreseen with an arm roll truck and a set of container. two containers of 25 m³ each should be permanently be on the market place. One could be used for wet waste and one for dry waste. The collection frequency should be held on the market opening days.

Figure 79: Arm roll dump truck (ex: Hyundai HD 260, 6 x 4)

Alternatively, a skip bin system could be foreseen. The skip bin system has the advantage to take less space and for this particular purpose, they are easier to handle.

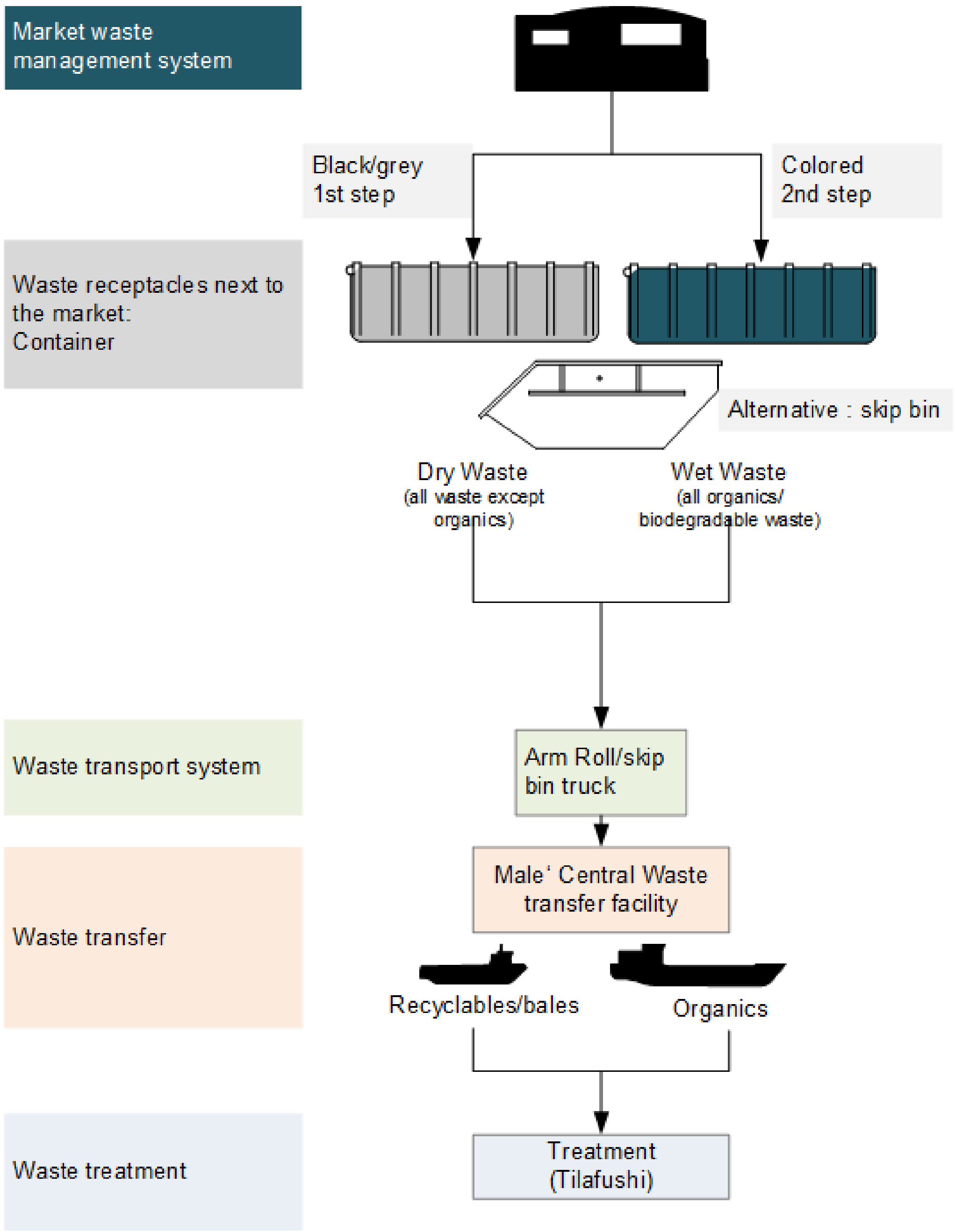


Figure 80: Market waste management system

For market waste it is suggested to extent to proposed collection service to two additional container collection points.

These points could be built as simple concrete slabs, similar to those already build as passing through the channel.

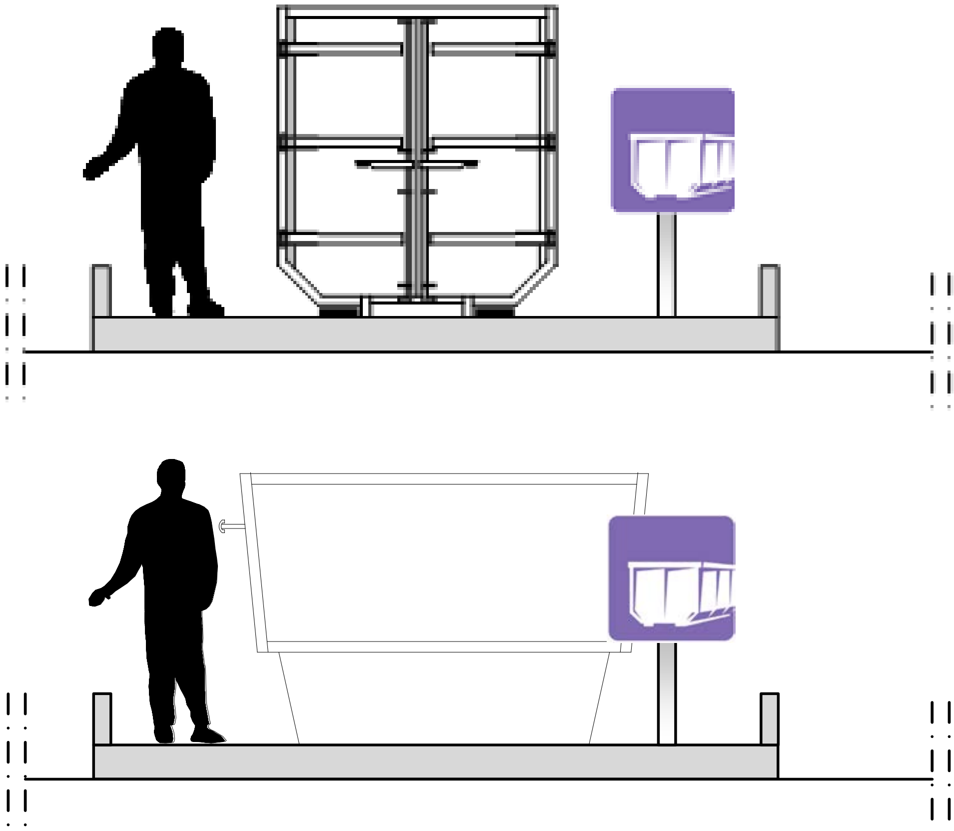
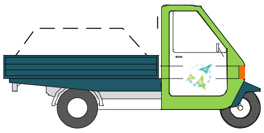
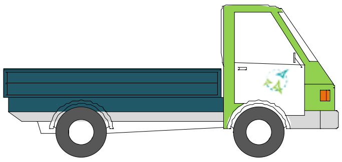


Figure 81: suggested layout for market waste collection point

Waste transport

This phase is crucial to improve the efficiency of the system. Actually, WAMCO has already ordered tricycles for the door-to-door collection and some compaction trucks for wider roads. Based on the actual waste forecast and data, the urban characteristics of Male', the frequency, the type of collection (door 2 door/collection point), it is a first and necessary step, but it seems to be not sufficient to improve the waste collection efficiency. The particularity of the

Maldives in General and Male' in particular is to develop adapted and flexible solutions. One key to the success could be the variability of collection vehicles combined with a professional and optimized fleet management.

Suggested vehicle fleet for Waste collection and transfer service Male				
Vehicle type	Designation	Units actual	Units Total	Comments
	Tricycle Loading capacity (240 l)	25	50	Increasing by 25 units
	Tricycle truck Loading capacity 2-3 m³ (10 times higher than a tricycle)		20	(type Piaggio Ape or similar)
	Small loading truck capacity 4-5 m³		20	Piaggio porter, Isuzu NLR 250 or similar
	Compaction truck 5 m³	10		Model HD72 press pack
	Open dump truck (with a tarp/cover) 6 m³		10	Model HD 65
	Compaction truck 9 m³ *with lifting device up to 1100 l*		2	Model press pack HD 120 or similar

Suggested vehicle fleet for Waste collection and transfer service Male				
Vehicle type	Designation	Units actual	Units Total	Comments
	Armroll dump truck 25 m³ + set of 20-25 containers 6 x 2 wheels		4	Only For market waste pick-up service and transfer stations
	Alternative (skip bins)	-	2	For market waste collection

Figure 82: Transport strategy short and middle term

The transport strategy should also be based on the optimisation of the transport paths and ways. Most of the streets of Male are narrow and blocked additionally by motorbikes. The implementation of a customer friendly door 2 door collection required adapted solutions.

Only small vehicles could pass but small vehicles have also small collection capacities and that means that they need to make more round trips. For middle width roads the use of small open trucks is recommended while bigger trucks circulate through the main avenues. The collection paths should be optimized in such a way that small vehicles (tricycles) could empty on the middle-sized vehicle (small trucks) which empty on the big size vehicle. The big size vehicles will go then to the new transfer station.

The use of workers who will go into each household (WAMCO strategy) to bring down the waste and transfer it to the designated vehicle is very labour and time intensive, and increase the risks of direct contamination and exposure of the workers with the waste, increase the risk that the waste will fall down on the street, as well as the rupture of the waste bags during the transfer.

As part of the overall strategy for Male’ special pick up services should be arranged for identified waste streams in particular it should be guaranteed that all identified waste streams should be collected, transported and transferred separately with the help of standardised and adapted closed receptacles at least at the transfer facility.

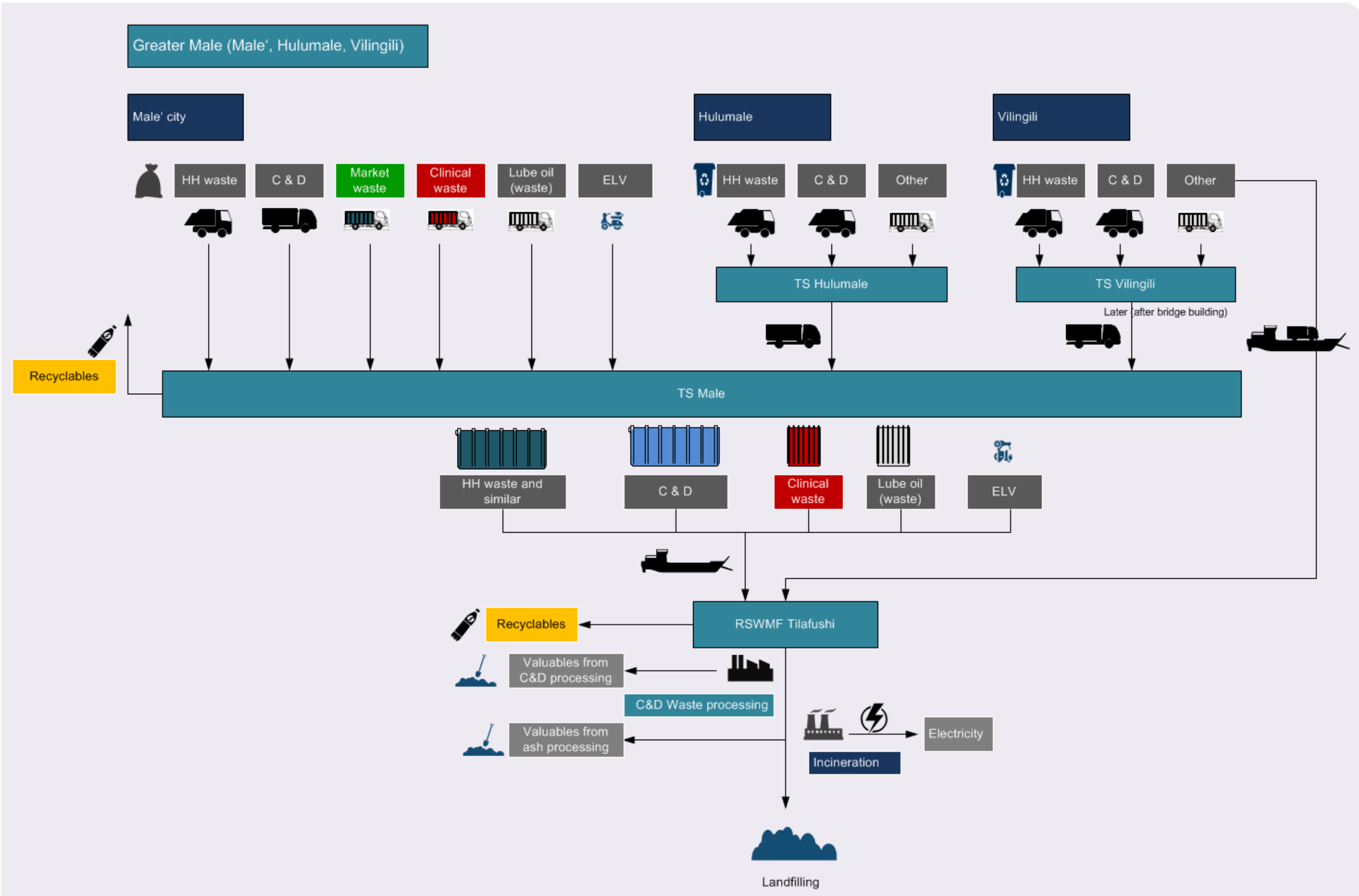


Figure 83: Schematic view of suggested Male' collection, transfer and transport system

1.6. Special case 4: Industrial Islands and airport Islands

Velana airport and in general airports in the Maldives are managed by national management corporation created for this special purpose. They are responsible for collecting, transporting and treating their generated waste. In order to harmonised the situation it is recommended to include this generated waste in the foreseen waste collection and transport system. Commercial waste from airports should be collected in standardised bins and brought to a transfer point for transfer to Tilafushi or should be brought by an own vessel of the airport corporation dedicated to waste transport. The bins should be labelled or clearly marked in order to identify them for financial charging purposes.

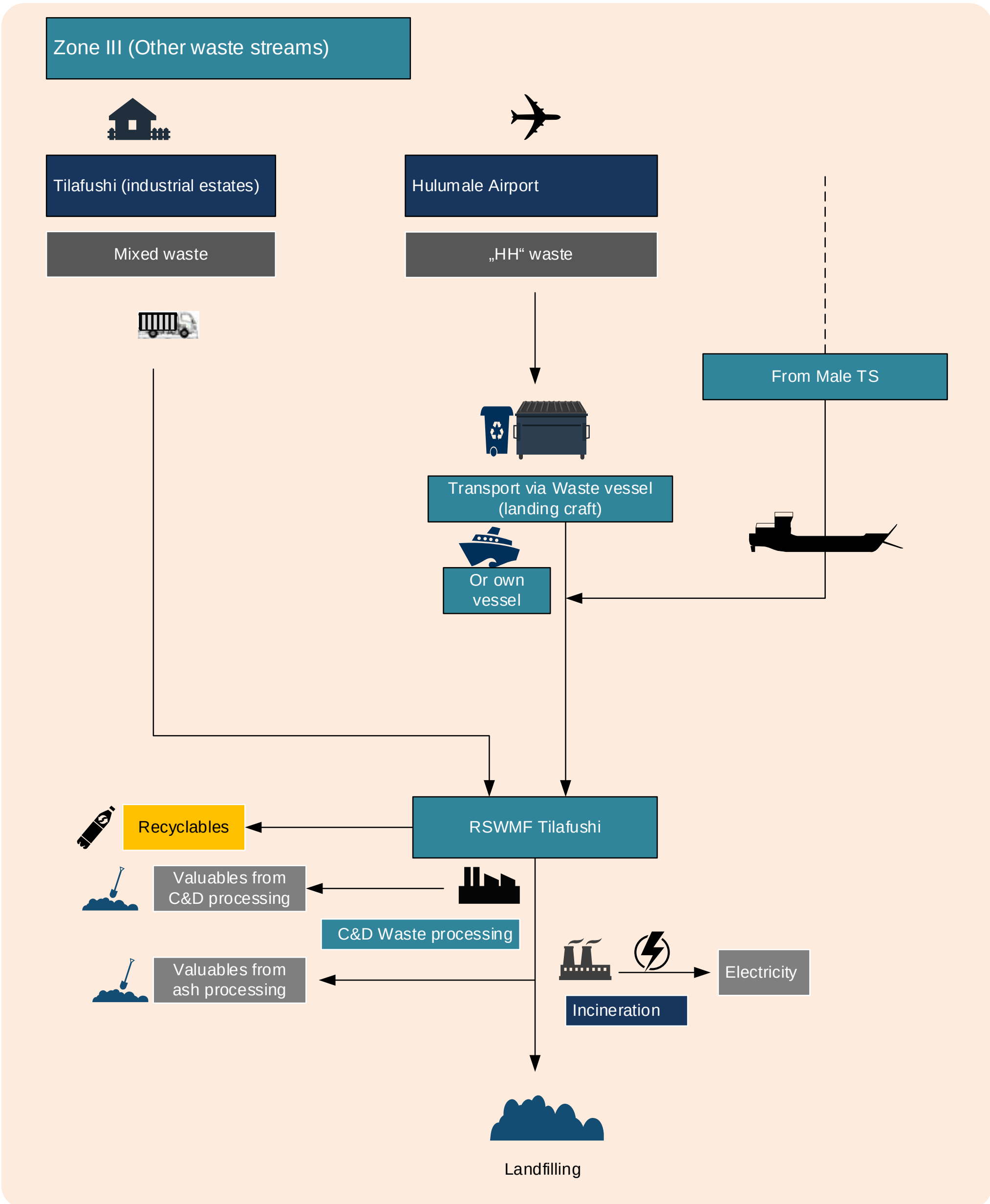


Figure 84: schematic overview of Industrial waste streams from Tilafushi and Velana airport

Industrial waste similar to HH waste from Tilafushi Island should be brought directly by the generator to the new RSWMF. A special pick-up service could also be organised (f. ex by WAMCO) as an option.

2. ISWMC

The design of RWMF is based on the quantity of waste collected and transported from the islands to the facility. With the building of the ISWMC it is expected that Islands citizens will compost the organic part of waste on the islands for own purposes. The residual waste and valuable fractions will be collected from the islands and transported to the RWMF.

Upcoming ISWMC should be planned and build in such a way to present an additional value to the community in terms of:

- Living condition
- Working opportunities
- Business opportunities
- An environmental improvement

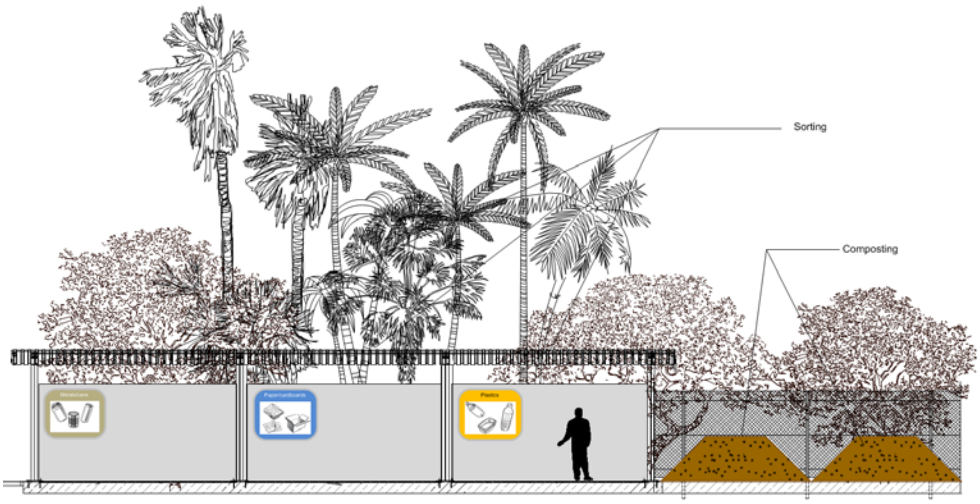


Figure 85: Layout design of an ISWMC

The detailed design of the facilities are not part of this FS but the following tasks for upcoming work are recommended:

- Assessment of all Islands, which have actually no ISWMC (population, island specificities, waste generation etc.)
- Participatory approach with island citizens to determine the special needs
- Site identification
- Site design with focus on composting, sorting, temporary storage and preparing/packaging of valuable fractions

3. Waste transfer and outer-island transport

Transportation of waste in the region is a challenge considering high cost of maritime transportation; limited infrastructure; and accessibility problems, primarily on account of absence of adequate harbour and jetties in many islands, impassable shallow waters and impenetrable reefs. The dispersed habitation generating small quantities of waste, long transportation routes and treacherous sea conditions make the challenge even greater.

The proposed waste transportation and transfer system should be compatible with the existing transportation routes and linkages. The existing accessibility facilities created at the islands will be utilized for transportation of waste as well. Some of the inhabited islands currently do not have proper harbour and access facilities. However, the Government of Maldives has plans to provide access facilities to all inhabited islands in near future.

Waste transport from Islands have been planned by the presented sub-zones and catchment areas of chapter 1. The actual preferred option is to develop an Island-to-Island waste collection including resorts island with a centralised facility on Tilafushi.

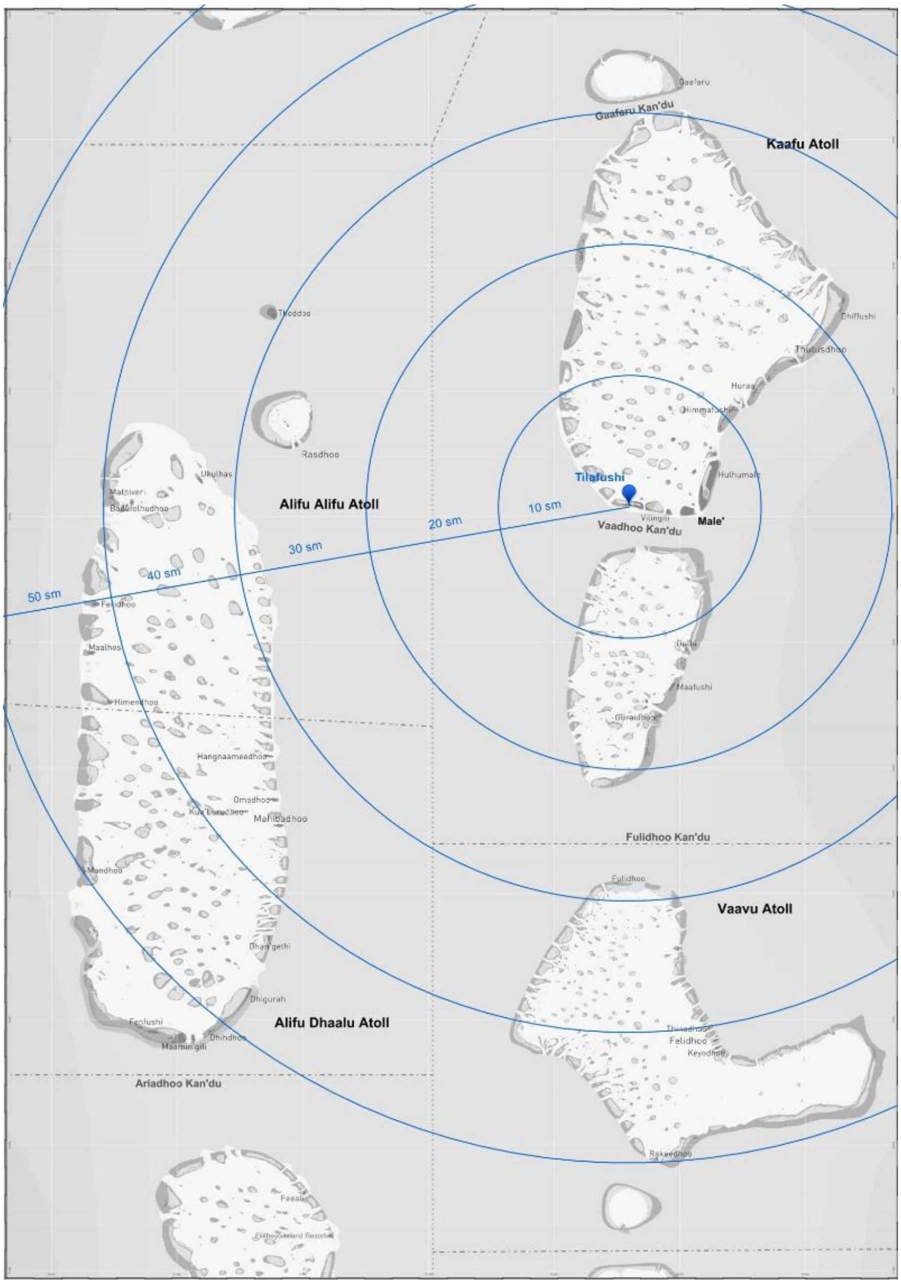


Figure 86: Distances radius to Tilafushi in seamiles

With one vessel per catchment area and an “Island to Island” waste collection and transport system (including resort waste), an average speed of 11 knots and an average up- and unloading time of 30 minutes we have the following outer island transport system:

From	to	km	seamiles	net Time	un-uploading	Total time	cumulative			Frequency	residual
Zone III b : Kaafu south atoll and Vaavu atoll											
Rakeedhoo	Keyodhoo	18,4	9,93	0:54	0:30	1:24					0,20
Keyodhoo	Felidhoo	1,13	0,6	0:03	0:30	0:33	1:57				1,51
Felidhoo	Thinadhoo	2	1,1	0:06	0:30	0:36	2:33				0,99
Thinadhoo	Alimata Aquatic resort	12,5	6,74	0:36	0:30	1:06	3:40				0,31
Alimata Aquatic resort	Dhigiri Tourist resort	5,7	3,1	0:16	0:30	0:46	4:27	day 1			1,29
Dhigiri Tourist resort	Fulidhoo	9	4,87	0:26	0:30	0:56	5:23				0,45
Fulidhoo	Rihiveli Beach resort	14,7	7,95	0:43	0:30	1:13	6:37				0,76
Rihiveli Beach resort	Olhuveli Beach and spa resort	6,5	3,5	0:19	0:30	0:49	7:26				0,50
Olhuveli Beach and spa resort	Fun Island Resort	1	0,56	0:03	0:30	0:33			day 4 (rest)	1/3	1,65
Fun Island Resort	Fihaalhohi Island Resort	10,2	5,5	0:30	0:30	1:00	1:33				0,59
Fihaalhohi Island Resort	Adaaran Club Rannalhi	2,97	1,6	0:08	0:30	0:38	2:11				1,49
Adaaran Club Rannalhi	Guraidhoo	12,2	6,58	0:35	0:30	1:05	3:17				1,29
Guraidhoo	Holiday inn Resort Kandooma	0,62	0,34	0:01	0:30	0:31	3:49	day 2			4,01
Holiday inn Resort Kandooma	Dream Island Maldives	0,39	0,21	0:01	0:30	0:31	4:20				1,60
Dream Island Maldives	Cocoa Island Maldives	1,6	0,86	0:04	0:30	0:34	4:55				0,60
Cocoa Island Maldives	Biyadhoo Island Resort	1,54	0,83	0:04	0:30	0:34	5:29				0,35
Biyadhoo Island Resort	Maafushi	4,3	2,32	0:12	0:30	0:42	6:12				0,96

From	to	km	seamiles	net Time	un-uploading	Total time	cumulative			Frequency	residual
Maafushi	Anantara Veli Resort & spa	3,52	1,9	0:10	0:30	0:40	6:52				7,68
Anantara Veli Resort & spa	Anantara Dhigu Resort and spa	0	0	0:00	0:00	0:00	6:52				1,09
Anantara Dhigu Resort and spa	Naladhu	0	0	0:00	0:00	0:00	6:52				0,45
Naladhu	Gulhi	1,89	1	0:05	0:30	0:35	7:28				0,69
Gulhi	Embudhu Village	10,4	5,6	0:30	0:30	1:00		day 3			2,17
Embudhu Village	Taj Exotica Resort and spa Maldives	2,51	1,36	0:07	0:30	0:37	0:37				1,17
Taj Exotica Resort and spa Maldives	Jumeirah Vittaveli	13,9	7,48	0:40	0:30	1:10	1:48				0,64
Jumeirah Vittaveli	Velassaru Maldives	4,73	2,55	0:13	0:30	0:43	2:32				0,89
Velassaru Maldives	Adaaran Prestige Vaadhoo	2,58	1,39	0:07	0:30	0:37	3:09				1,28
Adaaran Prestige Vaadhoo	Tilafushi	9,59	5,18	0:28		0:28	3:37				0,50
Total		153,87	83,05	7:33	12:00	19:33	7:48				35,10
Tilafushi	Rakeedhoo	96,2	51,9	4:43		4:43	8:32				

From	to	km	seamiles	net Time	un-uploading	Total time	cumulative			Frequency	residual
Zone III c : Aalifu Alifu and Alifu Dhalu atoll											
Thoddoo	Velingandu Island Resort	16,5	8,9	0:48	0:30	1:18					6,07
Velingandu Island Resort	Rasdhoo	4,41	2,38	0:12	0:30	0:42	2:01	day 1		1/5	1,34
Rasdhoo	Ukluhas	15,1	8,16	0:44	0:30	1:14	3:16				3,63

From	to	km	seamiles	net Time	un-uploading	Total time	cumulative			Frequency	residual
Ukluhas	Velidu Island resort	5,45	2,94	0:16	0:30	0:46	4:02				4,68
Velidu Island resort	Gangehi Island Resort	7,5	4,1	0:22	0:30	0:52	4:54				1,66
Gangehi Island Resort	Mathiveri	3,23	1,74	0:09	0:30	0:39	5:33				0,60
Mathiveri	Bodufolhudhoo	3	1,63	0:08	0:30	0:38	6:12				2,39
Bodufolhudhoo	Nika Island resort	0,7	0,38	0:02	0:30	0:32	6:44				2,25
Nika Island resort	Madogali Tourist resort	9,42	5,1	0:27	0:30	0:57	7:42				0,63
Madogali Tourist resort	Feridhoo	5,7	3,1	0:16	0:30	0:46		Day 2			0,93
Feridhoo	W Hotel and spa	10,7	5,76	0:31	0:30	1:01	1:01				1,39
W Hotel and spa	Maalhos	10,2	5,5	0:30	0:30	1:00	2:01				1,36
Maalhos	Himendhoo	7,64	4,13	0:22	0:30	0:52	2:53				1,36
Himendhoo	Arthuruga Beach & water villas	9	4,87	0:26	0:30	0:56	3:50				2,97
Arthuruga Beach & water villas	Constance Moofushi	9,82	5,3	0:28	0:30	0:58	4:49				1,16
Constance Moofushi	Diamonds Thundufushi beach and water villa	11	5,91	0:32	0:30	1:02	5:51				1,82
Diamonds Thundufushi beach and water villa	Mandhoo	9,74	5,26	0:28	0:30	0:58	6:50				1,19
Mandhoo	Anganga Island Resort and spa	13,4	7,2	0:39	0:30	1:09	7:59				1,37
Anganga Island Resort and spa	Mirihi Island Resort	6,29	3,39	0:18	0:30	0:48		Day 3			1,16
Mirihi Island Resort	Conrad Maldives Rangali Island	6,25	3,38	0:18	0:30	0:48	0:48				0,60

From	to	km	seamiles	net Time	un-uploading	Total time	cumulative			Frequency	residual
Conrad Maldives Rangali Island	Fenfushi	15,3	8,27	0:45	0:30	1:15	2:03				2,52
Fenfushi	Sun Island	1,85	1	0:05	0:30	0:35	2:39				3,42
Sun Island	Holiday Island	0	0	0:00	0:00	0:00	2:39				7,06
Holiday Island	Maamingili	4,35	2,35	0:12	0:30	0:42	3:21				2,35
Maamingili	Dhihdhoo	4,52	2,44	0:13	0:30	0:43	4:05				9,59
Dhihdhoo	Lux Maldives	2,59	1,4	0:07	0:30	0:37	4:42				0,58
Lux Maldives	Dhigurah	4,51	2,43	0:13	0:30	0:43	5:26				0,37
Dhigurah	Ranveli Village	2,1	1,13	0:06	0:30	0:36	6:02				2,67
Ranveli Village	Vakarufalhi Island Resort	3,68	1,99	0:10	0:30	0:40	6:43				0,93
Vakarufalhi Island Resort	Centara Grand Island resort	2,69	1,45	0:07	0:30	0:37	7:20				1,24
Centara Grand Island resort	Twin Island Resort	2,51	1,35	0:07	0:30	0:37	7:58				1,86
Twin Island Resort	Dhangeti	5,96	3,22	0:17	0:30	0:47					0,81
Dhangeti	Ranveli Village & spa	1,26	0,68	0:03	0:30	0:33	0:33				2,26
Ranveli Village & spa	Vilamendhoo Island Resort	1,72	0,93	0:05	0:30	0:35	1:08				0,93
Vilamendhoo Island Resort	Lily Beach Resort & spa	2,38	1,28	0:06	0:30	0:36	1:45	Day 4			3,05
Lily Beach Resort & spa	Mahibadhoo	11,6	6,27	0:34	0:30	1:04	2:49				2,07
Mahibadhoo	Kunburudhoo	5,1	2,75	0:15	0:30	0:45	3:34				7,33
Kunburudhoo	Omadhoo	4,58	2,47	0:13	0:30	0:43	4:18				1,56

From	to	km	seamiles	net Time	un-uploading	Total time	cumulative			Frequency	residual
Omadhoo	Hangnamedhoo	6,32	3,41	0:18	0:30	0:48	5:07				3,39
Hangnamedhoo	Chaya Reef Ellaidhoo	17,7	9,54	0:52	0:30	1:22	6:29				1,80
Chaya Reef Ellaidhoo	Havaveli Resort Maldives	4,89	2,64	0:14	0:30	0:44	7:13				1,86
Havaveli Resort Maldives	Mayfushi Island Resort	5	2,71	0:14	0:30	0:44					1,43
Mayfushi Island Resort	Bathala Island Resort	5,95	3,22	0:17	0:30	0:47	0:47				1,24
Bathala Island Resort	Banyan tree Madivaru	6	3,25	0:17	0:30	0:47	1:35	Day 5			0,75
Banyan tree Madivaru	Tilafushi	55,9	30,2	2:44	0:30	3:14	4:50				
Total		343,51	185,51	16:51	22:00	14:51					99,63
Tilafushi	Thoddoo	60,6	32,7	2:58		2:58	3:59				

From	to	km	seamiles	net Time	un-uploading	Total time	cumulative			Frequency	residual
Zone III a : Kaafu North Atoll											
Gaafaru	Helengeli Island Resort	13,5	7,29	0:41	0:30	1:11					2,26
Helengeli Island Resort	Eryadu Island Resort	17,5	9,44	0:53	0:30	1:23	2:35				0,50
Eryadu Island Resort	Makundu Island	5,45	2,94	0:16	0:30	0:46	3:22				0,57
Makundu Island	Summer Island Maldives	3,8	2	0:11	0:30	0:41	4:03	day 1		1/3	0,36
Summer Island Maldives	One & only Reethi Rah	1,43	0,77	0:04	0:30	0:34	4:38				1,14
One & only Reethi Rah	Vivanta by TAJ	5,28	2,85	0:16	0:30	0:46	5:24				1,33

From	to	km	seamiles	net Time	un-uploading	Total time	cumulative			Frequency	residual
Vivanta by TAJ	Coco Bodu Hithi	5,73	3,1	0:17	0:30	0:47	6:12				0,99
Coco Bodu Hithi	Meeru Island Resort and Spa	36,7	19,8	1:53	0:30	2:23					2,84
Meeru Island Resort and Spa	Dhiffushi	1,59	0,86	0:04	0:30	0:34	0:34				2,12
Dhiffushi	Thulusdhoo	10,2	5,5	0:31	0:30	1:01	1:36				3,85
Thulusdhoo	Gasfinolhu Island Resort	2,67	1,44	0:08	0:30	0:38	2:14				0,40
Gasfinolhu Island Resort	Adaaran Select Hudhuranfushi	1,68	0,91	0:05	0:30	0:35	2:49				1,76
Adaaran Select Hudhuranfushi	Club Med Kani Resort	1,1	0,6	0:03	0:30	0:33	3:23				2,27
Club Med Kani Resort	Huraa	1,25	0,67	0:03	0:30	0:33	3:57	Day 2			3,64
Huraa	Four seasons Resort Maldives Kuda Hura	0,85	0,46	0:02	0:30	0:32	4:29				1,05
Four seasons Resort Maldives Kuda Hura	Chaya Island Dhonveli	1,16	0,63	0:03	0:30	0:33	5:03				1,47
Chaya Island Dhonveli	Himmafushi	2,85	1,54	0:08	0:30	0:38	5:42				4,95
Himmafushi	Thulagiri Island	8,89	4,8	0:27	0:30	0:57	6:39				0,86
Thulagiri Island	Banyan Tree Vabbinafru	6,88	3,72	0:21	0:30	0:51	7:30				0,48
Banyan Tree Vabbinafru	Angsana Ihuru	0,69	0,37	0:02	0:30	0:32					0,45
Angsana Ihuru	Baros Maldives	2,5	1,35	0:07	0:30	0:37	0:37	Day 3			0,75
Baros Maldives	Bandos Island Resort & spa	7,42	4	0:22	0:30	0:52	1:30				2,24

From	to	km	seamiles	net Time	un-uploading	Total time	cumulative			Frequency	residual
Bandos Island Resort & spa	Paradise Island Resort & spa	7	3,78	0:21	0:30	0:51	2:22				2,83
Paradise Island Resort & spa	Fool moon Maldives	3,91	2,11	0:12	0:30	0:42	3:04				
Fool moon Maldives	Club Faru	2,1	1,11	0:06	0:30	0:36	3:40				1,51
Club Faru	Kurumba Maldives	2,85	1,54	0:08	0:30	0:38	4:19				1,80
Kurumba Maldives	Tilafushi	11,6	6,24	0:35	0:30	1:05	5:25				
Total		166,58	89,82	8:33	13:30	22:03					42,41
Tilafushi	Gaafaru	62,3	33,6	3:12		3:12	3:12				

From	to	km	seamiles	net Time	un-uploading		cumulative			Frequency	residual
Zone III d : Greater Male region											
Male TS	Tilafushi	8,82	4,76	0:25	0:30	0:55					207,19
Total		8,82	4,76	0:25	0:30	0:55					207,19
Tilafushi	Male TS	8,82	4,76	0:25		0:25					

That means:

- For Zone III a (north Kaafu Atoll): The vessel capacity should be at least 42 t/trip with a 3 day trip to arrive at Tilafushi
- For Zone III b (Vaavu Atoll and south Kaafu Atoll)): The vessel capacity should be at least 35 t/trip for a 3 day trip
- For Zone III c (Alifu Alifu and Alifu Dhalu Atoll) : the vessel capacity should be at least 100 t/trip for a 5 day trip
- For zone III d (Greater Male Region) : The vessel(s) capacities should be at least 200 t/day

3.1. Transfer station Male'

The transfer concept considered obviously the shipping of different waste fractions to the dumpsite to Thilafushi. Actually and, besides the fact that the upgrading and rehabilitation of Thilafushi, will take some time, and will happen after the construction of the TS, it is recommended to start the transfer concept based on the hygienic process of containers. On short term (2-3 years) the main objective is to organise the transport of in safe and close receptacles of two main streams :

- The construction and demolition waste
- The HH waste and all waste similar to HH waste (commercial, airport etc.)

Small quantities of autoclaved waste (harmless waste) could be considered in the HH waste flow. In consistency with the mid term strategy the waste acceptance and transfer could be then optimised with special containers for wet and dry waste (second step), the wet waste containers could by brought directly to Thilafushi dumpsite. The dry waste could be pre-sorted and pressed into bales for a further use.

This use could be a temporary/short term storage on site, a mid-term and long term storage of bigger amounts on Thilafushi. With increasing complexity of the solid waste management system and the Dumpsite at Thilafushi, a new logistic concept becomes a necessity.

Islands which are too far from the dumpsite site needs to transfer their waste economically on centralized waste points.

The location of a centralized transfer station has already been defined. The transfer station should respond to the need of the implementation of a viable and state of the art waste management concept. The space availability in Male is very limited but the construction of the waste transfer station will have a major impact of the improvement of the system.

The infrastructures of the station has been dimensioned in such a way that future strategies in terms of sorting, recycling and waste flow handling should be taken in account.

Also the station should be a focal point for the development of WAMCOs activities and should contribute to the strengthening of the operational structures.

Therefore the station should be more than only a transfer infrastructure. It should be developed to the operational headquarter for WAMCOs fleet with a maintenance area and a recharging/refuelling area as well as a civic amenity area for the handling of different waste flows

The proposed site for construction of the Transfer Station is located on the south of Island of Male in a newly reclaimed area and has a surface of approx. 6.000 m².

The site is surrounded by the south harbour and some administrative buildings. It's located in the public ownership area. A water supply and an electricity connection points have been already established in the front of the site. Rain water drainage to the sea exists along the road.

The transfer station is consisting of an asphalted entrance. After the entrance gate there is an office container on concrete strip foundation and some asphalted a weighbridge, and parking lots. The incoming trucks will be conducted through an asphalted traffic road over a ramp to an unloading asphalted platform. The incoming waste collection trucks will unload the waste in five waste containers of a capacity of 25 m³ and disposed on the down part of the area. The unloading surface and the waste transfer container surface are protected against heavy rainfall by a metallic shed construction. The site is protected by a surrounding mesh wire (or alternately metallic bar) fence and entrance gate.

Figure 87: 3D layout of the TS in Male

Figure 88: 3D layout of the TS in Male’

Figure 89: 3D layout of TS in Male'

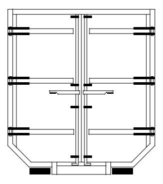
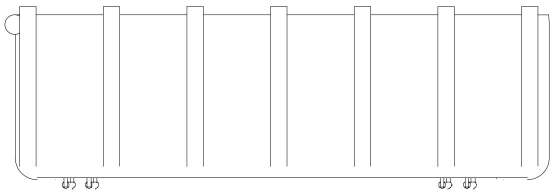
Figure 90: 3D layout of TS in Male'

Figure 91Suggested container system for TS Male'

Incoming trucks (existing situation)	10
Incoming trucks (forecast)	20
Outgoing Vessels (long distance transport)	2-3
Transport to landfill/operation time	Uploading time at TS : 1-2 hr One way: 45 min Waiting and unloading time at dumpsite: 1 hr. Return way: 45 min Unloading/operation at TS : 30 min. operation time: approx. 4 hrs 50 1 rotation: approx. 200 m³/day/vessel

Transfer area has been dimensioned for:

Upper side (Incoming trucks)	Waste compaction truck (small max 10 m) 2 axial Turning radius: 6,0 m-7,0 m Buffer of 1 m Uploading height 4,0 m
Down side (Outgoing truck)	1 Hook lift truck single 3 axial Turning radius : 9,0 m Buffer of 2 m Loading height according hook lifting device with 25 m³ container

Containers	Width [m]	Length [m]	Height [m]
			
25 m³	2,3	5,0	2,00

Key figures

TS Male City	
Capacity	75.000 t/year
Site surface (m²)	6.114 m²

Access area, Circulation and transfer area (asphalted)	5.500 m²
Parking/container storage and foreseen area for sorted waste	200 m²
Green area/landscaping	To be determined
Buildings	Administration, social and maintenance building control building (container) with weighbridge
Infrastructure	Perimeter fence and gate Surface water drainage concrete ditch : Firefighting reservoir and pump Potable water tank (01) and pump Septic tank (01) Lightning poles (5)+ shed mounted (8)
Operation	6 days/week Minimum 8 hrs./day (opening time depending on local collection concept) Personnel : min. 3 persons + administration
Equipment	1-2 Hook lift truck set of containers (20) 1 fork lift 1 multipurpose loader small equipment (security and office)

The transfer vessel are landing craft type vessels and there is an access ramp to the area for docking purposes.

Similar to the waste collection strategy in Male' city a variation of different waste vessels should be foreseen (to be more flexible depending on the waste streams, the daily capacities of recyclables, etc.). For the main waste containers of wet waste and mono-loading a landing craft vessel is suitable.

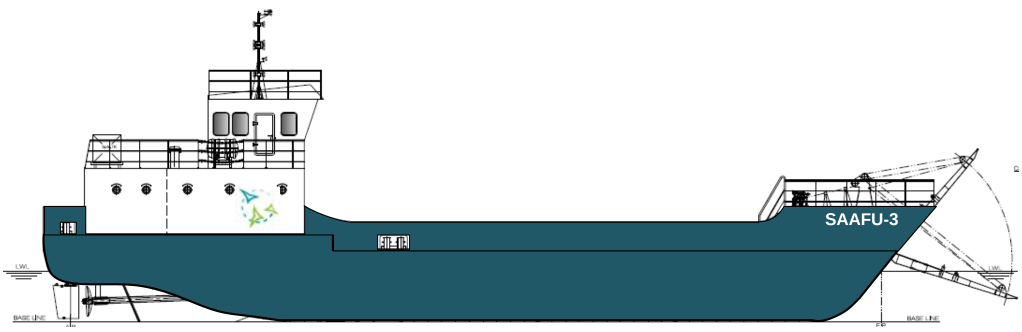


Figure 92: schematic drawing of Waste collection vessel (landing craft type)

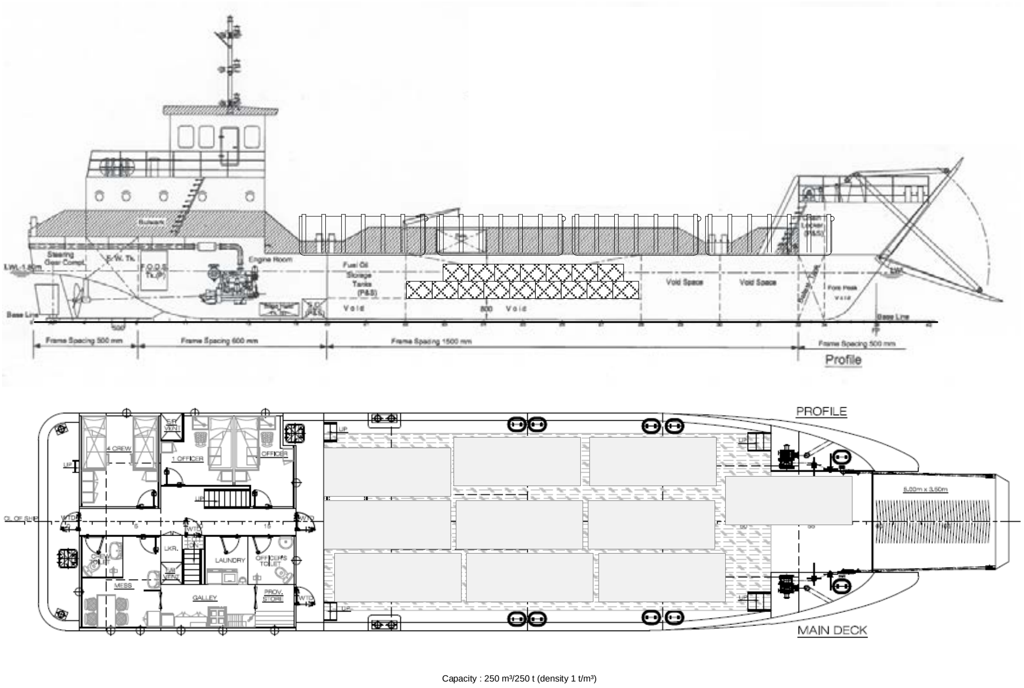


Figure 93: transport capacities of the Vessel (Greater Male waste transfer)

The armroll trucks will drive into the vessel backwards and unload the 25 m³ container. At Tialfushi another armroll truck of the same type upload the container and bring it to the waste incineration plant. This is the most advantageous method in terms of space savings and vehicles savings. Main inconvenient is the need of at least 1-2 arm-roll truck at the RSWMF.

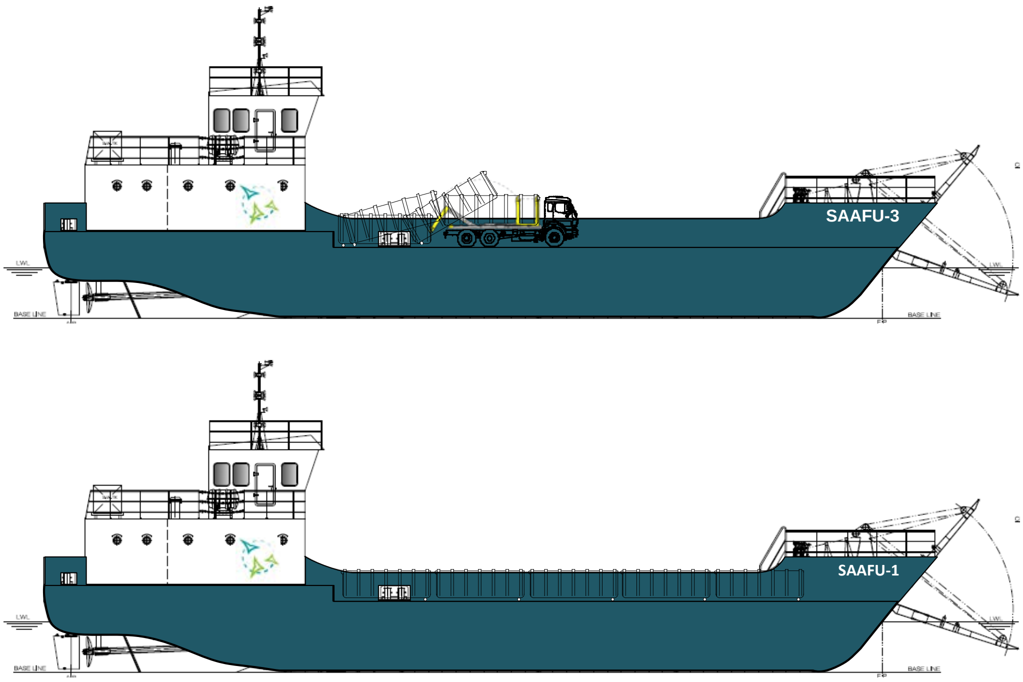


Figure 94: un-load and transfer option for the containers

Alternatively the arm roll trucks could be transported with the container to the RSWMF. Inconvenient is the space use on board as well as the higher number of trucks. Main advantage is the time saving during the on and offloading process.

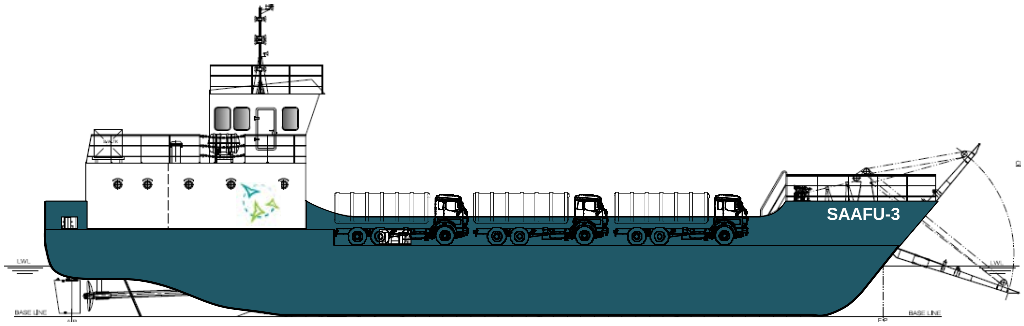


Figure 95: second un-load option for containers

For the dry and sorted fraction the use of a small vessel/Dhoni (like the one used actually for the mixed waste) seems the most economical approach. Due to the fact that dry waste is harmful in terms of pollution and baled, a small vessel could handle it easier (for example for the transport and handling of recyclables bales).

The only recommendation is to foresee these vessels with a crane for the up and unloading process.

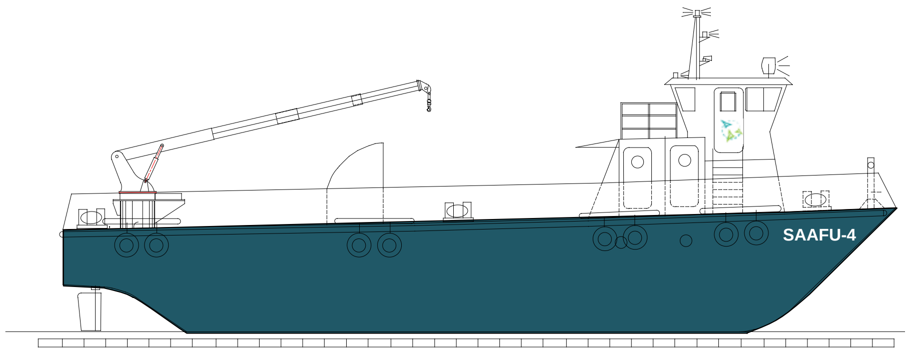


Figure 96: schematic drawing of a vessel for dry, baled and valuable fractions

In case of harsh weather conditions equipment are needed for the loading of the waste container sidewards (with a crane).

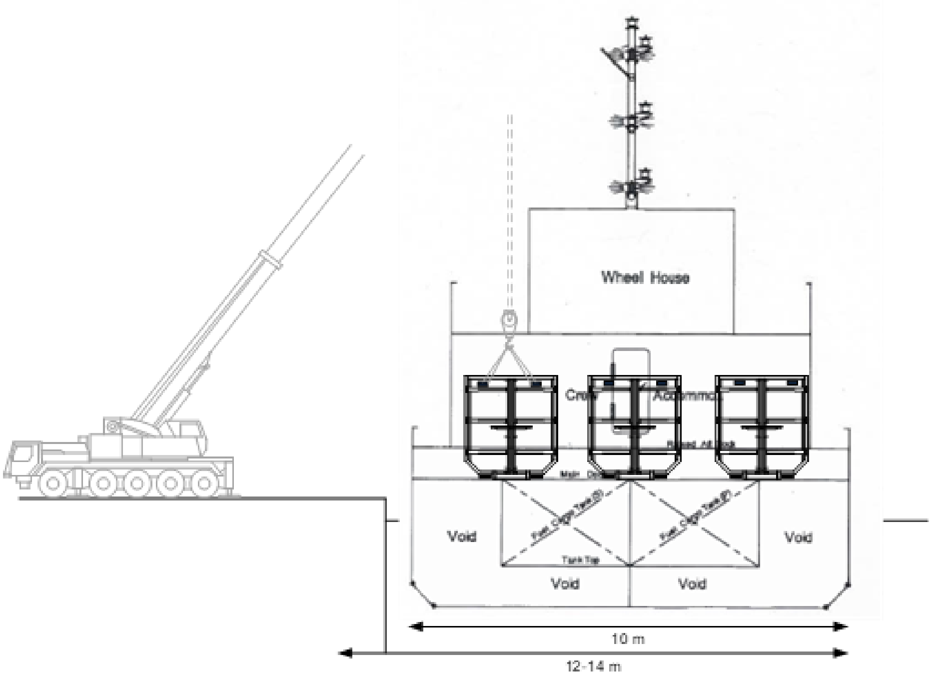


Figure 97: Un-loading process sideward (harsh weather conditions)

3.2. Transfer facilities in Hulhumale and Vilingili

The actual final waste transfer strategy for the greater Male region is still under development. Actually three options are under discussion.

3.2.1. Waste transfer option 1

The first option foresee the transport of the waste from Hulhumale and Velana airport in a direct haul (without additional transfer) to Male TS. Also the waste from Vilingili could be brought in a direct haul to Male' after the bridge construction on long term.

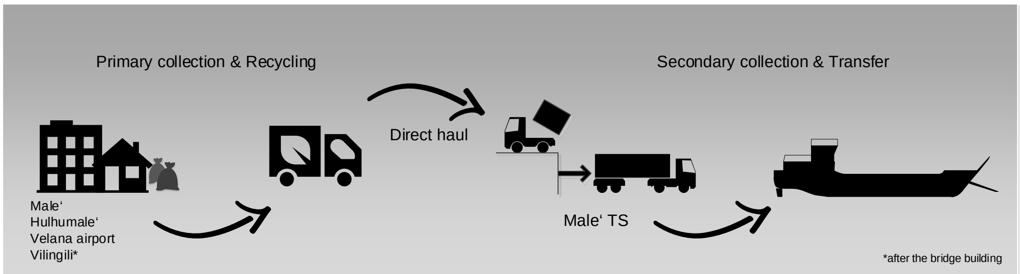


Figure 98: Option 1 –direct haul-

In this option, the allocated area in Hulhumale should be foreseen for a pilot civic amenity and for parking lots and maintenance purposes. The area will be consisting mainly of:

- an asphalted area
- an entrance gate with a small entrance control building
- shed constructions for containers
- sheds for operation equipment
- miscellaneous parking lots

- a repairing and maintenance building (with social facilities).
- Some small auxiliary infrastructure (landscaping etc..)

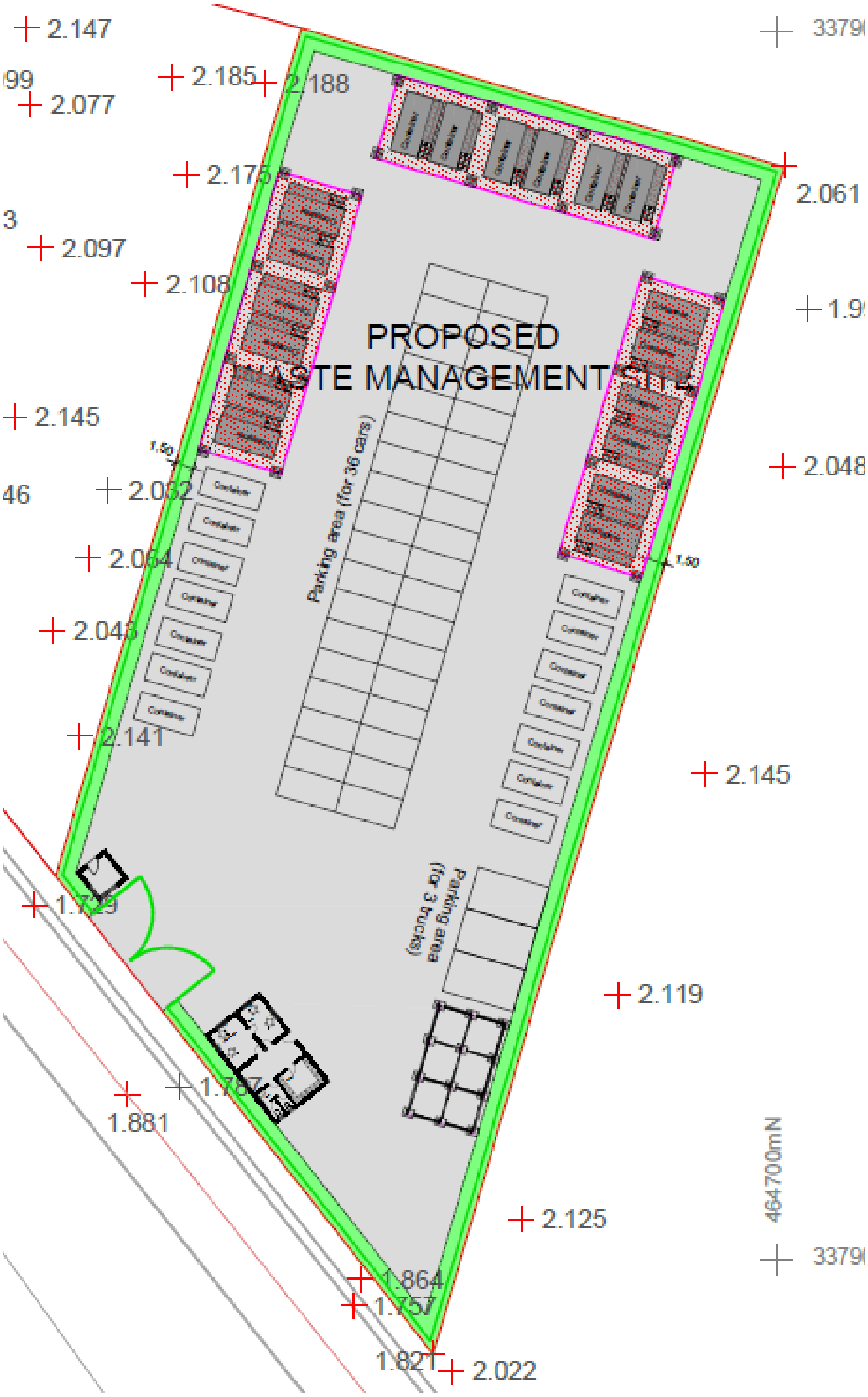


Figure 99: concept layout of the waste facility in Hulhumale

Figure 100: Picture of a civic amenity

Figure 101: Picture of a civic amenity

The complete architectural design should be made in such a way that is included in the overall urbanistic concept of Hulhumale.

3.2.2. Waste transfer Vilingili

The Island of Vilingili is actually not connected with the others so that there is a need of transferring the waste to Male' or to Tilafushi. The allocated land plot is the actual ISWMC of the island. The centre is in poor conditions and needs to be rehabilitated and upgraded to a small transfer station consisting of:

- An entrance gate with a small entrance control building (new)
- A rehabilitated administration building (new small building)
- A shed or storage room for recyclables
- And the rehabilitated transfer area (asphalt or concrete carriageway, shed of old dump area, construction of a ramp on the old dumpsite area)

- The area should completely be fenced

The area should be cleaned from waste and illegal dumping and completely asphalted. The ISWMC of Vilingili has the particularity that some cultural elements have been included (boundary wall). This should be kept in the new concept.

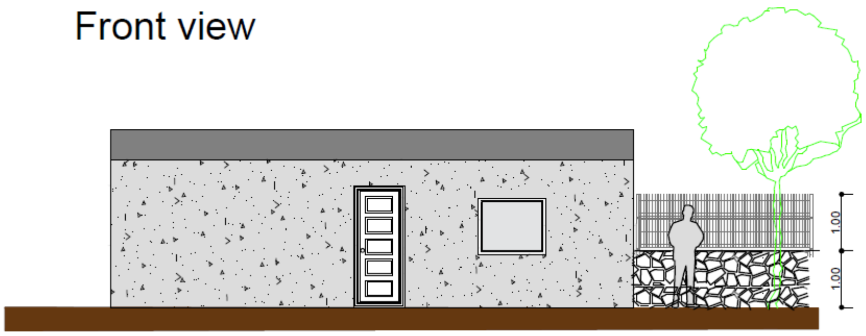


Figure 102: New small administration building with mesh fence over fencing wall

Figure 103: New concept for TS Vilingili

3.2.3. Waste transfer option 2

Second option is the building of a small transfer facility in Hulhumale as additional transfer hub for the greater Male region. The area in Male has a surface of 5,000 sqm, which is very limited for a Transfer station. Particularly on a middle and long-term perspective and if the ambitious population and housing program in Hulhumale' is implemented as scheduled an additional need of transfer areas might become necessary. A designated area was allocated in Hulhumale', which could be used for the waste management in general, and for transfer purposes in particular.

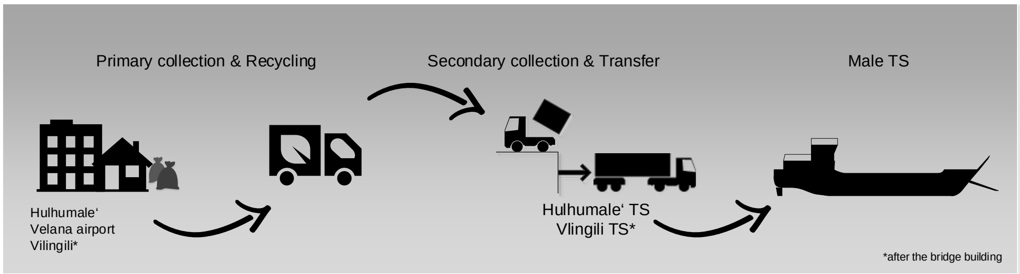


Figure 104: Option 2 small transfer station in Hulhumale

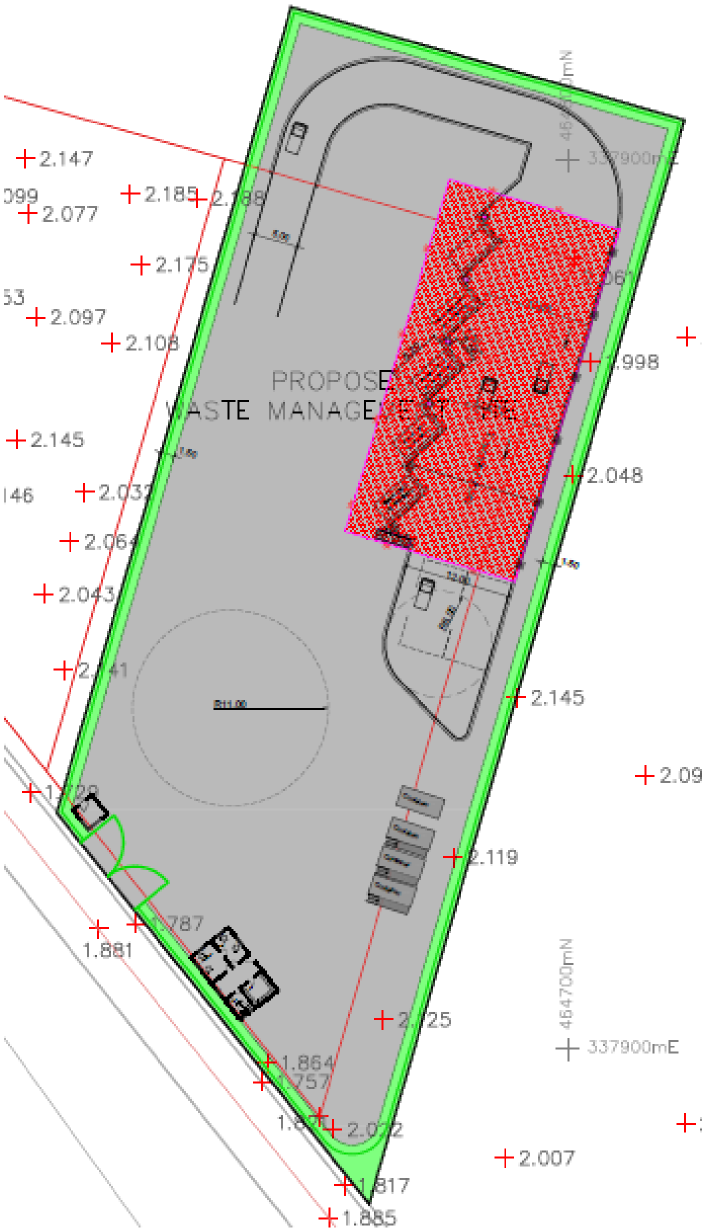


Figure 105: tentative concept layout for the TS Hulhumale (small)

3.2.4. Waste transfer option 3

The third option could be the construction of the transfer facility in Hulhumale as the main transfer station. Considering the important development of the Greater Male region in the next years the risk that Male' transfer station becomes overloaded is high. Particularly the lack of space for the infrastructures related to waste management (technical infrastructure and auxiliary infrastructure like WAMCO headquarter, parking lots for waste equipment, for maintenance etc.) makes additional space mandatory. The possibility of providing additional area in Hulhumale opens new perspectives for the Greater Male waste management. If there is a possibility to have an additional area, the Male' TS could be unburdened and the option to transport the waste to Hulhumale as the main TS might becoming more interesting.

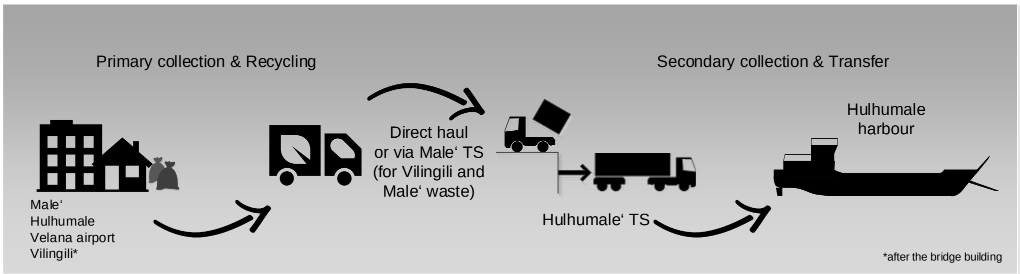


Figure 106: Option 3 main transfer station in Hulhumale

Figure 107: Suggested site in Hulhumale'

With this area, a sustainable waste transfer station could be designed with all facilities, according state of the art, perfectly shaped and harmonised within the development strategy of the Island.

With this additional area the possibilities of a sustainable waste management will increase while a modern and well dimensioned TS in Hulhumale could also disencumber the Transfer station in Male' which was planned under narrow conditions.

This bigger transfer station will have :

- A surrounding fence
- A small entrance and control building with a weighbridge
- An administrative building with offices, lockers, rest rooms, and a Wamco shop
- A bigger transfer area for 12-16 containers
- A maintenance garage
- Parking lots for collection vehicles
- Parking facilities for heavy equipment
- Parking lots for staff
- Storage areas for additional containers
- Landscaping, etc.

The transfer station will be built under the architectural and urbanistic conditions of Hulhumale in order to be included in the development plans of the Island.

The concept for Male and Vilingili TS remains unchanged.

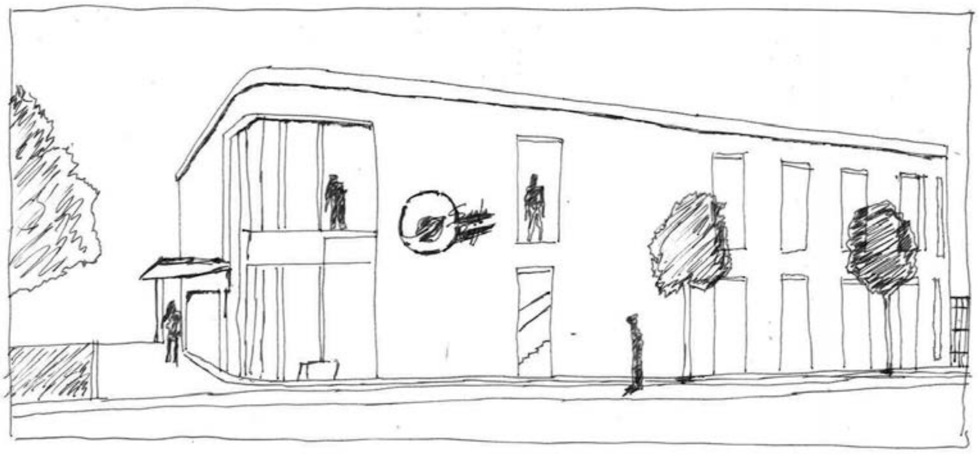


Figure 108: Preliminary layout for Administrative building (big TS)

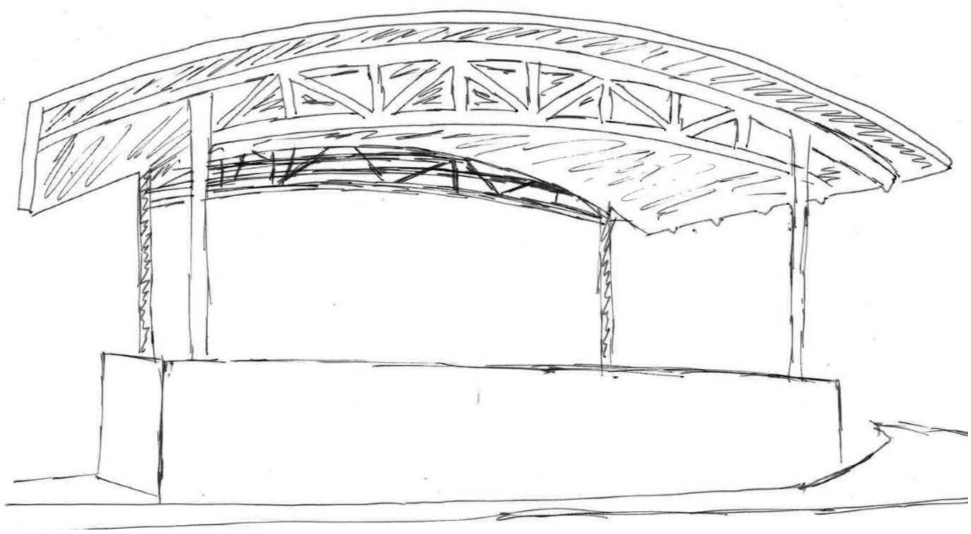


Figure 109: preliminary layout for transfer shed (curved metallic shed or tent membrane)

3.2.5. Estimated costs and cost breakdown

Designation	Unit	Costs/unit in USD	Total in USD
Transfer Station Male'	*Total*		*$3.397.000,00*
Site preparation, installation & management	LS	$50.000,00	$50.000,00
Site Clearing and general earthw orks	LS	$20.000,00	$20.000,00
Roads and carriagew ays	LS	$450.000,00	$450.000,00
Civil w orks			
Administration building (6 storey)	LS	$1.150.000,00	$1.150.000,00
Transfer area	LS	$1.500.000,00	$1.500.000,00
Shed buildings	LS	$150.000,00	$150.000,00
Site infrastructure	LS	$25.000,00	$25.000,00
Fence & gates	LS	$12.000,00	$12.000,00
Weighbridge	LS	$40.000,00	$40.000,00
Designation	Unit	Costs/unit in USD	Total in USD
Transfer station Hulhumale' (small actual site)	*Total*		*$2.050.000,00*
Site preparation	LS	$25.000,00	$25.000,00
Site Clearing and general earthw orks	LS	$15.000,00	$15.000,00
Roads and carriagew ays	LS	$360.000,00	$360.000,00
Civil w orks			
Administration building	LS	$240.000,00	$240.000,00
Transfer area	LS	$1.200.000,00	$1.200.000,00
Shed buildings	LS	$150.000,00	$150.000,00
Site infrastructure	LS	$15.000,00	$15.000,00
Fence & gates	LS	$5.000,00	$5.000,00
Weighbridge	LS	$40.000,00	$40.000,00
Designation	Unit	Costs/unit in USD	Total in USD
Transfer station Hulhumale' (big)	*Total*		*$4.435.000,00*
Site preparation	LS	$60.000,00	$60.000,00
Site Clearing and general earthw orks	LS	$30.000,00	$30.000,00
Roads and carriagew ays	LS	$1.440.000,00	$1.440.000,00
Civil w orks			
Administration building	LS	$350.000,00	$350.000,00
Transfer area	LS	$2.000.000,00	$2.000.000,00
Shed buildings	LS	$450.000,00	$450.000,00
Site infrastructure	LS	$50.000,00	$50.000,00
Fence & gates	LS	$15.000,00	$15.000,00
Weighbridge	LS	$40.000,00	$40.000,00

Designation	Unit	Costs/unit in USD	Total in USD
Transfer Station Vilingili	*Total*		*$387.000,00*
Site preparation, installation & management	LS	$10.000,00	$10.000,00
Site Clearing and general earthw orks	LS	$10.000,00	$10.000,00
Roads and carriagew ays	LS	$180.000,00	$180.000,00
Civil w orks			
Administration building small	LS	$100.000,00	$100.000,00
Transfer area/shed	LS	$70.000,00	$70.000,00
Site infrastructure	LS	$5.000,00	$5.000,00
Fence & gates	LS	$12.000,00	$12.000,00

Designation	Unit	Costs/unit in USD	Total in USD
Waste facility Hulhumale' (small actual site)	*Total*		*$470.000,00*
Site preparation	LS	$15.000,00	$15.000,00
Site Clearing and general earthw orks	LS	$15.000,00	$15.000,00
Roads and carriagew ays	LS	$200.000,00	$200.000,00
Civil w orks			
Administration building	LS	$70.000,00	$70.000,00
Transfer area	LS		$0,00
Shed buildings	LS	$150.000,00	$150.000,00
Site infrastructure	LS	$15.000,00	$15.000,00
Fence & gates	LS	$5.000,00	$5.000,00

Option 1 a			*$4.254.000,00*
Transfer station Male'			$3.397.000,00
Transfer station Vilingili			$387.000,00
Waste Facility Hulhumale'			$470.000,00
Option 1 b			*$3.104.000,00*
Transfer station Male' (w ithout admin building)			$2.247.000,00
Transfer station Vilingili			$387.000,00
Waste Facility Hulhumale'			$470.000,00
Option 2 a			*$5.834.000,00*
Transfer station Male'			$3.397.000,00
Transfer station Vilingili			$387.000,00
Transfer station Hulhumale' (small)			$2.050.000,00
Option 2 b			*$4.684.000,00*
Transfer station Male' (w ithout admin building)			$2.247.000,00
Transfer station Vilingili			$387.000,00
Transfer station Hulhumale' (small)			$2.050.000,00
Option 3 a			*$8.219.000,00*
Transfer station Male'			$3.397.000,00
Transfer station Vilingili			$387.000,00
Transfer station Hulhumale' (big)			$4.435.000,00

Table 28: Cost estimation and breakdown for transfer stations

3.3. Outer Island transport concept

The outer Island transport concept should be developed considering the particularity of the islands in terms of docking, the amount of waste and type of intra-island collection system. The vessel capacity is smaller than the vessels foresee for Greater Male' region (approx. 50-100 m³). All harbours in zone III except Greater Male' region and Tilafushi don't have any ramp access for a landing craft device therefore the up and un-loading system is sideward. Actual, on a preliminary design approach it is suggested to foresee on the vessel:

- A crane for lifting the bins from the Island jetty/berth into the vessel
- The bins on Resort and Island level have a maximum volume of 770-1100 l
- The bins should be unloaded, via a permanent bin tipper which is on the vessel, into 4-5 containers of 25 m³
- These containers will then be un-loaded with arm-roll trucks on Tilafushi similar to the un-load system for Greater Male' vessels.

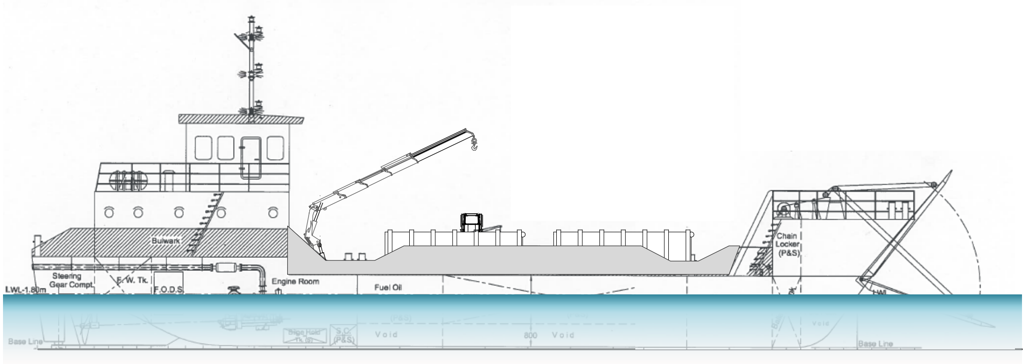


Figure 110 : Outer-Island vessel type

Figure 111: example of a bin tipper

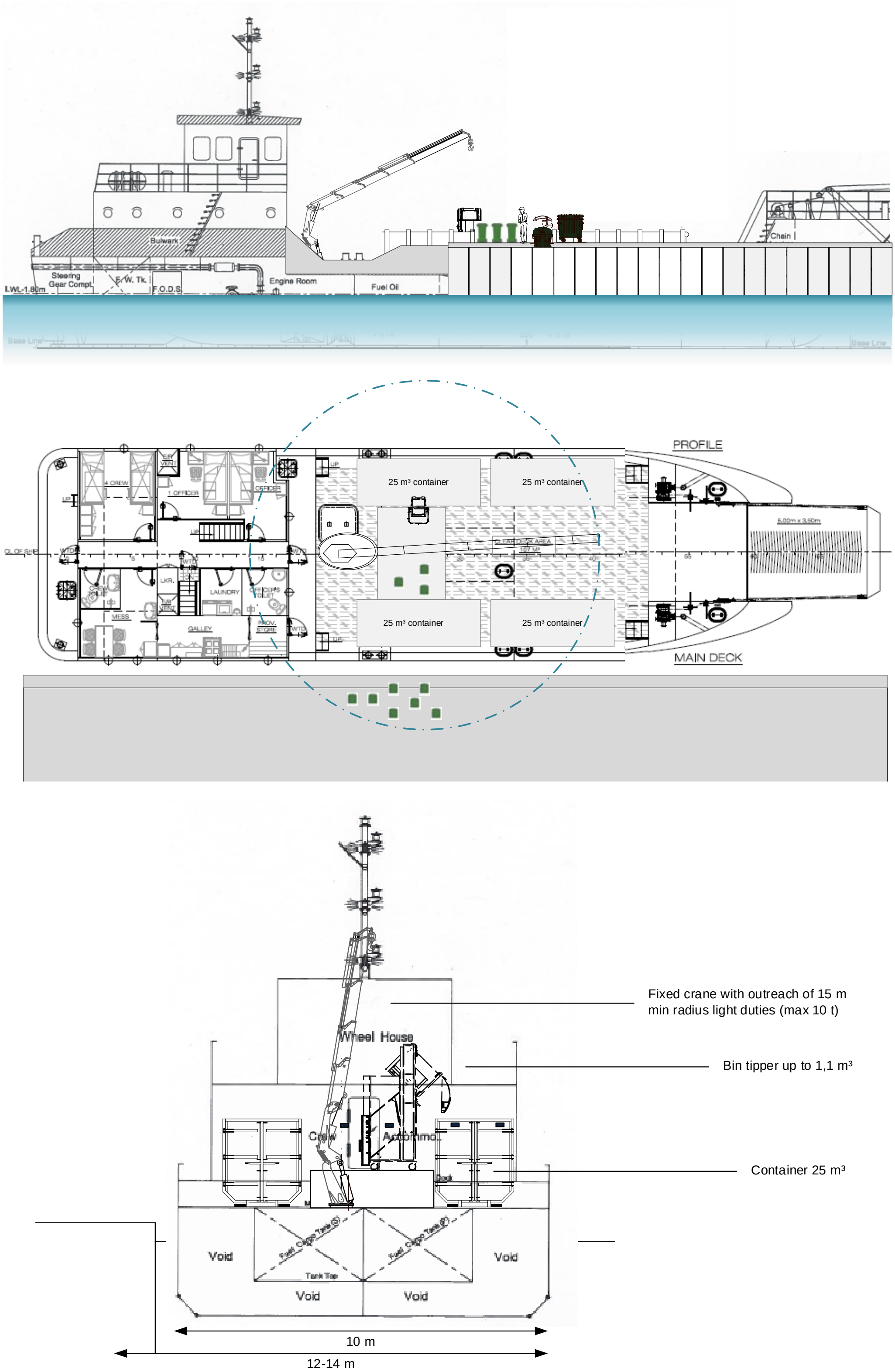


Figure 112: outer Island waste bin unload system

4. Regional Solid waste management Facility

4.1. Short term waste treatment and disposal strategy

The actual situation is characterized by a centralized uncontrolled dumpsite in Thilafushi and many fly tips within the Islands of the zone. Main objective should be the upgrading/rehabilitation of the dumpsite in Thilafushi to a Regional SWM Facility with controlled dumping area and additional pre-treatment (baling, screening, sorting, crushing, etc.). As soon as the new RSWMF started its operation an extensive dumpsite and fly tips closing campaign should start. This campaign can be organised in 2 lots. One lot should be launched very fast for small dumpsites and fly tips which need to be eradicated in priority and in a second phase (2020-2021) for most of the rest of the uncontrolled dumpsites on the islands and atolls.

4.2. Site location and description

The RWMF has been designed to provide long term environmentally sustainable solution for waste management in the region. The design of the RWMF has been done considering factors such as waste composition, quantity reaching RWMF, applicability in the local condition and regulatory compliance. Limitations of scarcity of land and the requirement to protect the fragile eco-system have also been considered during the design of RWMF. The preferred location for the RSWMF was the area around the old dumpsite of Tilafushi. This has the advantage to reduce environmental risks on another location and islands, to conduct in parallel the dumpsite rehabilitation (overlapping of risks). The vocation of Tilafushi as an industrial island plays also in favour of a site location of the facility on this Island.

Figure 113: Actual site location of the dumpsite and future RSWMF (actually not reclaimed)

The RWMF shall comprise of following components:

- A Waste acceptance, and processing platform (including docking facilities)
- Temporary storage for recyclables;
- The main Facility : the Waste to energy plant (Incineration with electricity production)
- A Landfill cell for residual waste (including a leachate collection and management system)
- A C&D waste processing plant

- Buildings and infrastructure (roads, and supplies)
- An ELV processing facility
- Landscaping

A tentative layout and surface demand was already handed over to the client for preparing the land reclamation procedures.

Designation	Surface in m²
Waste Incineration	
Building, including roads, infrastructure etc.	Approx. 2 ha
Harbour/C&D Waste processing/administration/C&D/ELV vehicle processing	Approx. 2 ha
Landfill	
Base surface	2,2 ha
Embankment/roads etc	Approx. 0,5 ha
Leachate treatment, firefighting, water supply	
Infrastructure area (leachate, firefighting, water supply etc.	Approx. 1,5 ha
Temporary storage of baled waste	Approx. 6,8 ha
Total in [ha]	Approx. 15 ha

4.3. General design aspects

All detailed design for the facility should be made considering the particular climate conditions in the region.

Daily rainfall data supplied by the client for Hulhule Male for the period starting from Jan 1975 to Dec 2016 (42 years) were used to identify maximum annual daily rainfalls and they were subjected to extreme value analysis. Figure 114 shows annual daily maximum rainfall and Figure 115 shows distribution extreme rainfall over return period.

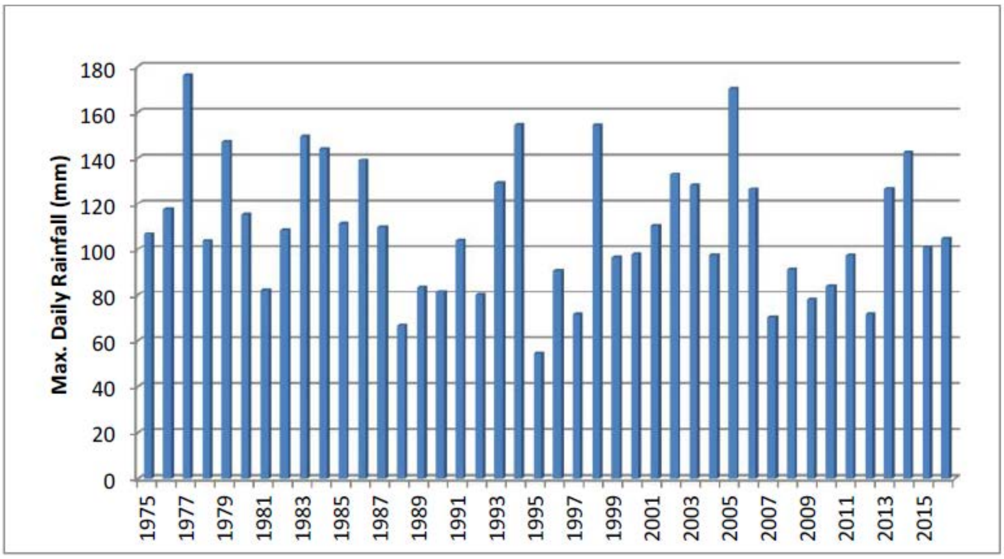


Figure 114: Annual Daily Maximum Rainfall at Hulhule Male (1975 – 2016)

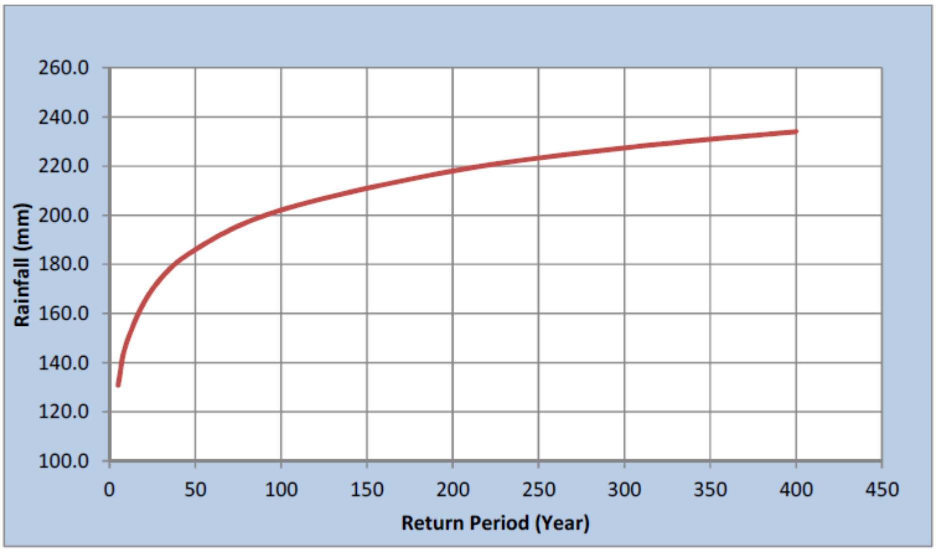


Figure 115: Rainfall Values for Different Return Period – Hulhule Male

Runoff Coefficient for Storm Water Management

Main factors to determine runoff coefficient for a watershed are soil type, land use and slope. In case of Maldives, characteristics of soil and slope remain more or less same among the islands. However, there is significant difference in percentage share of land area being used for residential purpose, commercial activities, agriculture, forest/scrub etc. Runoff coefficient is very high for street and roofs. For street it is ranging from 0.70 to 0.95 depending of type of material like asphalt, concrete and brick used for construction whereas it is very low (~0.1) for lawns and parks.

Satellite images of Maldives Islands show that residential area is dominant in most of the inhabitant islands and percentage of agriculture and scrub/forest are relatively small. They also show that even at highly populated or commercial islands like Male or Hulhule Male there parks, playground and lawns. Considering these facts, it is appropriate to use 0.4 as runoff coefficient for the most inhabitant islands. However, it would be as high as of 0.8 for Male – capital of Maldives due to high land-use for residential and commercial purposes. For Tilafushi most of the considered area is not paved, run-off coefficient has been taken for pre-dimensioning as 0,35

Daily rainfall data supplied by the client for Hulhule Male for the period starting from Jan 1975 to Dec 2016 (42 years) were used to identify maximum annual daily rainfalls and they were subjected to extreme value analysis. Both Normal Distribution and EV1 Distribution were applied on these data and fittingness of distribution system on data was checked at 95% confidence limits. Figure 1 shows annual daily maximum rainfall and Figure 2 shows distribution systems on extreme rainfall of Hulhule Male.

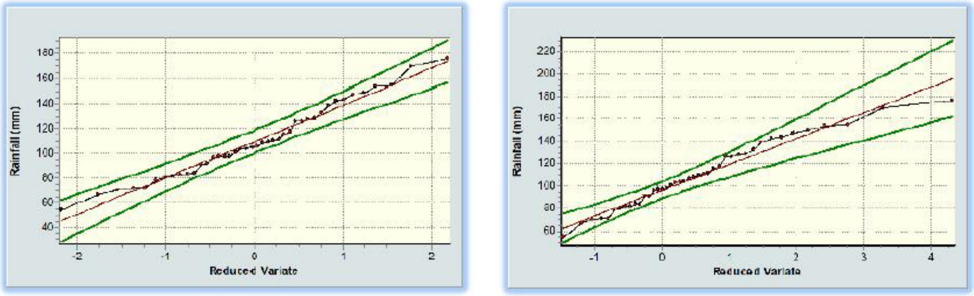


Figure 116: Extreme Rainfall Distribution for Hulhule Male (left – Normal Distribution and right – EV1 Distribution)

From these distributions extreme rainfalls for return periods for 2, 5, 10, 25, 50, 100, 200, 300 and 400 years were estimated and presented in Table 28.

Return Period (yr)	2	5	10	25	50	100	200	300	400
Design Rainfall (mm) - Normal Distribution	109.6	134.4	147.4	161.2	170.2	178.2	185.5	189.6	192.4
Design Rainfall (mm) EV1 Distribution	104.8	130.8	148.1	169.9	186.0	202.1	218.0	227.4	234.0

Table 29: Design rainfall distributions

Table 28 shows that design rainfall for higher return period (say greater than 50 years) is lower for “Normal Distribution” than “EV1 Distribution”. Also increment rainfall from “Normal Distribution” is too low from 50 yr return period onwards. Using such low values are highly risky in the design. Therefore, it is recommended using “EV1 Distribution” for the estimations of design rainfall. Figure 3 shows design rainfall curve for different return periods.

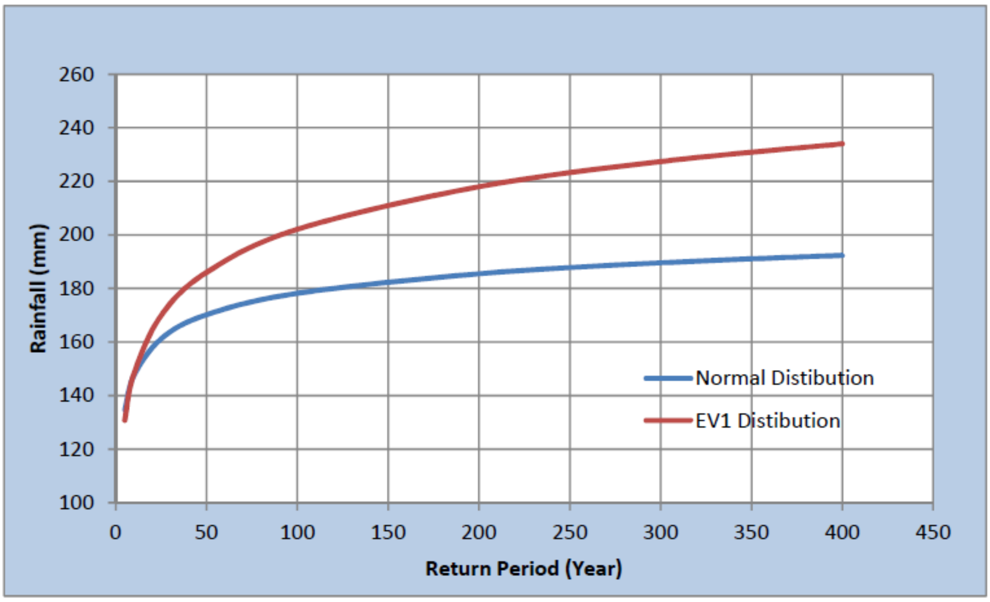


Figure 117: Rainfall Values for Different Return Period – Hulhule Male

For detailed design the recommendation from ADB's Climate Risk and Vulnerability Assessment should taken into account[4]

Sea Level Rising: Project Facilities (WTE) should be levelled in such way that the main sensitive installation parts are over 2,1 m over MSL.

Increase of monsoon rainfall during 2021 to 2050 of 200 – 300%: This point is subject to stakeholder discussion and acceptance. For preliminary design purposes of the rainwater system, the following design parameters have been taken into account:

- Shortest decisive rain duration: 15,0 min
- Reference rainfall int. r 15,1 : 373,33 l/(s.ha)
- Rainfall frequency (return period): 5 years
- Design rainfall intensity r D,n: 373,33 l/(s*ha)
- Min peak runoff coefficient: 0,35
- Max development part transport catchment area : 1,0%

Cyclone winds strength up to a category 2 (winds speeds of 154-177 km/hr), because the cyclone zone is expected to expand and north/central region 3 will be part of the expanded zone : this is also a point to discuss and to get clear agreement with all stakeholders

Design implications for RWMF:

Quay wall in the harbour area have been increased to 1,7 m of MSL with adapted reinforcement structure

Additional buffer zones for protective measures (green area, sourrounding dam) have been foreseen for a later development stage

[4] Climate Risk and Vulnerability Assessment, Greater Malé Environmental Improvement and Waste Management Project Ephrat Yovel Draft version, 17 December 2017

Backflow inverters should be foreseen in all outlet structures as far as the outlet is under MSL in many cases, and if possible, elevating the outfalls to reduce the pressure of incoming water during tides and storms.

Power lines should be insulated. Protective structures around all power components to protect them from exposure to elements. Elevation of mechanical and electrical systems; and Backup power

Berms and any foundation filters will need to waterproof, if necessary, to avoid water seepage from below, due to increasing water pressure.

Roofs and all vertical structures on critical structures and housed process equipment need to be designed to withstand category 2 wind speeds if necessary after consultation with all stakeholders

4.4. Waste Incineration

Incineration of the municipal waste, after recovery of recyclables and removal of inert materials, is proposed for the project. Incineration will not only destroy the potentially harmful substances in the waste, but also reduce the volume of the waste for disposal in landfill. Incineration is also the most suitable processing technology for management of heterogeneous mixed waste, transported from islands and resorts.

For the waste stream which will be processed in the W-t-E-plant see mass balance in Chapter 3.

Waste composition	
Items	%
Combustible	39 - 50
Water	18 - 33
Ash	23 - 35
Heating values	6.500 - 9.500 kJ/kg

Design values	
Hu	7.500 KJ/kg
Combustible	42 %
Water	29 %
Ash	29 %
C	29,2 %
S	0,4 %
H	4,2 %

O	18,4 %
N	0,9 %
Cl	0,6 % (max. 1 %)
F	0,1 %

Table 30: waste composition and design value for WTE

4.4.1. Process and Design Parameters

A mass burning combustion system, which can take non homogeneous waste and requires little or no pre-treatment has been proposed for the project. Common mass burning incinerator systems include moving grate types, rotary kilns and fluidized bed incinerators. However, the moving grate system is recognized as being the most feasible, well-proven and widely used technology for combustion of mixed waste. The moving grate technology can also accommodate large variations in waste composition and calorific value. The moving grate incinerator consists of a layered burning of waste on the grate while transporting material through the furnace. On the grate, the waste is dried and then burned at high temperature with supply of air. The ash (including non-combustible fractions of waste) leaves the grate as slag/bottom ash through the ash chute.

Major components of the moving grate incinerator include:

- Waste feeding system;
- Incineration grate;
- Combustion chamber;
- Bottom ash discharger;
- Air pollution control system;
- Stack; and
- Control and monitoring system proposed.

The following sections provide the description actually designed of different components of the incineration system:

4.4.2. Design Capacity and Loading conditions

Based on the Analyses of the waste composition and the various recycling scenarios, the following design values are obtained for the combustion plant:

- Design value (“normal”) 7.500 KJ/kg
- Minimum value 6.500 KJ/kg
- Maximum value 9.500 KJ/kg

At the maximum value, it was assumed that high amounts of plastic are still contained in the garbage due to a lack of separation. Furthermore, it was taken into account in this assumption that the water content of the organic waste from gardens is lower during the drying time. With the assumption of a throughput of 400 t/d (≙ 16,7 t/h) and the above-mentioned heating values, the power range of the system listed in the following table results. In the normal case, the throughput is 16,7 t / h with a calorific value of 7.500 KJ / kg. The thermal power in this case is 34,8 MW. With a heating value of 6.500 KJ / kg and a throughput of 16,7 t h, the thermal power is 30,2 MW (= 87 %).

With a calorific value of 9.500 KJ / kg, the throughput drops to 13,2 t / h with a thermal capacity of 34,8 MW (= 100%).

When designing the system, both thermal and mechanical short-term overloads of 10 % are permitted. This increases the throughput with a heating value of 7.500 KJ/kg to 18,3 t / h and the thermal power to 38,1 MW.

The design range is shown in the table below, the table also showing the flue gas volume flows:

Load-	Heat value	Throughput		therm. Capacity		Flue gas
Point	kJ/kg	t/h	%	MW	%	Nm³/h
1	7.500	16,7	100	34,8	100	97.270
2	6.500	16,7	100	30,2	87	84.300
3	9.500	13,2	79	34,8	100	97.388
4	7.500	11,7	70	24,4	70	68.148
5	6.500	13,5	80	24,4	70	68.148
6	9.500	11,7	70	30,8	89	86.320
7	7.500	18,3	110	38,1	110	106.590
8	6.500	18,3	110	33,1	95	92.378
9	9.500	14,5	87	38,1	110	106.980

Table 31: Design range and performance

In the design range, the flue gas volumetric flows fluctuate between 68,000 Nm³/h and 107,000 Nm³/h. For this area the flue gas cleaning is to be designed.

The performance diagram and a PID diagram are presented in Annexe

4.4.3. Logistics

General waste delivery (see also harbour and waste acceptance area)

The waste should be delivered exclusively in containers with the Landing Crafts.

Specification of the container

Hook-Lift-Container

- Volume 25 m³
- Length 5 m
- Width 2,5 m
- Height 2 m

A delivery of loose waste with Dhoni's shall be excluded.

The delivery point (ramp) is designed in such a way that 2 Landing Crafts can be deliver on at the same time.

Chemicals

Sodium bi-carbonate

The transport of the sodium bi carbonate takes place in big bags with a weight of 1 t. The unloading of the transport vessel takes place in the new harbour of Thilafushi. The big-bags are transported from the port to the plant by truck.

Activated carbon

The activated charcoal is transported in big bags with a weight of 1 t.

The unloading of the transport vessel takes place in the new harbour of Thilafushi. The transport of the big bags from the port to the plant is by truck.

Ammonia water

Tanker carries out the transport of ammonia water. The ammonia water is conveyed to the ammonia water tank bearing via the pumps of the tanker.

Diesel oil

Tanker transports the diesel. The diesel oil is transported to the diesel oil tank via the pumps of the tanker.

Acid / lye

The acids / alkalis are transported in IBC containers. The unloading of the transport vessel takes place in the new harbour of Thilafushi. The IBC containers are transported from the port to the facility by truck.

Slag

The transport of the slag from the wet purifier to the slag treatment is carried out by means of a conveyor belt. The processed slag is transported by truck to the harbour of Thilafushi.

Metals from slag preparation

Fe- and non-ferrous scrap from slag processing are transported by truck to the port of Thilafushi for loading on ships.

Flue gas cleaning residues

The flue gas cleaning residues are transported in big bags by truck to the landfill site.

4.4.4. Main process engineering

Main process engineering facilities are:

- Waste disposal funnel with three-part hydraulically actuated funnel flap
- Filling tank, double walled with water cooling
- Plunger entry, hydraulically actuated
- Grate including grate drive
- Primary air supply (5 zones, separately adjustable) including primary air blower and primary air preheater
- Wet de-slagger (tapper or slab conveyor) with slag conveyor (vibrating trough, belt conveyor) and coarse-grain separation

- Boiler system, 4-train (horizontal or vertical), steam parameters 40 bara, 480 ° C, Firebox lining: SiC plate ventilated

1st train: SiC plate, back-ventilated above the SiC plates, gladding (Inconel weld)

2nd train: without installations

3rd/4th train: According to design as horizontal or vertical train with super heater and economizer

Boiler de-ashing, consisting of:

- Chutes and compensators, trough conveyors, impact mills and pneumatic transport equipment

Water-steam circuit consisting of

- Condensation turbine with generator including oil supply
- Feed water system consisting of the feed water tanks, feed water pumps and the desecrator
- seawater-cooled condenser (condensate pumps, condensate tank, condensate preparation)
- Feed water treatment (R / O system)

Flue gas cleaning consisting of

- Reactor with additive injection (sodium bicarbonate, activated carbon, silos for ab-sorbent)
- Fabric filter with dust discharge and residual silo
- ID-Fan
- SCR catalyst with injection of ammonia water, ammonia water tank
- Stack

4.4.5. Bunker

Bunker volume 5.700 m³

Capacity (density = 0,35 t/m³) 5 days

Number of tipping points 4

4.4.6. Waste Feed System

The waste feeding system can be manual via feeding trolley as well as mechanical by automatic feed system. Although the manual waste feed systems have low capital costs, the operating efficiency also gets reduced during the loading process.

An automatic waste feeding system has been proposed so as to enable air tight waste supply to the combustion system. Waste is fed into the combustion chamber through a ram loader. The operations of the loader are programmed through a programmable logic controller inside the control panel.

4.4.7. Incineration Grate

The incineration grate has primarily two functions i) transportation and mixing of waste material; and ii) distribution of the incineration air into the furnace. The grate should be able to accommodate waste without any special preparation or crushing. The grate system shall be capable of transporting waste automatically from feeding to slag extraction without obstacles or clogging and without any manual intervention. The normal resident time of waste within the grate is 60 seconds.

4.4.8. Combustion Chamber

The waste is first dried, and then ignited in the combustion chamber, followed by complete burning in a series of combustion zones on the movable grate. In principle, the two combustion chambers, primary and secondary combustion chambers should be designed to ensure a long retention and reaction time of the flue gases at high temperatures. Moreover, the size, volume, and geometry of the furnace should minimize the risk of slag deposits and ash fouling on the furnace walls, which requires an adequately low thermal furnace load and as well as a low relative flue gas velocity in the furnace. Combustion chamber should be designed to ensure effective mixing of the flue gases both above the waste layer and at the inlet to the secondary combustion chamber.

Air is added at various places in the combustion chamber. Primary air is blown by fans into the areas below the grate, where its distribution can be closely controlled using multiple wind boxes, and distribution valves. The air can be preheated if the value of the waste degenerates to such a degree that it becomes necessary to pre-dry the waste. The primary air will be forced through the grate layer into the fuel bed. It cools the grate bar and carries oxygen into the incineration bed. Secondary air is blown into the incineration chamber at high speeds via, for example, injection lances or from internal structures. This is carried out to secure complete incineration and is responsible for the intensive mixing of flue-gases, and prevention of the free passage of unburned gas streams.

To achieve good burn out of the combustion gases, a minimum gas phase combustion temperature of 850 °C (1100 °C for some hazardous wastes) and a minimum residence time of the flue-gases, above this temperature, of two seconds after the last incineration air supply based on standard operating procedures for incinerators established internationally.

4.4.9. Bottom Ash Discharger

The bottom ash discharger is used for cooling and removal of the solid residue that accumulates on the grate. Water-filled pressure pistons and drag constructions are commonly used to extract the bottom ash. Other bottom ash discharges, such as belt conveyors are also used.

4.4.10. Air Pollution Control (APC) System

The flue gases discharged from the secondary combustion chamber are passed through various air pollution control systems for cleaning. The type of APC systems provided depends on the desired level of cleaning. The commonly used systems are electrostatic precipitators or baghouse filters for physical removal of dust and some heavy metals; chemical flue gas cleaning in dry/semidry scrubbers followed by fabric filters or wet scrubbers for washing/spraying the flue gas; and additional NOx, or dioxin removal in special filters.

For the proposed incineration plant any or all of the foresaid system can be used provided they meet the relevant local and international emission standards.

4.4.11. Stack

The cleaned and cooled gases from the gas cleaning system are discharged into a stack. The gases are discharged by means of an induced drafted fan.

4.4.12. Monitoring and Control Systems

The process control are required to ensure better combustion for improving the quality of rejects and reducing the quantity of rejects from incineration; better utilization of capacity; bring energy efficiency and less plant maintenance. Monitoring systems are required to ensure environmental compliance.

Emission measurement for the continuous determination of the following gas components

- HCl
- CO
- NO
- NO_2
- NH_3
- SO_2
- O_2
- Total carbon
- dust

Additional measurement:

- temperature
- Volumetric flow
- Mercury
- Continuous sampling for PCDD / F
- Emission Calculator

4.4.13. Electrical engineering

Concept power supply

The power supply to the system should be protected by

- Power supply from STELCO
- Own power production with steam turbine
- Self-current and emergency power supply with Genset

The following transformers should be used

- Machine tools 10,5/ 0,4 kV
- Self-service traction 10,5/ 0,4 kV (ID-fan)
- Power transformer with switchgear

The following networks are established

- Low voltage network 0,4 kV
- Direct current 220 V DC
  - o For control voltage switchgear
  - o Emergency oil pump, steam turbine
  - o *USV-System*
- DC power supply 24 V DC

- UDS-system with 220 V battery, minimum operating time 1 h

Lighting

According to the regulations of the Maldives

Safety lighting

In all workrooms as well as emergency lights in the escape routes, minimum lighting intensity 1 LUX

Earthing and lightning protection system

- foundation earthing ring system
- Each building part receives its own earthing rails to which the potential equalization of the corresponding building part is connected

Telecommunications

Video system for monitoring the following areas

- feeder area Landing Crafts
- Reception area Bunker
- Feed (filling funnel
- Observation of the fire room and the afterburning chamber
- Deslagging
- Slag transport belt

Observation monitors are installed in the central control room

The video system is connected to the UPS.

Telephone system

5 main lines and 30 branches

Industrial Intercom

- Intercom system between important plant areas and the control room
- Speaker system

Weather station

Automatic, electronic weather station with the following measured values

- Wind direction
- Wind speed
- Rel. humidity
- Air temperature
- Air pressure
- Precipitation

4.4.14. Control technology

Basis of the control system: Siemens PCS7 or equivalent.

Spare parts availability 15 years after start-up of the system.

Control functions are implemented in the automation units via software.

In case of encoder failure or transmitter failure, the following must be implemented:

- Automatic changeover to second encoder or maximum selection with double measurement of the same size
- Or regulation with a substitute value
- Or switch to manual mode

In the event of power supply faults, the control element, in the event of a switch, etc., the control circuit must be automatically brought into a safe state, e.g. On hand. Disturbances in the power supply must not lead to unwanted or dangerous switching operations. Measured values must be transmitted via 4 - 20 mA signals or Profibus.

Design of process control technology

The process system is divided into 3 spatial areas:

- Field : with the input and output levels (Sensors and actuators) with the required measuring transducer (remote IOs), isolating amplifier, power supply devices, etc.
- Switch rooms (measurement and control-rooms, E-rooms) : With the input and output levels of the process automation and with the required measuring transducers, isolation amplifiers, power supply devices, process automation system, etc., engineering station with 2 screens
- Central control room
    - Data bus system
    - Operating and monitoring system
    - Calculator for process management
    - Process management system and archiving

The following measured values are to be used:

- Temperatures Resistance thermometer Pt100 Thermocouples for temperatures above 600 ° C, preferably with probe head transmitters
- Pressure Transmitters in two-circuit technology (unit signal 4 - 20 mA) and a auxiliary voltage 24V DC
- Flow Ring chamber diaphragm or venturi nozzle with differential measuring transducer in two-line technique. In special cases, flow-through transducers with ultrasonic or inductive transducers.
- Level/Flow: E.g differential pressure transmitter in two-wire technology

In explosion-endangered rooms, intrinsically safe, electrical equipment and, where necessary, explosion-proofed fabrics are used for the measurement of measured values.

The signal transmission from the transducers and the control conductors (solenoid valves, actuators, etc.) to the input and output levels is carried out electrically. The individual devices are connected via single cables to terminal distribution boxes (remote I / O boxes). From there, the data are transferred to the process stations by means of a redundant bus system.

4.4.15. Operation and monitoring (O & M-system)

The main components are operated and monitored by the control room:

- Combustion
- associated auxiliary and auxiliary equipment
- Feed water / steam system
- Steam turbine

- other auxiliary equipment

The OaM-system consists of 3 operator stations with 2 printers. The control stations are equipped with two 20 "TFT monitors each.

A further station is mainly used for programming the PLS, drawing and general documentation tasks (engineering station), but can also be used as an O & M-work station.

The event / protocol and colour printers are used jointly by all operator stations. The servers directly control the alarm printer.

The system is designed with 2 redundant servers.

General requirements for the O & M system:

- User-friendly interface with Windows technology
- Pull down menus for convenient system operation and detailed information output
- Detailed images for targeted information search and plant operation
- Faceplates for detailed information and control
- Sub images for detailed information
- Highly developed user access control
- Trend curves for analogue values
- Real-time and historical curves
- Powerful alarm processing with options for early warning
- Shift, daily, monthly and annual reports
- Hour counting, event reporting, alarm counting, etc. as standard
- Object-oriented database
- Screen display with high-resolution colour graphics
- Real-time multi-tasking operating system
- Fast network
- Fast trend indications for setting PID control circuits

4.4.16. Archiving

The backup is executed with an archive station. Data, screens and curves can be stored via redundant mass storage devices. The temporal progression of the measured values can be represented in graph images of different colours. The minimum storage time is 1 year.

4.4.17. Network

The automation devices, the servers and the engineering station are connected via an in-industry Ethernet network with TCP / IP protocol. This network is redundant.

All network connections are implemented with standard Ethernet RJ45 as a twisted two-wire line or 802.3 BUS couplers.

4.4.18. Fire protection

For fire detection, fire detection systems are provided in all areas of the plant. These must be carried out as an "open system", so that they can be serviced by authorized specialist companies in addition to the installer.

4.4.19. Fire water supply

Fire-fighting water pumps and a small pressure-control pump, which is driven by means of an electric motor or a diesel unit (in the event of a power failure), provide the low-pressure water supply. The extinguishing water pumps extract the extinguishing water from the effluent reservoirs of approx. 350 m³. The replenishment is carried out via the rainwater system.

The extinguishing water pumps feed the firefighting water pipes (DN 80 - DN 250 / pressure: 15 bar) to which the rising pipes installed in the buildings are connected.

The following fire-fighting measures are foreseen:

Outdoor area

- Pillar hydrants in the "green area" (distance 60 - 100 m)
- Pillar hydrants in the transport sector (distance 60 - 100 m)

Bunker area

- Fire alarm system
- Fire extinguisher with extinguishing agent according to the requirements (powder, water, CO2)
- Fire extinguishing system (2 cannons, arranged on the front side)
- Spray Flood Extinguishing System
- Spray flood extinguishing system for the delivery funnel of the garbage incinerator
- Water curtain for glass of the sickle

Acceptance area

- Fire alarm system
- Inner hydrants with rigid D-tube, 30 m long
- Fire extinguisher with extinguishing agent according to the requirements (powder, water, CO2)
- Spray flood extinguishing system above the tipping points

Energy buildings

- Fire alarm system throughout the building
- Internal hydrants in the stairs with form-resistant D-tubes, 30 m long
- Fire extinguishers with extinguishing agents meet the requirements (powder, water, CO2)
- Mobile fire extinguishers in the field of electric rooms (30 kg CO2-bottles)
- CO2-system for the double floor areas in the electric rooms. The outsourcing is carried out automatically via a two-line dependency of the fire alarm system (CO2-warning devices)

Combustion plant

- Fire extinguisher with extinguishing agent according to the requirements (powder, water, CO2)
- Water hydrants with foldable C-tube, 20 m long

Administrative area

- Fire extinguisher with extinguishing agent according to the requirements (powder, water, CO2)

4.4.20. Shredder system

A shredder is used for the preparation of the bulky waste. This is fed via a bunker belt and a feed belt, designed as plate belts. The speed of the two bands can be controlled via a frequency converter at the acceptance area as well as the filling funnel of the shredder are to be equipped with a device for de-dusting.

A detection device for the detection of hot, energetic parts is to be installed in the shaft after the shredder. If a certain energy density is exceeded, a spray flood extinguishing system is triggered fully automatically.

The transport of the crushed bulky waste takes place via a conveyor belt into the bunker. A separate operator station must be erected in the immediate vicinity of the crushing plant for the control of bulky waste crushing.

The system is designed for a throughput of 150 m^3 / h.

4.4.21. Supply of drinking, domestic and service water

Rainwater is used to supply the system with service and operating water. With an annual rainfall of 2,000 mm / m^2, the roof and traffic areas will have a rainfall of 23,000 m^3.

The rainwater from the roof surfaces is directed directly into the rainwater storage basin. The rainwater from the traffic areas is passed through a sand trap and an oil separator before it is directed into the rainwater storage basin.

The fire water pool is filled from the rain water storage tank, or water is fed back in the event of a fire. For this purpose, a corresponding pump must be provided.

From the rainwater basin, the feed water pump of the power station is fed via a feed pump with pressure maintenance.

Likewise, the boiler feed water system is fed from the rainwater storage basins to produce boiler feed water.

Waste water treatment

The following sewage flows occur during operation of the system:

- Sanitary water (sanitary area, kitchens, emergency showers) approx. 25 EWG
- Excess rainwater
- Waste water from the workshops
- Boiler cleaning, dripping water slag
- Process wastewater from the water-steam cycle

These are treated or disposed of as follows:

- Excess rainwater Derivation into the sea
- Waste water Introduction Wet de-slagger
- Process waste water Introduction Wet de-slagger
- Sanitary water Biological small sewage treatment plant

4.4.22. Cooling water

The exhaust steam from the steam turbine is cooled by a seawater-cooled condenser.

The cooling water supply is via the inlet construction with an integrated pump shaft.

The redundant cooling water pumps are accommodated in the inlet construction.

These are designed to cover the entire operation including the failure of the turbine at full boiler operation.

The cooling water is fed directly to the condenser via an approx. 150 m long line with a diameter of approx. 1,300 mm. The cooling water absorbs the waste heat from the condensing steam and is returned to the sea via the return pipe, which is also about 150 meters long. The return of the cooling water is approximately 50 m away from the collection point.

The cooling water intake from the sea is cleaned by means of a rough raking in the inlet structure. The screenings are removed and burned in the incinerator. The mechanical fine cleaning is performed before entering the condenser. By means of filtration, smaller particles are removed from the cooling water, which can lead to damage and contamination of the heat exchanger surfaces in the condenser.

The filter is cleaned by partial backwashing. The backwashing water is fed into the cooling water return and thereby back flushed into the sea

4.5. C & D Plant

4.5.1. Components

C&D waste processing has been dimensioned for a Throughput of 600 t/day.

The C & D waste treatment plant consists of the following components:

- Input control
- Presorting
- A feeding hopper (min 15 m³)
- pre-screening (vibration feeding chute, manual change flaps for grain sizes 0-10 and 10-60 mm)
- a sorting station
- pre-crushing (pre-crusher with a gap setting of 150 mm final grain size 0- approx. 200 mm and add. oversize grain up to 300 mm)
- crushing (Toggle jaw crusher)
- magnetic separation
- classifying (vibration screen)
- Power supply
- Belt conveyors and discharge shafts

The transport containers are dumped on a sorting plate. The material is roughly presorted by using a wheel loader. Coarse concrete and stone chunks are sorted out and pre-shredded.

The pre-shredding is done either with an excavator with chisel or by hand.

The remaining material is classified in the pre-screening. The fine material <150 mm reaches a sorting station, where wood, plastics and metals are sorted by hand. The rejected materials are collected in containers.

Wood and plastics are transported to the WTE for incineration

The rejected metals could be sell.

The material from the pre-shredding, the coarse fraction from the screening and the residue from the sorting are crushed by a crusher. After the crusher a magnetic separation is arranged.

The deposited material is collected and marketed together with the metal from the sorting.

After the magnetic separator, the material is divided up in the fractions

37,5	-	63	mm
20	-	37,5	mm
3,35	-	20	mm
and		< 3,35 mm	

The individual fractions are stored on the corresponding production heaps and transported after loading in containers to the places of use. The loading of the finished products takes place by a wheel loader.

Main components should be installed over an open shed construction to be protected against heavy rainfall. The shed should be open or having enough air circulation due to extensive dust generation.

Depending on the required output product, the installation could be extended to additional screens and chutes and with an air separator.

Supplier should provide additionally wear and spare parts for at least two year and guarantee a periodical service.

4.5.2. Siting criteria for storage and processing facilities

Consideration of environmental issues and suitability as well as adequacy of the chosen sites are the main criteria. A ‘buffer zone of no development’ shall be maintained of 30 m for 500 TPD or more- around processing or recycling site and shall be incorporated in the land use plans of the concerned authority. In the case of successful implementation of ‘no development zone,’ the buffer zone inside the facility boundary should be limited to 10 m (for 500 or more TPD of C&D waste).

4.5.3. Cost estimation and breakdown

Construction and Demolition w aste processing plant			
Designation	Unit	Costs/unit in USD	Total in USD
C&D w aste processing plant			
Civil w orks including installations engineering	*subtotal*		*$1.236.500,00*
Civil w orks including installations engineering	LS	$200.000,00	$200.000,00
Process engineering/mechanical parts (inkl. Steel construction)	LS	$817.800,00	$817.800,00
Electrical engineering	LS	$55.000,00	$55.000,00
Process control	LS	$32.700,00	$32.700,00
Mean and spare parts	LS	$131.000,00	$131.000,00
Equipment	*subtotal*		*$470.000,00*
Wheel loader	unit	$450.000,00	$450.000,00
containers (5 pcs, 10 m³)	unit	$20.000,00	$20.000,00
Total C&D plant (without contingencies)			**$1.706.500,00**
w orks, engineering, process control and mean & spare parts			$1.236.500,00
Equipment			$470.000,00
contingencies	10%		$170.650,00
Total C&D plant (with contingencies)			**$1.877.150,00**

Table 32: Cost estimation (net) and breakdown for C&D waste processing plant

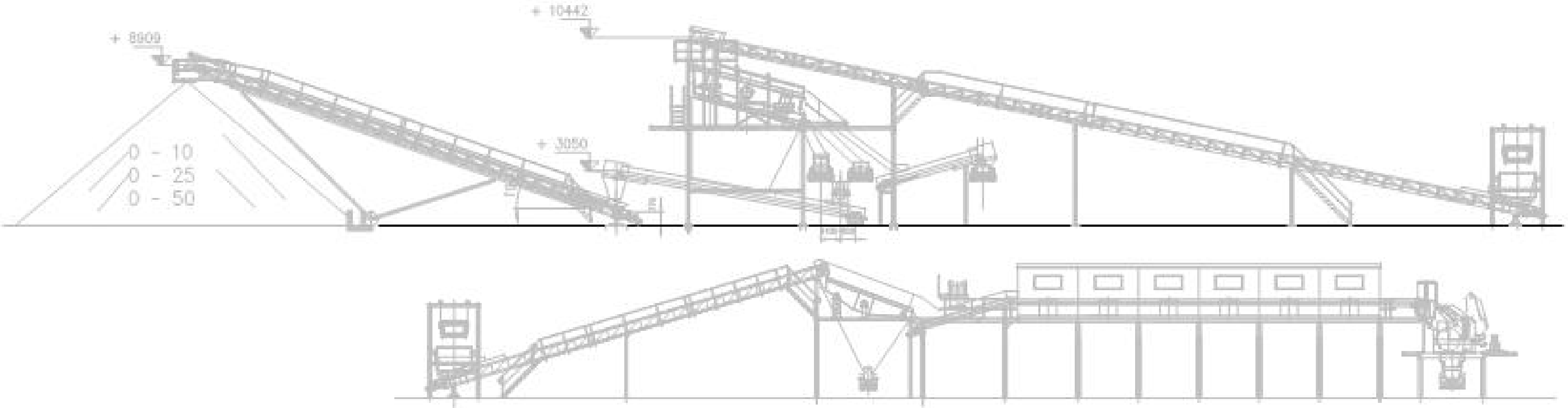


Figure 118: Preliminary design of the C&D waste processing plant

4.6. Site Infrastructure

4.6.1. Harbour

A docking facility exists actually for the dumpsite of Tilafushi. But this area is actually in poor conditions. Waste have been discharged loosely without any protection and security measures creating a wild tipping area with all risks and hazards such as leachate and attracting vectors of decease like flees and mosquitos.

Figure 119: Actual docking facility.

This area needs to be rehabilitated as soon as possible and should be upgraded to the first part of the RSWMF: the controlled and state of the art waste acceptance and processing area. According to the observations on site and beside the fact that the situation is problematic it seems that the waste dumped on that area is mainly superficial and that old waste located in the deeper layers is mainly stabilized. The area should be widened, extended and paved in such way to allow:

- the acceptance of all vessels, boats and barges which might arriving with waste streams of zone III
- the acceptance of all different types of vessels, boats and barges (landing crafts, Dhonis and small vessels)
- a permanent cleaning and run-off of surface water
- The construction of light infrastructure, buildings and plants without any important settlements or land sliding.
- a good circulation of trucks and mobile equipment
- sufficient storage capacities for valuable waste fractions

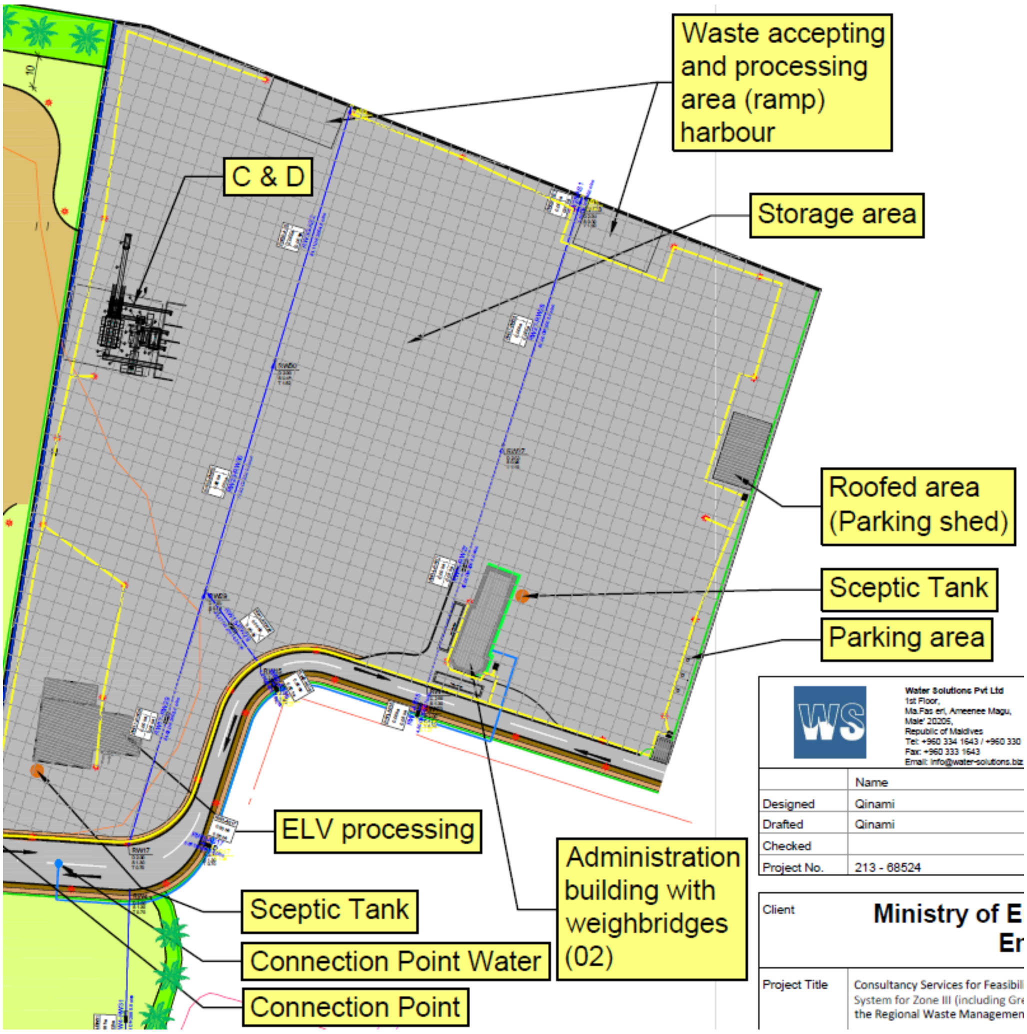


Figure 120: Layout of the new harbour and docking area

The actual concept designs shows a allocated area of 4 ha for the harbour and waste acceptance area which also includes the area foreseen for C&D waste processing and in a later stage the ELV processing. This corresponds also to the area identified as old, stabilised waste area. The rehabilitation and improvement of this area should comprise the following:

- Complete cleaning of the are from waste , deconstruction and moving of existing facilities
- Cutting/levelling of min 0,5-1,0 “top soil”
- Filling and compacting with material usual used for land reclamation and (if possible) C&D waste recycling material (filling material)
- Harbour/Docking rehabilitation by placing a new concrete Quay wall in front of the old one (Backfilling with adequate filling material) or sheet pile construction
- Construction of two ramps with the docking capacity of 2 landing crafts/ramp simultaneously (1 ramp is dedicated to C&D waste, the other one for HH waste)
- Construction of a concrete platform 30 cm thickness in different sections. The concrete platform (slab) should be extended to the area of the C&D

waste processing plant and the ELV facility. *(Profiling and compaction of the ground surface to achieve a density of 4MN/cm²)*

- Construction of the administration building (see also next chapter) including 2 weighbridges
- Construction of a fence limiting this area against the old dumpsite.
- Construction of parking bays, sidetracks, surface water runoff, lightning etc.

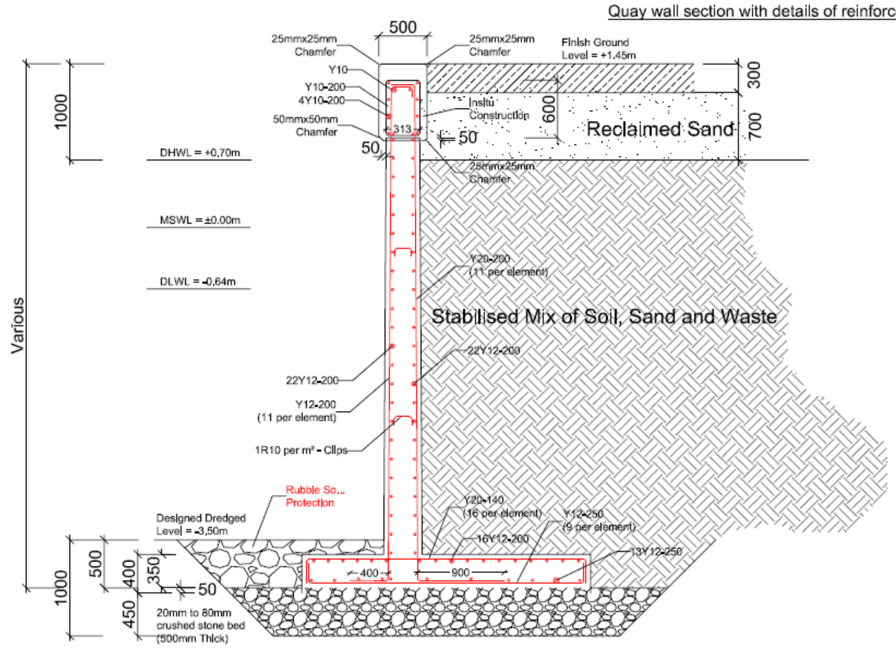


Figure 121: Preliminary detail of the Quay wall section

4.6.2. Administration

The administration building was designed to be as functional and practical as possible without taking too much space due to the land scarcity issue. Nevertheless, previous experiences and requirements have been taken in account in order to develop a practical and aesthetical infrastructure. The concept design of the building consists of:

- The waste acceptance and administration office : the scale room and one additional small office
- Some social facilities (changing room, kitchen, shower and WC)
- a small area for hazardous waste storage (which needs a special treatment)
- and area for selling valuable fractions (WAMCO shop)

For the weighing of the waste two weighbridges have been foreseen:

- One weighbridge for the incoming waste from Tilafushi island itself
- One for the incoming and processed waste from the harbour/docking and C&D waste processing area.

A preliminary layout of the building is presented in Drawing in annexe

4.6.3. Storm Water Drainage

Waste acceptance/harbour area should be built with a slope in the direction of the seaside (min gradient of 1%) to allow an efficient surface drainage. Additional surface water ditches should be build surrounding the area

4.6.4. Site Fencing

Site fence is required to separate the dumpsite area from the new loading-unloading area to prevent any contamination or windblown litter and to have a clear demarcation between the old site and the newly rehabilitated area. Additional green belt is recommended to improve the working conditions on this new area. The fence should be built as PVC coated mesh supported by GI pipes or as a PVC coated metal panels which are more aesthetic and robust.

Figure 122: suggested fencing type

4.6.5. Cost estimation and cost breakdown

Designation	Unit	Costs/unit in USD	Total in USD
Harbour rehabilitation and Administration building	*Total*		*$4.148.100,00*
Site preparation and management	LS	$70.000,00	$70.000,00
Site clerance and w aste disposal	LS	$21.000,00	$21.000,00
Earthw orks (cut and fill)	LS	$175.000,00	$175.000,00
Harbour rehabilitation (quayw all, etc.)	LS	$300.000,00	$300.000,00
Concrete plattform/carriagew ays	LS	$2.625.000,00	$2.625.000,00
Administration building	LS	$200.000,00	$200.000,00
Weighbridges	LS	$80.000,00	$80.000,00
Parking lot for heavy equipment	LS	$150.000,00	$150.000,00
Site infrastucture (WS, electricity, sew age, lightnings etc..)	LS	$150.000,00	$150.000,00
Total works (without contingencies)			**$3.771.000,00**
contingencies	10%		$377.100,00
Total works (with contingencies)			**$4.148.100,00**

Table 33: Cost estimation (net) and cost breakdown for harbour and administration area

4.7. Other Facilities

4.7.1. ELV Processing (later stage)

The ELV is one the waste streams which was considered as a priority waste stream by MEE. The quantities are not as important as assumed while most of the vehicles (particularly motorcycles) are used in such a way to avoid a frequent replacement. The facility itself should also be very simple and practical. This could be a small building similar to a maintenance facility with some ramps or mountings for oil and lube drain and the dismounting of all mechanical parts. An additional car/vehicle press could be also foreseen for the carriages. At this stage no technical details have been developed while considering this facility not as an urgent need. A small area should and have been allocated at the waste acceptance area nearby the harbour.

4.7.2. Waste processing

In a short-term it is not recommended to proceed to an important waste processing. The most important issue is that the waste is brought and accepted only in closed and safe receptacles. Exceptions are only pre-baled valuable fractions like plastics, metal cans, or P&C. Dry waste container might dropped out if its guarantee that there are mono-charges (f. ex: only plastics, or paper or tyres, etc.) and without important impurities. C&D waste is brought directly to the C&D waste processing plant. All other waste should be brought either to the balling station preferably located in the south of the area or in a later (mid-term) to the WTE. With increasing waste on long term the sorting and recycling process should be improved and consequently waste processing on different areas of the Facility could be allowed

Temporary Storage of recyclables

Temporary waste storage facility for the storage of recyclables for three months should also be provided. Additional equipment like baler has been proposed for baling metal cans and other recyclables to reduce volume and increase handling efficiency. (See equipment chapter)

5. Waste disposal

The rejects from the incineration process will be disposed in a secured waste disposal facility. Secured waste disposal facility is required to protect the fragile environment, which is very sensitive to natural and anthropogenic disturbances.

5.1. Landfill Volume and Design Life

The residual waste from the waste to Energy is bottom ash, slag and the residues from the flue gas cleaning.

Bottom ash and slag is a valuable fraction which could be probably use for many purposes:

- As covering material for landfill
- As ballast layer or reinforcement layer in the road construction
- As filler/aggregate for construction blocks
- Etc.

It is highly recommended to develop a market for this product. It is also a matter of cost and space availability (landfilling surface) if the slag/bottom ash is not used. Further to the residues, it has to be evaluated whether and to what extent processed C&D Waste could be used as recycled construction material.

If it can be used, approx. another 0.7 ha of land is required to process bottom ash.

Designation	
Incineration capacity	500 t/d
Ash content	25 %
Ash quantity	125 t/d
Density slag	1,4 t/m³
Slag volume	89,3 m³/d
Landfill volume per year	32.590 m³/a
Height	10 m
Duration/Life time	20 years
Surface need	8,5 ha

The residues from the flue gas cleaning are hazardous waste which needs to be dumped in a controlled way. For this residual waste a landfill cell is needed.

Designation	
Residual waste from flue gas cleaning	Approx.. 570 kg/h
Density	700 kg/m³
Volume	0,8 m³/h

Landfill Volume	7.000 m³/a
Filling height	10 m (5 Big-Bag stacked)
Duration/life time	20 years
Surface need	2,7 ha

In conclusion :

For the start of the operation (2022) of a viable RSWMF at Tilafushi a land availability of :

10 ha-15 ha should be foreseen. Since the decision on the C&D waste and the bottom ash recycling cannot be anticipated, we suggest to secure the complete unallocated area which can be reclaimed stepwise according to upcoming available factual information.

Only one small part of actual dumpsite could be used unless the waste is removed entirely and soil/sand is compacted properly so that land reclamation of 5 additional ha (North lagoon/South lagoon) is needed

For further extension and development, additional buffer areas need already to be foreseen.

Operation phase	Active cell	Volume [m³]	Lifetime (only flue ash 7000 m³/a) in year	Lifetime Combination flue ash/bottom ash (33.000 m³/a) in year	Or BA and FA only the first 2 years and then only FA
1	I	32.000	~ 5	~1	~1
2	I + II	78.000	~ 11	~2,5	~11
3.1	II + III	42.000	~ 6	~1,5	~6
3.2	III	28.000	~ 4	~0,5	~4
Total		180.000	~ 26	~5,5	~ 20

Landfill Cell Design

The landfill base liner comprises of compacted dredged sand; HDPE liner (1.5-2,0 mm); protection layer of geotextile (500-1200 gsm); drainage layer (200 mm) of 20-40 mm gravel; and a final protection layer of locally available sand above the drainage layer. The base layer is to be maintained at 2% slope with slotted HDPE pipes placed at regular intervals for collection of leachate.

Leachate Collection and Treatment

The leachate collection system collects the leachate from the base of the landfill. The leachate collection pipes are slotted HDPE pipes of 250 mm diameter, placed at regular spacing within the drainage layer. Leachate from this network of pipes will flow in a leachate collection shat under gravity, constructed on the side of the landfill.

Since the waste disposed in the landfill will primarily be inert or rejects from incineration, leachate from the landfill is not expected to be highly contaminated.

parameter	unit	range
TOC	% by weight	0.3 - 5
EOX	mg/kg	0.05 - 3
arsenic	mg/kg	3 - 15
lead	mg/kg	1,000 - 3,500
cadmium	mg/kg	2 - 20
chromium	mg/kg	200 - 1000
copper	mg/kg	1,000 - 10,000
nickel	mg/kg	100 - 500
mercury	mg/kg	< 10
zinc	mg/kg	2,000 - 7,000

Table 34: average WTE slag parameters (Source ITAD survey 2006/2007)

In principle, most of the leachate could be recirculated and used for scouring the bottom ash. This has the advantage to have a “clean” ash for using in the construction sector. Inconvenient of the technology in combination with the leachate storage basin is the added concentration of the recirculated water, particularly of metals. Therefore, a leachate treatment with reverse osmosis in combination with the buffer ponds and the recirculation (negligible costs of a sprinkler system) could be envisaged.

Preliminary dimension:

Lechate Ponds

Two leachate buffer ponds have been dimensioned with a base surface of 2x 3860 m² = 7.720 m² . In these ponds incoming leachate is mixed and stored with rainwater on a storage height of 1 m (Water level). Both ponds are connected with a pipe (redundancy)

With average annual rainfall of 2.000mm we have an approx volume of rainwater of 15.400 m³ (7.720,00m² x 2,00 x 1,00 m), which could stored through the ponds.

The leachate quantity per year is calculated to approx.. 68,8 m³/d x365 d/year ≈ 25.000m³/a (according the to suggested operation phases)

Leachate generation (wet year)						
Leachate infiltration coefficient (Riegler et al., 1995)						
Landfill cell in operation			0.5 - 0.7			
Landfill cell not in operation			0.9 - 0.95			
Landfill cell sealed			0.02 -0.1			
	Av. annual rainfall:	2000	l/m²			
	Annual peak factor:	**1,25**				
	Ass. annual Rainfall:	2500	l/m²			
Period	**Surface Type**	**Surface**	**Run-off coefficient**	**Precipitation**	**Leachate quantities**	**Av. Leachate quantities**
		[m²]		**[mm]**	**[m³/a]**	**[m³/d]**
2020 - 2024	Capping	0	10%	2500	0	
	Open surface	7.700	70%	2500	13.475	
	Total	7.700			**13.475**	**36,9**
2025 - 2035	Capping	4.004	10%	2500	1.001	
	Open surface	10.696	70%	2500	18.718	
	Total	14.700			**19.719**	**54,0**
2036 - 2041	Capping	9.520	10%	2500	2.380	
	Open surface	12.980	70%	2500	22.715	
	Total	22.500			**25.095**	**68,8**
2042 - 2045	Capping	14.700	10%	2500	3.675	
	Open surface	7.800	70%	2500	13.650	
	Total	22.500			**17.325**	**47,5**
Restored phase	Capping	22.500	10%	2500	5.625	
	Open surface	0	70%	2500	0	
	Total	22.500			**5.625**	**15,4**
Relevant for Design					**25.095**	**68,8**

Table 35: Landfill leachate quantity calculation

The capacity of the treatment plant is chosen for peak levels with 120m³/d/0,8= 150m³/d. That gives us a output of the plant per year of: 120m³/dx 365d/a = 43.800m³/a

Leachate generation		
Design values		
	Annual quantities	**Daily quantities**
	[m³/a]	**[m³/d]**
Average year	20.076	55,0
Wet year	25.095	68,8
Peak factor	1	1,75
Max. value	25.095	**120,3**

Table 36: design values for R/O plant

In Conclusion: the capacity of the buffer ponds is with 43.800m³ bigger than the sum of leachate water and rainwater, which is approx. 25.000 +15.000 = 40.000m³/year.

5.2. Operation and management of the RSWMF

5.2.1. Personnel Requirement

Labour	Nos
Incinerator (DBO International)	
Plant manager (international)	1
Operations Manager (international)	2
Operations officer (international)	2
Operations officer (national)	2
Heavy Vehicle Operators (national)	7
Maintenance Officer (international)	1
Engineer (international)	2
Electrician/Engineer (national)	2
laborer / Support Personnel (national)	25
Security officer (international)	1
Security officer (national)	2
Finance Officer (international)	1
Administrative support (national)	3
Total	51
Landfill	
Operations Manager	1
Heavy Vehicle Operator	3
labourer / Support Personnel	6
Landfill Supervisor	1
Total	11
C&D Waste processing	
Operations officer (national)	1
Heavy Vehicle Operators (national)	2

Labour	Nos
labourer / Support Personnel (national)	5
Security officer (national)	1
	9

Table 37: Staff requirement

5.2.2. Fuel and Material

A fuel storage unit of a minimum of 7 -10 days capacity is required on site to ensure uninterrupted operations of equipment and vehicles on site. Emergency shut-off systems shall be provided in the event of spillage or fire. There shall be sufficient distance between the fuel storage depot and other facilities to prevent damage to other facilities in case of explosion or fire.

5.2.3. Utility Services

Utilities service to the site shall include electricity, potable water, water for other purposes (sanitary facilities, cleaning, irrigation, and fire protection) and sanitation facilities.

Drinking water provision will be made for the personnel's working on site. A water tank for drinking and domestic usage shall be provided on site.

5.2.4. Ground Water Monitoring

Regular ground water monitoring shall be done during operations of landfill. A minimum of 3 ground water monitoring wells shall be constructed; 2 upstream and 1 downstream for monitoring of water quality during operation phase.

5.2.5. Cost estimation and cost breakdown

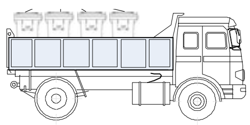
Designation	Unit	Costs/unit in USD	Total in USD
Waste to energy/Incinerator			
Civil w orks including installations engineering		*subtotal*	*$29.591.960,00*
system engineering	LS	$16.232.060,00	$16.232.060,00
Foundations	LS	$2.669.030,00	$2.669.030,00
building equipment and services	LS	$4.412.070,00	$4.412.070,00
Fire fighting system	LS	$1.067.612,00	$1.067.612,00
Outdoor facilities	LS	$1.111.188,00	$1.111.188,00
Social facilities/management building	LS	$600.000,00	$600.000,00
Storm and surge w ater resilience measures	LS	*$3.500.000,00*	*$3.500.000,00*
Process engineering/mechanical parts (inkl. Steel construction)		*subtotal*	*$43.414.250,00*
Crane system	LS	$1.525.160,00	$1.525.160,00
boiler, combustion, slag treatment	LS	$19.937.680,00	$19.937.680,00
Water-steam-circulation including boilerw ater processing	LS	$4.684.420,00	$4.684.420,00
Set of turbogenerators	LS	$5.664.880,00	$5.664.880,00
Seaw ater cooling	LS	$3.703.960,00	$3.703.960,00
Fluegas treatment including residual w aste treatment	LS	$6.372.990,00	$6.372.990,00
Emissions monitoring	LS	$457.548,00	$457.548,00
Auxiliary facilities	LS	$1.067.612,00	$1.067.612,00
Electrical engineering		*subtotal*	*$7.745.634,00*
Medium voltage installation and Transformers	LS	$522.912,00	$522.912,00
Low voltage installation	LS	$3.159.260,00	$3.159.260,00
Co-current flow installation	LS	$250.562,00	$250.562,00
Genset (emergency, shut-dow n)	LS	$3.812.900,00	$3.812.900,00
Process control	LS	$2.037.178,00	$2.037.178,00
Mean and spare parts	LS	$1.307.280,00	$1.307.280,00
Equipment		*subtotal*	*$580.000,00*
Hook-lift truck	1	*under immediate measures*	
Wheel loader	1	under immediate measures	
Fork-lift	2	$200.000,00	$400.000,00
Street sw eeping machine	1	$120.000,00	$120.000,00
small equipment (maintenance, electrical w orks, etc..)	LS	$60.000,00	$60.000,00
Total incinerator/WTE (without contingencies)			**$84.676.302,00**
Engineering, process control and mean & spare parts			$84.096.302,00
Equipment			$580.000,00
contingencies	10%		$8.470.000,00
Total incinerator/WTE (including contingencies)			**$93.146.302,00**
Landfill and infrastructure			
Landfill w orks and engineering		*subtotal*	*$3.420.000,00*
Site preparation	LS	$150.000,00	$150.000,00
Stite clearing and general earthw orks	LS	$150.000,00	$150.000,00
Roads and carriagew ays	LS	$600.000,00	$600.000,00
Landfill cells	LS	$780.000,00	$780.000,00
Leachate treatment	LS	$1.600.000,00	$1.600.000,00
Surface w ater management	LS	$90.000,00	$90.000,00
Ground w ater monitoring	LS	$50.000,00	$50.000,00
Equipment		*subtotal*	*$450.000,00*
Wheel loader	1	$450.000,00	$450.000,00
part of the equipment w hich w as placed in landfill previously w as now under immediate measures			
Total landfill and infrastructure (without contingencies)			**$3.870.000,00**
Engineering, civil w orks			$3.420.000,00
Equipment			$450.000,00
contingencies	10%		$387.000,00
Total landfill and infrastructure (including contingencies)			**$4.257.000,00**
Total WTE, landfill and infrastructure			$97.403.302,00

Table 38: Cost estimation (net) and cost breakdown for WTE and landfill

6. Equipment

6.1. Inner-Island Collection and transport system

6.1.1. Small & middle sized islands

Picture	Designation	Amount	Comment
Bins and receptacles			
	20 l bin for residual waste	Approx. 3.000	
	10 l bins for sorted fractions (plastics, P&C, etc..)	Approx. 3.000	Depending on the type of sorted fraction
		Approx. 3.000	
		Approx. 3.000	
Collection trucks			
		15	Small islands < 500 inh.
		10	500 inh. < middle sized islands < 1.000 inh.

6.1.2. Atoll capital and urbanized islands

Picture	Designation	Amount	Comment
Bins and receptacles			
	120 l bin	Approx. 4.000	Residual waste
	120 l bin different colour	Approx. 4.000	For sorted waste or wet waste

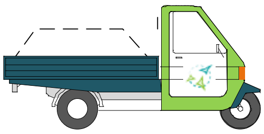
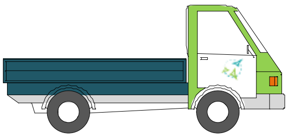
Picture	Designation	Amount	Comment
		Approx. 4.000	
Collection trucks			
	Compaction truck small 5 m³	10	

6.1.3. Hulhumale

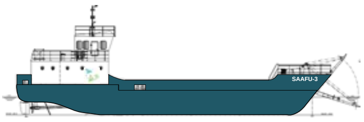
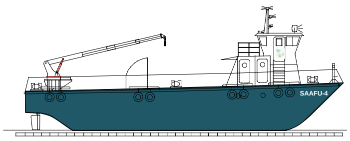
Picture	Designation	Amount	Comment
Bins and receptacles			
	660 l bin	Approx. 500	
Collection trucks			
	Compaction truck small 5 m³	3-4	
	Compaction truck 14 m³	1-2	Recommended alternative

6.1.4. Male'

Picture				Designation	Amount	Comment
Bins and receptacles						
				Plastic bags (60-120 l) 18-30 µm	Approx. 8,3 Mio/year	
				Plastic bags (20-40 l) 18-30 µm	Approx. 2,8 Mio/year	Depending on the sorting strategy in a later (mid term stage)
				120 l HDPE standardised bin	Approx 500	For commercials and restaurants
				Container 25 m³ with closing rooftop	2-3	For Market waste
				Skip bins	4	Alternative for Market waste
Collection trucks						
				Tricycle Loading capacity (240 l)	(25)	Not recommended

Picture	Designation	Amount	Comment
	Alternative to Tricycles : Tricycle tipper customized for Asian market		
	Tricycle truck Loading capacity 2-3 m^3 (10 times higher than a tricycle)	25	(type Piaggio Ape or similar)
	Small loading truck capacity 4-5 m^3	5	Piaggio porter, Isuzu NLR 250 or similar
	Compaction truck 5 m^3	10	Model HD72 press pack or similar
	Open dump truck (with a tarp/cover) 6 m^3	3	Model HD 65 or similar f. ex for C&D waste or special pick up services (bulky waste)
	Compaction truck 9 m^3 *with lifting device up to 1100 l*	2	Model press pack HD 120 or similar
	Armroll dump truck 25 m^3 6 x 2 wheels	1	Only For market waste pick-up service

6.2. Outer-Island transport system

Picture	Designation	Amount	Comment
Collection trucks			
	Landing craft vessel capacity > 50 t	2	
	Landing craft vessel capacity > 100 t	1	
	Optional Small vessel	1	For recyclables and bales

6.3. Transfer facilities

Picture	Designation	Amount	Comment
	Mobile crane Min 30 t loading capacity	1	
	Small forklift	2	1 for Male' 1 for Hulhumale'
	Small street sweeper	2	For cleaning purposes of the Transfer site in Male'

Picture	Designation	Amount	Comment
	Armroll dump truck 25 m³ 6 x 2 wheels	3	
	Set of container 25 m³ with close rooftop	50	
	Roll packers	3	
	Small multi-purpose wheel loader	1-2	Optional

6.4. RSWMF

Picture (for example puposes)	Designation	Amount	Comment
	Waste handler	2	  
	Small forklift	2	
	Small street sweeper	1	For cleaning purposes of the Transfer site in Male'
	Armroll dump truck 25 m³ 6 x 2 wheels	2	

Picture (for example puposes)	Designation	Amount	Comment
	Set of container 25 m³ with close rooftop	20	
	1 wheel loader	1-2	Mid-size loader
	Bale press 18 KN	1	
	Siever < 100 mm	1	For earth material preparation
	shredder	1	

6.5. Cost estimation and breakdown

Designation	Volume	Costs/unit in USD	Total in USD	
Collection and transport system			*Total*	*$4.128.011,82*
Collection system		*Units*	*subtotal*	*$1.115.486,94*
MGB 240	0,24	2210	$55,46	$122.574,89
MGB 1.100 Plastics	1,10	1670	$277,32	$463.122,31
Hoolk lift	10,00	11	$2.773,19	$30.505,06
	15,00	7	$3.327,83	$23.294,78
	20,00	10	$3.882,46	$38.824,63
Skips	3,00	6	$1.109,28	$6.655,65
	7,00	9	$1.442,06	$12.978,52
	10,00	8	$1.996,70	$15.973,56
Mobile Press	20,00	5	$27.731,88	$138.659,38
Litter bins	0,03	1300	$55,46	$72.102,88
On demand				
Hoolk lift	10	10	$2.773,19	$27.731,88
	15	10	$3.327,83	$33.278,25
	20	10	$3.882,46	$38.824,63
Skips	3	20	$1.109,28	$22.185,50
	7	20	$1.442,06	$28.841,15
	10	20	$1.996,70	$39.933,90
Additional Collection Vehicle	m3	*Units*	*US$/unit*	*$3.012.524,88*
Rear loader (16m3)	16	5	$200.020,10	$1.000.100,48
Multi Car (5m3)	5	4	$155.571,19	$622.284,74
Hook-lift truck		3	$111.122,28	$333.366,83
Skip loader truck		5	$94.453,93	$472.269,67
Push carts		80	$222,24	$17.779,56
On demand				
Tipping truck with crane, 7.5 to,		1	$88.897,82	$88.897,82
Tipping truck, 2.8 to, with crane		2	$33.336,68	$66.673,37
Hook lift truck		2	$111.122,28	$222.244,55
Skip loader		2	$94.453,93	$188.907,87

20 l bin residual	2.900	$10,00	$29.000,00
10 l bin yellow	2.900	$5,00	$14.500,00
10 l bin brow n	2.900	$5,00	$14.500,00
120 l bins grey	4.000	$36,00	$144.000,00
120 l bins yellow	4.000	$36,00	$144.000,00
120 l bins brow n	4.000	$36,00	$144.000,00
1,1 m³ bins grey	528	$180,00	$95.040,00

Lot	Equipment designation	Unit	Costs/unit in USD	Total in USD
1	Mobile w aste shredder	1	$350.000,00	$350.000,00
	Spare parts	LS	$15.000,00	$15.000,00
2	Rotating sieving drum	1	$220.000,00	$220.000,00
	Spare parts	LS	$4.000,00	$4.000,00
3	Bulldozer	1	$375.000,00	$375.000,00
	Spare parts	LS	$15.000,00	$15.000,00
4.1	Excavator	2	$220.000,00	$440.000,00
	Bucket shovel	1	$18.000,00	$18.000,00
	Log grab	1	$22.000,00	$22.000,00
	Spare parts	LS	$15.000,00	$15.000,00
4.2	Wheel loader	1	$170.000,00	$170.000,00
	Spare parts	LS	$10.000,00	$10.000,00
4.3	Waste handler	1	$250.000,00	$250.000,00
	5-tine grab	1	$27.000,00	$27.000,00
	Log grab	1	$22.000,00	$22.000,00
	Spare parts	LS	$15.000,00	$15.000,00
4.4	Telescope arm handler	1	$140.000,00	$140.000,00
	Fork lift	1	$25.000,00	$25.000,00
5	Arm-roll trucks	2	$140.000,00	$280.000,00
	Spare parts	LS	$5.000,00	$5.000,00
5.1	Container 25 m³	20	$4.000,00	$80.000,00
5.2	Tank truck	1	$190.000,00	$190.000,00
	Spare parts	LS	$10.000,00	$10.000,00
	Total			$2.698.000,00

Lot	Equipment designation	Unit	Costs/unit in USD	Total in USD
1	Mobile crane	1	$1.800.000,00	$1.800.000,00
	Spare parts	LS	$30.000,00	$30.000,00
1.2	Mobile conveyor Thilafushi	1	$100.000,00	$100.000,00
	Spare parts	LS	$5.000,00	$5.000,00
2	Telescope arm handler or w heel loader	2	$140.000,00	$280.000,00
	Fork lift	2	$25.000,00	$50.000,00
3	Arm-roll trucks	3	$140.000,00	$420.000,00
	Spare parts	LS	$5.000,00	$5.000,00
3.1	Container 25 m³	50	$4.000,00	$200.000,00
	Street sw eeper	2	$120.000,00	$240.000,00
3.2	Roll packer	3	$90.000,00	$270.000,00
3.3	Workshop equipment	LS	$390.000,00	$390.000,00
	Total			$3.790.000,00

CHAPTER 6: FINANCIAL ANALYSIS

1. Introduction / Methodology

1.1. Methodology

Evaluation period = 30 years

Price Increasing effects are not taken into account

After commissioning of the proposed investments no further capacity increases are anticipated for this financial analysis

RSWM system with different components offering finally four types of services. These are the:

- Waste collection and transport to Tilafushi by operating the
  - Waste collection and transport system, the
  - three Transfer Stations in Male, Hulhumale and Vilingili and the
  - 32 Island Waste Management Centres (IWMC)

  Input measure for this service is the households waste collected from households, commercial entities and the resorts

  Outputs are the quantities of recyclables finally sorted out for resale and the residual waste to be disposed of.
- Residual waste incineration and landfill disposal by operating the
  - WTE plant and the
  - landfill

  Input measure for this service is the total residual waste after sorting out the recyclables from the households waste, processing the C&D waste and treatment of the EoI Vehicles

  Outputs are the quantities of finally disposed flue ash, the bottom ash / slag and the as a by-product generated electricity
- Treatment of C&D waste

  Outputs of this treatment are the saleable recyclables and the residual waste to be burned at the WTE plant.
- Treatment of End-of-life vehicles

  Outputs of this treatment are the saleable recyclables and the residual waste to be burned at the WTE plant.

1.2. Assumed Quantities Development during the Evaluation Period

Based on the detailed analysis of the currently valid situation and the projections for the RSWMF design parameters for the reference year 2037 presented above, the financial analysis covering the evaluation period 2017-2047 assumes in particular the detailed developments presented in *Annex Financial analysis* and summarized in the following table:

		2017	2022	2027	2032	2037	2042	2047
Waste by types and sources								
Households waste	Mg/ day	215.1	354.4	465.7	526.6	611.0	721.6	854.1
Households	Mg/ day	130.9	239.0	321.4	358.5	411.8	482.3	564.8
Commercial	Mg/ day	23.5	43.6	58.6	64.9	74.1	86.2	100.2
Market	Mg/ day	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Resorts	Mg/ day	41.0	48.0	56.2	65.8	77.0	90.1	105.5
Airport	Mg/ day	10.0	14.0	19.4	27.0	37.5	52.1	72.4
Industrial waste	Mg/ day	6.1	6.3	6.5	6.8	7.0	7.3	7.5
C&D waste	Mg/ day	530.0	567.6	608.3	652.3	699.9	715.0	730.9
thereof recycables	Mg/ day	482.3	516.6	553.6	593.6	636.9	650.7	665.2
to incinerator	Mg/ day	47.7	51.1	54.7	58.7	63.0	64.4	65.8
Eol Vehicles	Mg/ day	0.8	1.0	1.3	1.6	2.1	2.7	3.4
thereof recycables	Mg/ day	0.7	0.9	1.2	1.5	1.9	2.4	3.1
to incinerator	Mg/ day	0.1	0.1	0.1	0.2	0.2	0.3	0.3
Clinical and Lube oil	Mg/ day	2.3	2.5	2.7	3.0	3.3	3.6	4.0
Total waste (all types)	**Mg/ day**	**748.2**	**925.6**	**1,078.0**	**1,183.5**	**1,316.2**	**1,442.9**	**1,592.4**
Waste by usage								
Composted waste	Mg/ day	8.2	15.3	21.9	30.6	43.1	51.4	61.3
Sorted PET for sale	Mg/ day	1.0	3.7	6.2	8.7	12.6	14.7	17.2
Sorted metal for sale	Mg/ day	0.7	2.5	4.1	5.8	8.4	9.8	11.5
Sorted P&C for sale	Mg/ day	3.8	9.8	16.1	21.6	27.8	32.5	38.0
Recycalbes from C&D waste treatmer	Mg/ day	482.3	516.6	553.6	593.6	636.9	650.7	665.2
Recycalbes from Eol vehicles treatme	Mg/ day	0.7	0.9	1.2	1.5	1.9	2.4	3.1
Remaning for incineration	Mg/ day	251.4	376.9	475.0	521.7	585.6	681.3	796.1
Total waste (all usages)	**Mg/ day**	**748.2**	**925.6**	**1,078.0**	**1,183.5**	**1,316.2**	**1,442.9**	**1,592.4**

Table 39: Quantities Projections for the Evaluation Period until 2047

Focussing on the expected developments later than 2037 it is assumed that for the waste types and sources the trends applied for the years before remain valid.

There regarding the expected development of the waste types and sources later than 2037 it is assumed that the trends applied for the years before remain valid. Contrary to that with respect to the sorting efficiency the Consultant does not expect further improvements. Instead it is assumed that the shares of sorted recyclables remain at the level reached in 2037. As a consequence the waste for incineration escalates during the years 2037 to 2047 compared to the previous decade.

For the annual quantities determining the different kinds of revenues and the variable operating expenses the daily numbers lead to the following yearly quantities. They are calculated for the households waste with 365 (calendar) days and for the C&D and Eol Vehicles waste with 310 working days.

		2017	2022	2027	2032	2037	2042	2047
For tariff setting								
Waste from households	Mg/ year	47,776	87,219	117,296	130,867	150,322	176,049	206,151
Waste from commerial, airport, industria	Mg/ year	15,784	24,626	32,162	37,318	44,582	54,423	67,068
Waste from resorts	Mg/ year	14,966	17,520	20,509	24,009	28,105	32,900	38,514
C&D waste	Mg/ year	164,300	175,971	188,580	202,211	216,954	221,654	226,593
Eol Vehicles	Mg/ year	242	310	397	508	651	834	1,068
Clinical and Lube oil	Mg/ year	832	913	1,001	1,098	1,205	1,321	1,449
Materials for resale								
PET	Mg/ year	383	1,343	2,252	3,173	4,594	5,375	6,288
Metal	Mg/ year	255	895	1,501	2,115	3,063	3,583	4,192
Paper and Cardboard	Mg/ year	1,397	3,567	5,877	7,893	10,133	11,855	13,870
Recycables from C&D waste	Mg/ year	149,513	160,134	171,608	184,012	197,428	201,705	206,200
Recycables from Eol vehicles	Mg/ year	218	279	357	458	586	750	961
Waste for incineration	Mg/ year	89,125	134,762	170,344	187,182	210,285	245,138	286,944
Composted waste	Mg/ year	3,010	5,579	8,006	11,178	15,731	18,775	22,388

Table 40: Forecast of Annual Quantities for the Evaluation Period until 2047

2. Investment Expenditure and Asset Replacements

2.1. Proposed Investments

Based on the quantities projections discussed above in the previous chapters the Consultant presents a detailed concept for an integrated solid waste management system for Zone III. As necessary for the implementation of this system, there are different investment needs listed and clearly specified bearing in mind the reference (design) year 2037.

The following table summarizes the identified investment needs (asset specifications and quantities) [5]. Listed are there moreover the expected unit purchasing costs for the required assets and their expected economic lifetime assuming a certain level of preventive maintenance. In total Table 3 shows investments in the different RSWMS components adding up to 144.90 million USD for works (construction and fitting-out of buildings) and operating equipment (goods). This amount includes physical contingencies. Price contingencies as well as taxes and duties are not included in the listed amounts.

[5] LS means here that a detailed listing of works necessary for the investment was prepared by the Consultant to estimate the investment amount. For the financial analysis these lists are only of minor importance and thus not presented here.

Asset Type	Quantity	Unit costs	Total costs	Asset Lifetime	R&M rate	Depreciation rate
	Number	1000 USD	1000 USD	years	percent	percent
Collection and transport equipment	**Total**		**8,060**			
For Greater Male			**4,165**			
MGB 240	2210	0.056	124.00	5	0.0%	20.0%
MGB 1.100 Plastics	1670	0.280	467.00	5	0.0%	20.0%
Hook lift bins	58	3.350	194.00	10	1.0%	10.0%
Skips	83	1.540	128.00	10	1.0%	10.0%
Mobile Press	5	28.000	140.00	5	2.0%	20.0%
Litter bins	1300	0.056	73.00	5	0.0%	20.0%
Rear loader (16m3)	5	202.000	1,010.00	7	2.0%	14.3%
Multi Car (5m3)	4	157.000	628.00	7	2.0%	14.3%
Hook-lift truck	5	112.000	560.00	7	2.0%	14.3%
Skip loader truck	7	95.000	665.00	7	2.0%	14.3%
Push carts	80	0.225	18.00	5	2.0%	20.0%
Tipping truck with crane, 7.5 to,	1	90.000	90.00	7	2.0%	14.3%
Tipping truck, 2.8 to, with crane	2	34.000	68.00	7	2.0%	14.3%
For outer islands			**1,645**			
Waste bins (small, medium, big)	LS		490	5	0.0%	20.0%
Compaction trucks 5 m³ (electric/ hybrid)	1	130.000	130	7	2.0%	14.3%
Compaction trucks 5 m³	4	120.000	480	7	2.0%	14.3%
Dump truck medium	10	35.000	350	7	2.0%	14.3%
Dump truck small	15	13.000	195	7	2.0%	14.3%
Customized vessels	3	750	**2,250**	10	3.0%	10.0%
Island Waste Management Centres (IWMC)	**Total**		**3,040**			
IWMC construction works	32	70	2,240	5	2.0%	20.0%
IWMC operating equipment	32	25	800	10	4.0%	10.0%
Transfer stations Male, Hulumale, Vilingili	**Total**		**9,624**			
Construction works	LS		5,834	20	2.0%	5.0%
Transfer stations equipment	Subtotal		3,790			
Mobile crane	1	1,800	1,800	7	2.0%	14.3%
Mobile conveyor Thilafushi	1	100	100	5	3.0%	20.0%
Telescope arm handler or wheel loader	2	140	280	7	2.0%	14.3%
Fork lift	2	25	50	10	2.0%	10.0%
Arm-roll trucks	3	140	420	7	2.0%	14.3%
Container 25 m³	50	4	200	10	1.0%	10.0%
Street sweeper	2	120	240	10	2.0%	10.0%
Roll packer	3	90	270	7	2.0%	14.3%
Workshop equipment and spare parts	LS		430			
Harbour rehabilitation	**Total**		**6,846**			
Habour rehabilitation works / Admin building	LS		**4,148**	20	2.0%	5.0%
Operating equipment landfill (immediate meas	Subtotal		**2,698**			
Mobile waste shredder	1	350	350	5	2.0%	20.0%
Rotating sieving drum	1	220	220	5	2.0%	20.0%
Bulldozer	1	375	375	7	2.0%	14.3%
Excavator	2	240	480	7	2.0%	14.3%
Wheel loader	1	170	170	7	2.0%	14.3%
Waste handler	1	299	299	7	2.0%	14.3%
Telescope arm handler	1	140	140	7	2.0%	14.3%
Fork lift	1	25	25	10	2.0%	10.0%
Arm-roll trucks	2	140	280	7	2.0%	14.3%
Container 25 m³	20	4	80	10	1.0%	10.0%
Tank truck	1	190	190	7	2.0%	14.3%
Spare parts	LS		89			
C & D waste treatment plant Tilafushi	**Total**		**1,877**			
Works	Subtotal		**1,877**			
Construction works	LS		1,216	20	2.0%	5.0%
Mechanical / electrical works	LS		517	15	5.0%	6.7%
Mean and spare parts	LS		144			
Operating equipment	Subtotal		0			
Wheel loader	0	400	0	7	2.0%	14.3%
End-of-life vehicles treatment facility	**Total**		**1,000**			
Civil Works	LS	90%	900	20	2.0%	5.0%
Mechanical / electrical works	LS	10%	100	10	3.0%	10.0%
Dumpsite rehabilitation works	**LS**		**15,000**			
Baling (and sorting) plant			**1,000**			
Civil Works	LS	40%	400	20	2.0%	5.0%
Mechanical / electrical works	LS	60%	600	10	2.0%	10.0%
Mobile C&D waste processing plant for Hulhumale			**1,045**	15	2.0%	6.7%
WTE plant and ash landfill	**Total**		**97,403**			
Construction works ash landfill	LS		3,762	20	2.0%	5.0%
Wheel loader	1	495	495	7	2.0%	14.3%
Works Incinerator	Subtotal		92,574			
Construction works	LS		32,552	40	2.0%	2.5%
Mechanincal / electrical works	LS		58,518	15	2.0%	6.7%
Mean and spare parts	LS		1,504			
Operating equipment incineration plant	Subtotal		572			
Fork-lift	2	220	440	10	2.0%	10.0%
Street sweeping machine	1	132	132	10	2.0%	10.0%
Total Investment need (Works and Goods)			**144,896**			

Table 41: Identified Investment Needs for Regional Waste Management Zone III

2.2. Allocation of Investments to ADB Projects 1 and 2

For the realization of the proposed investments listed above and their financing the ADB and the Government of Maldives decided to allocate the different measures to two different projects (phases).[6] Following the agreement the realization of Project 1 is foreseen to be implemented between 2018 and 2021, whereas the Project 2 investments are scheduled for 2019 until 2023. The allocation of the different procurements of works and goods according to the latest available information shows the following Table 4. Listed there are moreover the consulting services considered as necessary for a successful implementation of the proposed RSWM system. They add up to 6.24 million USD and include in particular implementation assistance services (project management, design and construction supervision) taking into account some physical contingencies, but not any price contingencies.

Scope and Costs	Project 1	Project 2	Project Packages	
	1000 USD	1000 USD		
Improved waste collection/ transfer in Greater Male				
Transfer stations Male, Hulumale, Vilingili	5,834		Package 2	Works
Collection and transfer equipment	4,165		Package 7	Goods / Equipment
Transfer station equipment	3,790		Package 9	Goods / Equipment
Improved dumpsite management/logistics Thilafushi Island				
Habour rehabilitation works / Admin building	4,148		Package 1	Works
End-of-life vehicles treatment facility	1,000		Package 3	Works
C & D waste treatment plant Tilafushi	1,877		Package 4	Works
Operating equipment landfill (immediate measures)	2,698		Package 6	Goods / Equipment
Improved outer island community waste management				
IWMC construction works	2,240		Package 5/10	Works
IWMC operating equipment	800		Package 5/10	Goods / Equipment
Collection and transfer equipment	1,645		Package 7	Goods / Equipment
Outer islands transfer vessels	2,250		Package 8	Goods / Equipment
Awareness and behavour change campaign	325		Consulting	
Implementation assistance	1,414	4,000	Consulting	
Incremental Admin Costs	500		Incremental Administrative Costs	
Waste to Energy, residual waste landfill and infrastructure		97,403		
Baling (and sorting) plant		1,000		
Mobile C&D waste processing plant for Hulhumale		1,045		
Dumpsite rehabilitation		15,000		
Total incl. Contingencies, before taxes	**32,686**	**118,448**		
Both projects	151,135			

Table 42: Indicative Procurement Plan: Allocation to ADB Projects

2.3. Short-term Investment Schedule 2018 – 2022

Bearing in mind the allocation of the specific investments to the projects / phases and the expected time needed for the preparation of bidding documents, the bidding process and the realization of works the Consultant considers the following short-term investment schedule as realistic.

According to this schedule the C&D waste treatment plant will be commissioned at the beginning of 2020, whereas the ELV dismantling workshop starts

[6] See for example Draft Aide Memoire of the ADB inception mission for the Greater Male Environmental Improvement and Waste Management Project dated July 2017.

operating at the beginning of 2021 and the incineration plant is commissioned at the beginning of 2023. Moreover, the schedule projects the delivery of the main operating equipment (goods) for 2018 and 2019.

		Total 1000 USD	2018	2019	2020	2021	2022
Works and Goods (base amounts)							
Improved waste collection/ transfer in Greater Male	Project 1	12,548	4,125	8,423	0	0	0
Improved dumpsite management/logistics Thilafushi	Project 1	8,956	6,561	2,395	0	0	0
Improved outer island community waste manageme	Project 1	6,828	0	4,174	2,654	0	0
Dumpsite rehabilitation works	Project 2	14,286	0	0	4,762	4,762	4,762
Baling (and sorting) plant	Project 2	910	0	0	637	273	0
Mobile C&D waste processing plant for Hulhumale	Project 2	950	0	0	0	950	0
WTE plant and ash landfill	Project 2	88,546	0	0	15,184	45,264	28,098
Subtotal Works and Goods		**133,024**	**10,686**	**14,992**	**23,237**	**51,249**	**32,860**
Consulting Services / Recurrent Costs (base amounts)							
Awareness and behavour change campaign	Project 1	295	184	111	0	0	0
Implementation assistance	Project 1	1,286	329	383	383	191	0
Incremental Admin Costs	Project 1	500	169	132	132	66	0
Implementation assistance	Project 2	4,000	0	0	1,333	1,333	1,334
Subtotal Consulting Services / Recurrent Costs		**6,081**	**683**	**625**	**1,848**	**1,590**	**1,334**
Total Investments without contigencies	Project 1	30,413	11,369	15,617	3,169	257	0
Total Investments without contigencies	Project 2	108,692	0	0	21,916	52,582	34,194
Contingencies (physical only)	Project 1	2,273	992	1,171	92	19	0
Contingencies (physical only)	Project 2	9,756	0	0	1,820	4,888	3,049
Total investments including contingencies	Project 1	32,686	12,361	16,788	3,260	276	0
Total investments including contingencies	Project 2	118,448	0	0	23,735	57,470	37,243
Taxes and duties	Project 1	1,931	732	999	188	13	0
Taxes and duties	Project 2	7,107	0	0	1,424	3,448	2,235
Total investment amount incl taxes	Project 1	34,617	13,093	17,788	3,448	289	0
Total investment amount incl taxes	Project 2	125,555	0	0	25,160	60,918	39,477
Overall investment amount		**160,173**	**13,093**	**17,788**	**28,608**	**61,207**	**39,477**

Table 43: Short-term Investment Schedule

2.4. Asset Replacements, Depreciations and Residual Values

The short-term investment schedule presented above defines, together with the type specific economic lifetimes of the newly purchased assets, future replacement needs. Applied are in this analysis the representative lifetimes already shown in *Table 44* above. Listed are there also the corresponding depreciation rates to use for the application of the straight line depreciation method. These rates and the asset purchasing costs determine the depreciation amounts listed in the following table. They represent the annualized costs for the usage of the assets in operation and are usually taken into account in tariff calculations with the target to ensure that in the future necessary replacements can be funded by previously collected service tariff revenues.

	USD / year
Waste collection and transport service	**2,480,586**
Collection and transport system	1,116,171
Island Waste Management Centres (IWMC)	528,000
Transfer stations Male, Hulumale, Vilingili	756,414
Baling (and sorting) plant	80,000
Residual waste incineration and landfill disposal	**5,639,223**
Harbour rehabilitation / Landfill	867,005
Incinerator	4,772,218
Tilafushi C&D waste treatment plant	95,269
Mobile C&D waste treatment plant	69,667
Eol vehicles treatment	55,000
Total RWSM services	**8,270,078**

Table 44: Annual Asset Depreciations by RSWM Services

However, taking the assumed representative asset lifetimes into account, it becomes obvious that all between 2018 and 2022 newly purchased M&E works and the operating equipment have to be replaced before 2047, the last year of the evaluation period. The detailed replacement years and related expenditure by RSWM components are listed in *Annex Financial analysis* together with the residual values of the assets in operation at the end of 2047. A summary is shown in the following table. An impression of the structure of the projected capital expenditure during the investment phase 2018 to 2022 and the following operating phase 2023 to 2047 is given in the next figure.

	NPV	Both Projects 2017 - 2022	2023 - 2027	2028 - 2032	2033 - 2037	2038 - 2042	2043 - 2047	Residual values
Collection and transport equipment	17,262	8,060	5,488	3,884	5,488	8,060	4,943	4,916
Island Waste Management Centres (IWMC	7,886	3,040	2,240	3,040	2,240	3,040	2,240	1,188
Transfer stations Male, Hulumale, Vilingili	14,139	9,624	2,870	590	2,870	9,194	2,870	6,182
Baling (and sorting) plant	1,309	1,000	0	600	0	1,000	0	470
Waste collection and transport service	**39,287**	**21,724**	**10,598**	**8,114**	**10,598**	**21,294**	**10,053**	**12,756**
Incinerator	88,411	93,146	0	572	58,518	572	0	28,319
Dumpsite rehabilitation works	11,762	15,000	0	0	0	0	0	0
Harbour rehabilitation / Landfill	15,691	11,103	2,504	3,104	1,065	11,014	2,504	6,916
Waste incineration and landfill disposal	**115,865**	**119,249**	**2,504**	**3,676**	**59,583**	**11,586**	**2,504**	**35,235**
C&D waste plant Tilafushi	2,140	1,877	0	0	517	1,216	0	738
Mobile C&D waste processing plant	1,151	1,045	0	0	1,045	0	0	279
ELV treatment plant	1,163	1,000	0	100	0	1,000	0	529
Total investments and replacements	**160,914**	**144,896**	**13,102**	**11,890**	**71,743**	**35,096**	**12,557**	**49,536**

Table 45: Investment and Replacement Schedule until 2047

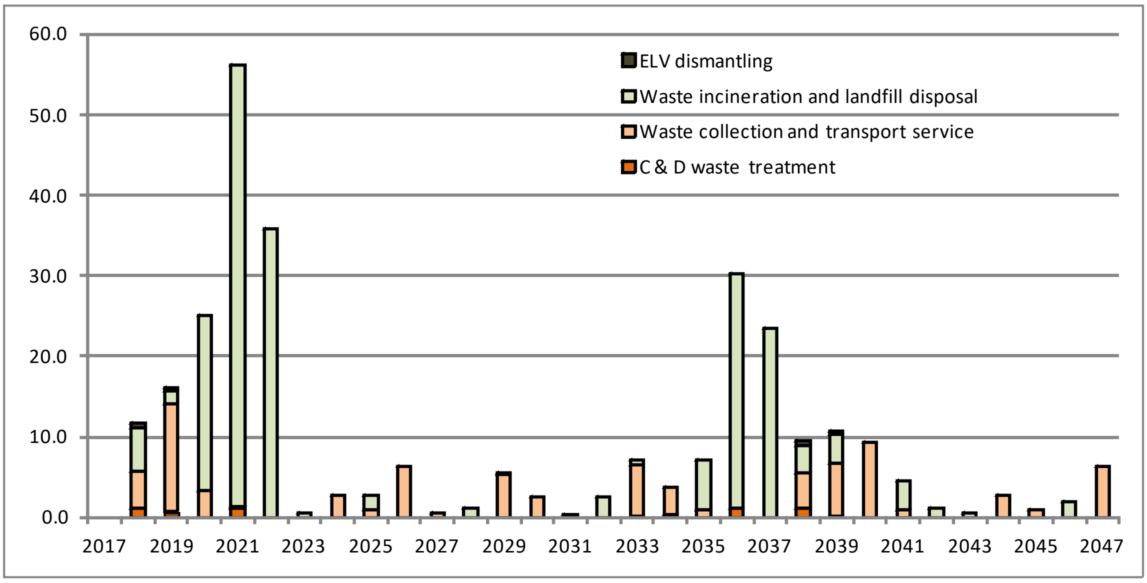


Figure 123: Projected Capital Expenditure for Investments and Replacements (million USD)

3. Financing of Investments and Replacements

3.1. Financing of the Proposed Investments

3.1.1. Project 1 and Project 2 Financing Plan

Following the (Draft) Aide Memoire of the ADB review mission for the Greater Male Environmental Improvement and Waste Management Project dated September 2017, the implementation of Project 1 will be supported by an ADB grant amounting to 24.95 million USD. Moreover, the indicative financing plan lists a contribution of the Government of the Maldives amounting to 4.6 million USD.

For Project 2 the indicative financing plan presented in the Aide Memoire shows beside a 24.92 MUSD granting by the ADB and a 29.68 MUSD contribution of the Government of the Maldives three additional sources of funds: It is expected there that the Japan Fund for Joint Crediting Mechanism (JFJCM)´will offer a 10 million USD grant with the target to support the adoption of the WTE plant as a low-carbon technology. Moreover, the provision of two loans is expected by the ADB and the Government of Maldives. The first one amounting to 30 million USD shall be provided by the Asian Infrastructure Investment Bank (AIIB) whereas the second loan amounting to 20 million USD shall be provided by the Islamic Development Bank (IDB).

However, considering the information regarding the international projects funding support provided in the Aide Memoire as fix, the Consultant assumes for the following analysis the detailed projects financing plan shown in the next table. There for each year the necessary disbursements are allocated according to their share on the total Project 1 and Project 2 funding.

	Type	Share on total	Total 1000 USD	2018	2019	2020	2021	2022
International sources								
ADB, Project 1	Grant	15.6%	24,950	9,435	12,662	2,641	211	
ADB, Project 2	Grant	15.6%	24,920			4,990	12,090	7,840
Asian Infrastructure Investment Bank	Loan	18.7%	30,000			6,012	14,556	9,432
Islamic Development Bank	Loan	12.5%	20,000			4,008	9,704	6,288
Japan Fund for Joint Carbon Financing	Grant	6.2%	10,000			2,004	4,852	3,144
Subtotal, International sources		**68.6%**	**109,870**	**9,435**	**12,662**	**19,655**	**41,413**	**26,704**
Local sources								
Government of Maledives, Project 1	Equity	4.8%	7,736	2,926	4,126	619	65	-
Government of Maledives, Project 1	Taxes	1.2%	1,931	732	999	188	13	0
Government of Maledives, Project 2	Equity	20.9%	33,528			6,721	16,268	10,539
Government of Maledives, Project 2	Taxes	4.4%	7,107	0	0	1,424	3,448	2,235
Subtotal, Local sources		**31.4%**	**50,303**	**3,657**	**5,125**	**8,952**	**19,794**	**12,773**
Total Disbursements		100.0%	**160,173**	**13,093**	**17,788**	**28,608**	**61,207**	**39,477**
Funding gap / to be clarified			**-**	**-**	**-**	**-**	**-**	**-**

Table 46: Projects Financing Schedule

3.1.2. Project Loans and Debt Service Payments

Reflecting the lack of currently available information on the foreseen project loan conditions, the Consultant assumes for the following financial analysis that the

- The AIIB loan amounting to 30 MUSD is characterized by a tenor of 30 years with a grace period of 5 years followed by 25 years of equal principal repayments starting in 2025. The interest rate is fixed at 1.5% for the complete tenor. Interest payments during the construction phase are capitalized, thereafter to pay annually.
- The IDB loan amounting to 20 MUSD is characterized by a tenor of 25 years with a graced period of 3 years followed by 22 years of equal debt service payments (fix annuity). The interest rate is fixed at 3% for the complete tenor. Interest payments during the grace period / construction phase are capitalized.
- For both loans the front-end fee and the commitment charge are fixed at zero.

The following table shows the development of the loan accounts during the Project 2 construction phase, while the next figure displays the development of the debt service payments. These payments add up in 2025 to about 3 million USD and decrease thereafter continuously. Thus, compared to the necessary replacement expenditure starting in 2023 *(see Figure 123 above)* they are relatively low.

		2019	2020	2021	2022	2023
Asian Infrastructure Investment Bank						
Disbursement	1000 USD	0	7.200	11.360	11.440	0
Interest during construction	1000 USD	0	54	194	368	0
Loan obligation (end of year)	1000 USD	0	7.254	18.808	30.616	30.616
Islamic Development Bank						
Disbursement	1000 USD	0	4.800	7.570	7.630	0
Interest during construction	1000 USD	0	72	260	496	0
Loan obligation (end of year)	1000 USD	0	4.872	12.702	20.827	20.145

Table 47: Development of Project Loan Accounts until 2023

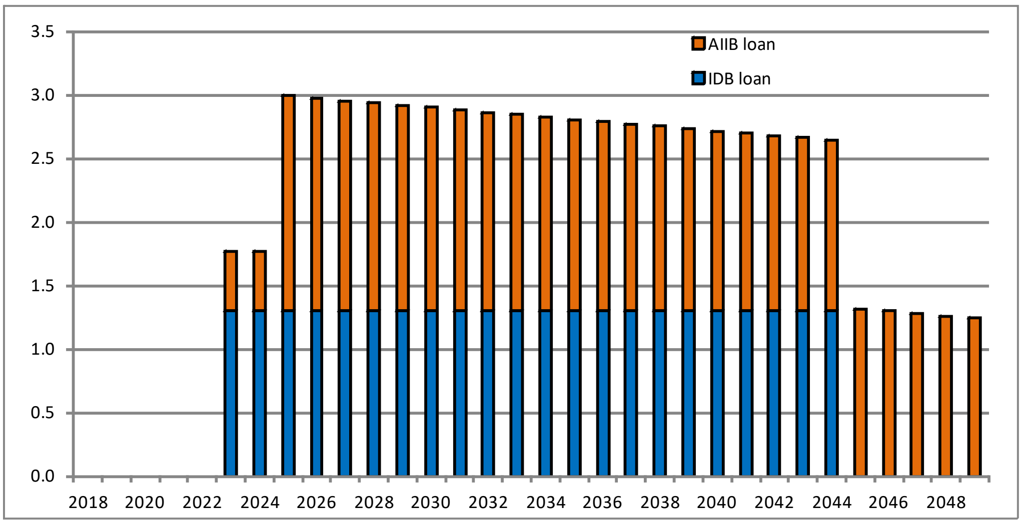


Figure 124: Debt Service Payments for the Project Loans (million USD)

3.1.3. Weighted Average Cost of Capital

By the characteristics of the two project loans assumed above the loan disbursements and debt service payments are fixed. This allows the calculation of the weighted average cost of capital (WACC) for the proposed projects measures. This reference interest rate is the benchmark for the evaluation of the financial impacts of the proposed investments measured by the financial internal rate of return (FIRR).

However, as displayed in the following table the WACC calculation is based on the effective interest rates of the AIIB loan (1.55%) and the IDB loan (3.14%), reflecting the impact of the complete loan conditions. For the grants and the government contribution this rate is set to zero and 10%, respectively. Moreover, for the two loans the influence of the corporate tax (currently 15%) is taken into account and the after tax rates are fixed. Because price increases are not considered in this analysis (i.e. rates estimated at 0% per annum) weighting these rates with the shares of the sources on the project financing leads to 3.35 % for the WACC.

	Capital Investments		Nominal	Corporate	After	WACC
	1000 USD	%	Rate	Profit Tax	Tax Rate	After Tax
ADB grants	49,870	33.0%	0.00%	15.0%	0.00%	0.00%
Asian Infrastructure Investment Bank	30,000	19.8%	1.55%	15.0%	1.32%	0.26%
Islamic Development Bank	20,000	13.2%	3.14%	15.0%	2.67%	0.35%
JFJCM grant	10,000	6.6%	0.00%	15.0%	0.00%	0.00%
Government of Maledives	41,265	27.3%	10.00%	0.0%	10.00%	2.73%
Total Capital Investment	**151,135**	**100.0%**				**3.35%**

Table 48: Weighted Average Cost of Capital

3.2. Financing of necessary Asset Replacements

Regarding the financing of necessary replacements because newly purchased assets are outworn at the end of their economic lifetime, the Consultant assumes that they have either to be financed by previously collected revenues or by a viability gap funding from the Government of the Maldives. A (partial) loan funding is not foreseen.

4. Operating Expenditure for the Services

4.1. Main Cost Types

The main cost types related to the operating of the different components of the RSWM system are the expenses for

- preventive maintenance and minor repairs of the assets in operation,
- operating staff expenses and the
- consumption of fuel (diesel).

The assumptions applied for these cost types are presented in the following subsections. Thereafter, in separate sections for each service additionally relevant operating expenses are presented, if considered as necessary. As a result the development of the expected grand total OPEX can be projected and compared to the served waste quantities.

4.1.1. Repair and Maintenance Expenses

The repair and expenses considered by the Consultant as necessary to ensure that the in 2018 and thereafter newly purchased assets remain in good conditions during their economic lifetime are calculated using the asset type specific maintenance rates and the corresponding asset purchasing costs, both already presented in *table 41* above. This leads to the following expenses per year:

	USD / year
Waste collection and transport service	**437,080**
Collection and transport system	157,400
Island Waste Management Centres (IWMC)	76,800
Transfer stations Male, Hulumale, Vilingili	182,880
Baling (and sorting) plant	20,000
Residual waste incineration and landfill disposal	**2,052,327**
Harbour rehabilitation / Landfill	219,482
Incinerator	1,832,845
Tilafushi C&D waste treatment plant	50,171
Mobile C&D waste treatment plant	20,900
Eol vehicles treatment	21,000
Total	**2,581,478**

Table 49: Annual Repair and Maintenance Expenses for RSWM Services

4.1.2. Staff expenses

For projecting the personal expenses the Consultant expects that staff with different qualification levels and thus expenses per employee will be engaged. Their number depends in particular on the equipment to be used for executing the different tasks.

Focusing on the waste collection and transport the Consultant assumes, for example, that for each compaction truck one skilled driver and three unskilled workers are needed. Bearing in mind the number of foreseen compaction and other trucks as well as other equipment and facilities needed, this leads to the staff requirements listed in the following table. Combining these numbers of required staff (including backups for holiday / illness replacements) with the Consultant’s estimate for appropriate annual expenses per head based on information provided by WAMCO this leads to total staff expenses amounting to about 1.8 million USD per year as listed in the next table.

		Operation manager	Operation specialist	Skilled worker	Unskilled Labourer	**Expenses USD / year**
Expenses per head	MVR/month	23,000	19,000	14,500	9,000	
	USD/year	18,200	15,000	11,400	7,100	
Collection and transport system			9	79	158	**2,157,400**
for Greater Myle			5	40	80	1,099,000
for outer islands				35	70	896,000
for customized vessels			4	4	8	162,400
Island Waste Management Centres (IWMC)				35	85	1,002,500
Transfer stations Male, Hulumale, Vilingili			4	10	18	301,800
Baling (and sorting) plant			2	4	12	160,800
Harbour rehabilitation / Landfill		1	2	5	8	162,000
Tilafushi C&D waste treatment plant		1	1	4	8	135,600
Eol vehicles treatment		1	2	0	7	97,900
Total						**4,018,000**

Table 50: Annual Staff Expenses for the different RSWM Components 2022 – 2027

Worth to mention in this context is that the Consultant expects that the number of staff proposed for C&D and Eol vehicles treatment is sufficiently high for all operating years until 2047. Reason is that both service facilities will according to the waste projections be operated at the design capacity (see Annex Financial analysis). Contrary to that the Consultant considers the annual staff expenses for all other RSWM components listed in *Table 51* above only as appropriate for the years until 2027. For the years thereafter it is expected that the additional work due to the increasing quantity of households waste to handle cannot completely be compensated by increases in the staff productivity. As a consequence regarding the staff expenses for these services an annual **increase by 2%** is assumed.

4.1.3. Fuel Consumption

Like the annual staff expenses discussed above the fuel consumptions and expenses are projected by the Consultant focusing on the equipment used for the RSWM components. Assuming fuel purchasing cost amounting to 9.15 MVR or 0.60 USD per liter and taking into account the number of used equipment leads finally to the fuel consumption expenses for 2022 – 2027 listed in Table 15.

Regarding the development of the fuel expenses later than 2027 the Consultant assumes due to the increasing households waste to handle for the relevant RSWM components (again) annual increases by 2%. Exceptions are only made for the fuel consumption related to the C&D waste treatment facility and the incineration plant. For both the waste quantity projections indicate an operating at the design capacity for all years until 2047.

	USD / year
Collection and transport system	1,150,000
Transfer stations Male, Hulumale, Vilingili	150,000
Baling (and sorting) plant	45,000
Harbour rehabilitation / Landfill	90,000
Incinerator	50,000
Tilafushi C&D waste treatment plant	45,000
Total	**1,530,000**

Table 51: Fuel Consumption and Expenses for the RSWM Components 2022 – 2027

4.2. OPEX for Waste Collection and Transport Service

Beside the above mentioned cost types for waste collection and transport also expenses for the purchasing and distribution of plastic bags for Male have to be taken into account. In the following it is assumed that each household in Male receives for every calendar day one 20 liters plastic bag (grey, 0.02 USD/unit) plus every third day one 60 liters bag (yellow, 0.01 USD/unit). For the year 2022 this leads to expenses amounting to 295 thousand USD. Thereafter higher expenses are necessary because of the increasing number of households living in Male.

To be taken into account are moreover expenses for WAMCO's general administration staff. These are the executive employees (five directors and seven department managers) mentioned in WAMCO's organizational chart and seventeen (skilled) employees working in the corporate affairs or finance department (see Section 7.6 of Chapter 2 of the FS). For their engagement the Consultant assumes in the following expenses amounting to annually 440 thousand USD in 2022 to 2027. For the years thereafter annually increases of the expenses by. 1% due to the growing number of served customers (households et al) are projected by the Consultant.

Last but not least for projecting the OPEX related to the waste collection and transport service the Consultant added a 5% mark-up to cover the expenses for other consumables, not explicitly taken into account before. The detailed numbers for the OPEX are presented in Annex Financial analysis. There it becomes also obvious that the Consultant fixes the OPEX for the years before 2020 at 80% of the amounts determined for the following year to reflect WAMCO's efforts to improve its services quickly. An impression of the structures is given in the following figures.

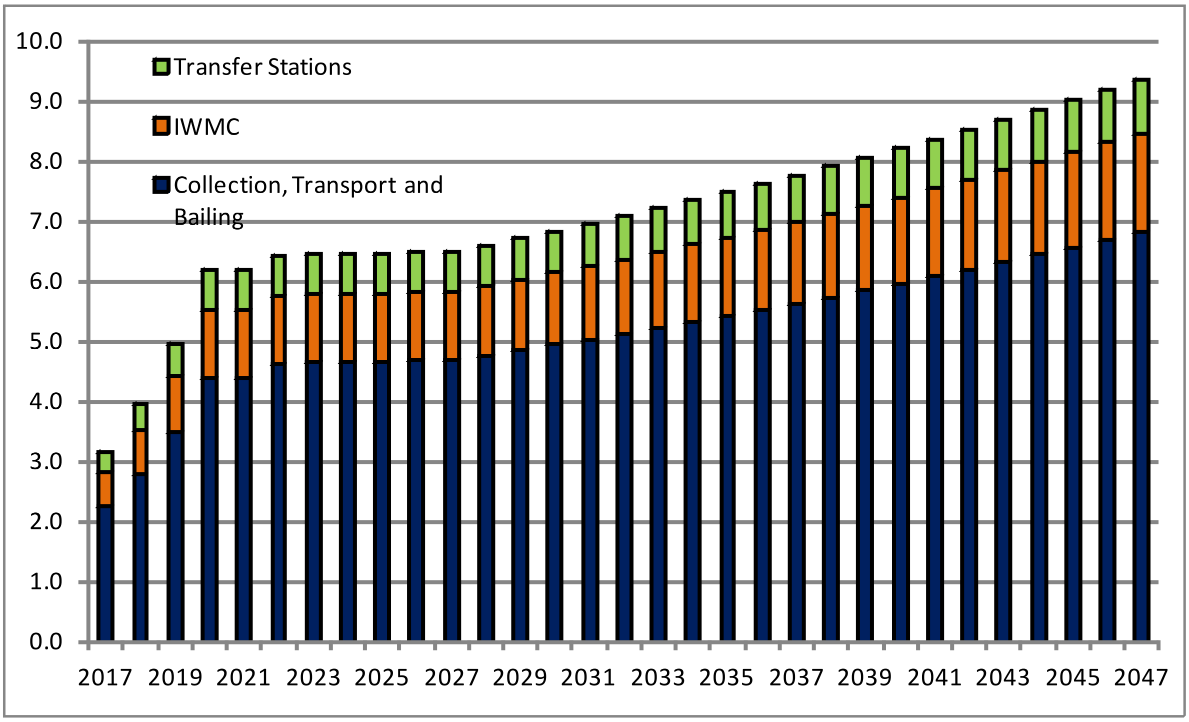


Figure 125: OPEX for Waste Collection and Transport by RSWM components (million USD)

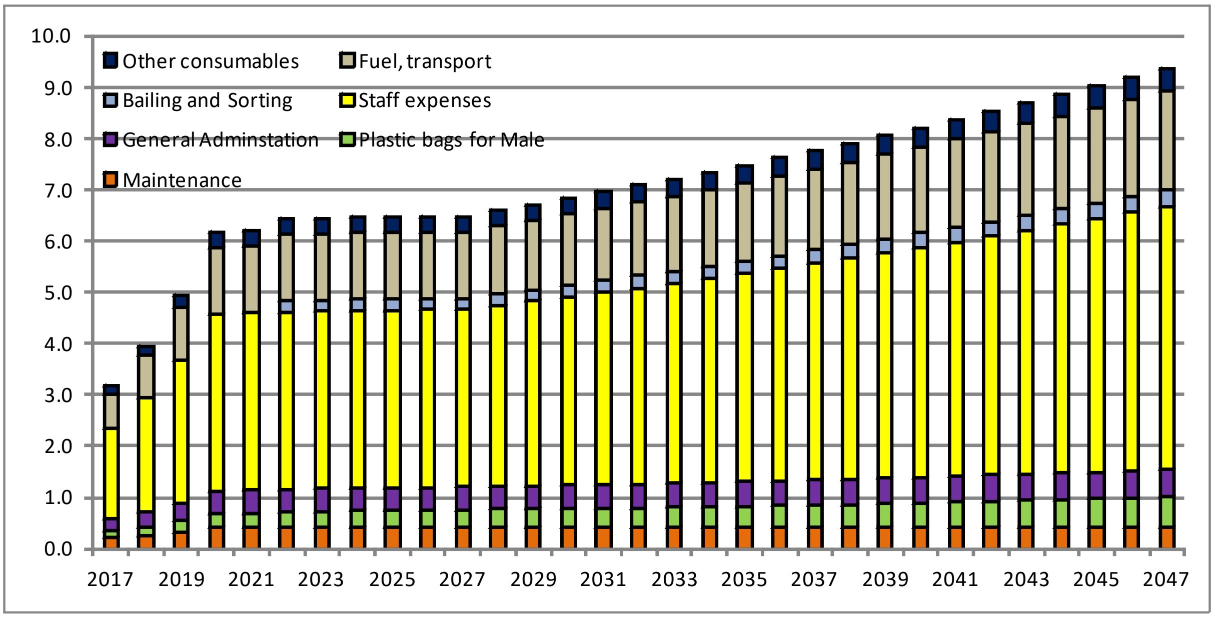


Figure 126: OPEX for Waste Collection and Transport by cost types (million USD)

The operating expenses presented above can (and will) partly be covered by the revenues due to the sale of recyclables sorted out during the collection and transport process. Bearing this fact in mind the expenses per Mg collected households waste displayed in the following figure can be interpreted as upper bounds for the service tariffs necessary to cover only the related OPEX or the "full costs", i.e. the OPEX plus depreciations.

Looking at the developments in the figure below demonstrates that even focusing only on the waste collection and transport service, high amounts per Mg are needed to cover the corresponding expenses. As a consequence of this result the Consultant considers the significant improvement of the waste sorting efficiency (as assumed above) combined with the realization of good resale prices for the recyclables as essential for cost coverage without requesting inacceptable high service tariffs from the households or other WAMCO customers.

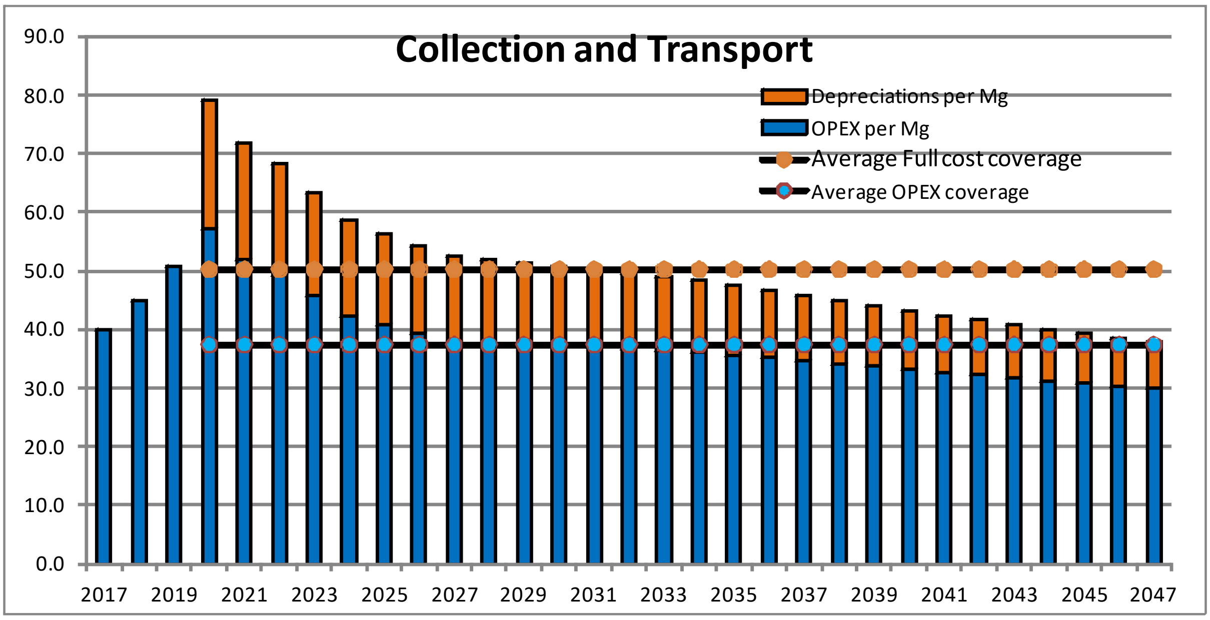


Figure 127: Cost coverage tariffs for the Waste Collection and Transport Service (USD/Mg)

4.3. OPEX for Waste Incineration and Landfill disposal

For the projection of the expenses induced by the operation of the Tilafushi landfill the Consultant takes in addition to the already in Subsection 4.1 discussed expenses (repair and maintenance, fuel) only a 10% mark-up for the purchasing of other consumables into account. Consequence is an increase in the corresponding OPEX from 334 thousand USD valid for the years 2020 (commissioning) to 2027 up to 445 thousand USD in 2047. Regarding the years before 2020 the Consultant assumes that the OPEX are 80% of the amount determined for the following year showing the need to build up capacities quickly.

Contrary to that the projected operating expenses for the incineration plant remain constant for all years starting with the assumed commissioning at the beginning of 2023 and lasting until the end of the evaluation period, 2047. Reason is the Consultant’s expectation that the WTE plant will be operated every year at its design capacity (500 Mg per day, 345 operating day per year). For the corresponding OPEX forecast beside the already in Subsection 4.1 mentioned expenses (repair and maintenance and fuel) the following annual expenses are taken into account:

- For the international staff listed in Subsection 5.2.1 (10 employees) 1.2 million USD.
- For the national operating staff listed in Subsection 5.2.1 as well (41 employees) 370 thousand USD. These staff members ensure together with the international staff a three shift operating of the incinerator.

- For electricity based on a daily consumption of 1.5 MWh, 345 days of operation and 230 USD / MWh purchasing costs (non-subsidized STELCO price) 119 thousand USD.
- For Sodium bicarbonate (416 kg/h, 218 USD/Mg) 750 thousand USD.
- For Hearth-furnace coke (14 kg/h, 1,30 USD/kg) 151 thousand USD
- For Ammonia water (25%, 60 kg/h, 136 USD/Mg) 68 thousand USD
- For Big bags designated to store the residues from flue gas cleaning (10 per operating day, 10 EUR per unit) 35 thousand USD
- Water consumption (1.8 m³/h, 8 USD per m³ non-subsidized price), 119 thousand USD

This leads to total operating expenses for the incineration plant adding up to slightly less than 4.7 million USD per year. For the grand total OPEX related to the waste incineration and landfill disposal this means an escalation from 334 thousand USD calculated for 2022 (landfill operation only) up to about 5.2 million USD projected for 2023. With respect to the OPEX per Mg residual waste, this escalation means an increase from 3 USD up to 36 USD as demonstrated in the next figure. There it becomes moreover visible that the OPEX per Mg remain higher than 18 USD in the long run. Taking additionally into account the depreciations, the expenses per Mg remain higher than 39 USD.

To avoid that these expenses per Mg have an unacceptable impact on WAMCO's financial viability and/or the customer tariffs for this specific service, the development of markets for the - at least in principle - saleable outputs of the incineration plant (bottom ash/slag and electricity) is necessary. Otherwise, the sustainable operating of the incineration plant is from the Consultants point of view only possibly if it is subsidized, for example by the Maldivian State.

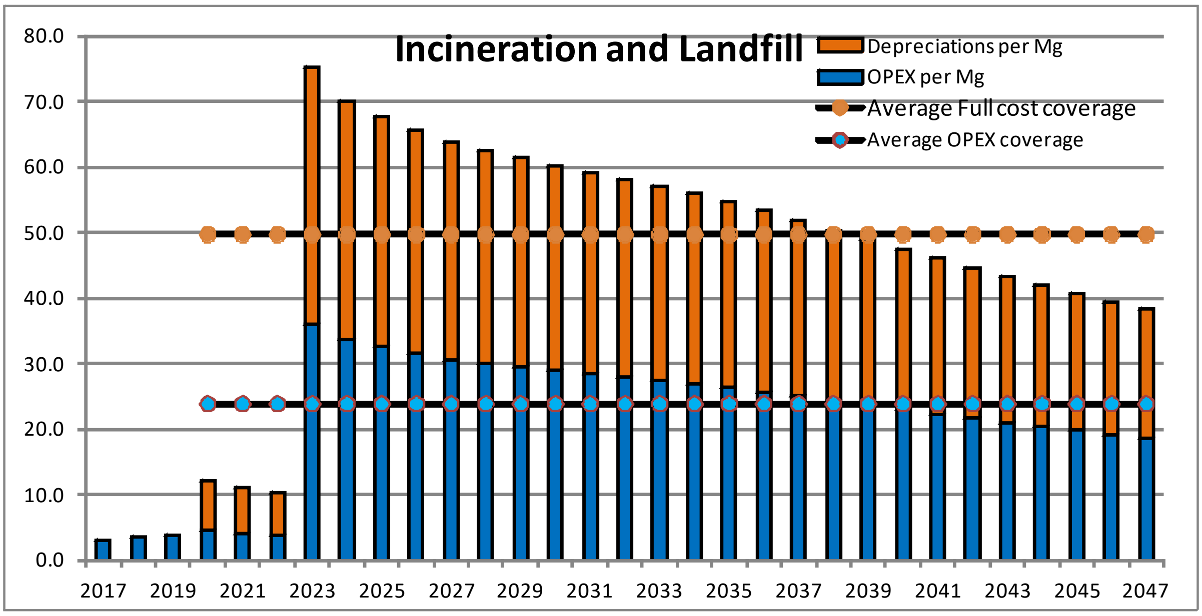


Figure 128: Expenses for Waste Incineration and Landfill Disposal per Mg residual waste (USD/Mg)

4.4. OPEX for Treatment of C&D Waste

Regarding the projection of the operating expenses related to the treatment of C&D waste in Tilafushi[7] the Consultant takes beside the already in Subsection 4.1 discussed cost types (repair and maintenance, staff and fuel) the following expenses explicitly into account:

- 57,000 USD for electricity based on a daily consumption of 0.8 MWh, 310 days of operation and 230 USD / MWh purchasing costs (non-subsidized STELCO price),
- 20,000 USD for water based on a daily consumption of 8 cbm, 310 operating days and 8 USD / cbm purchasing costs.
- 435,240 USD for the disposal of 12,740 Mg residual waste resulting from the C&D treatment to be burned at the WTE plant. The corresponding unit costs are fixed at 26 USD / Mg with the target to cover the resulting OPEX for operating the Incineration plant and the landfill (see above, internal cost allocation). Otherwise these expenses would finally have to be considered as induced by the burning of households waste and thus increase the corresponding tariff to pay by households.

Moreover, a 5% mark-up for the purchasing of other consumables is applied. This leads to constant total operating expenses amounting to 780 thousand USD for all operating years of the C&D treatment facility, starting with the commissioning at the beginning of 2020 and lasting until 2047.

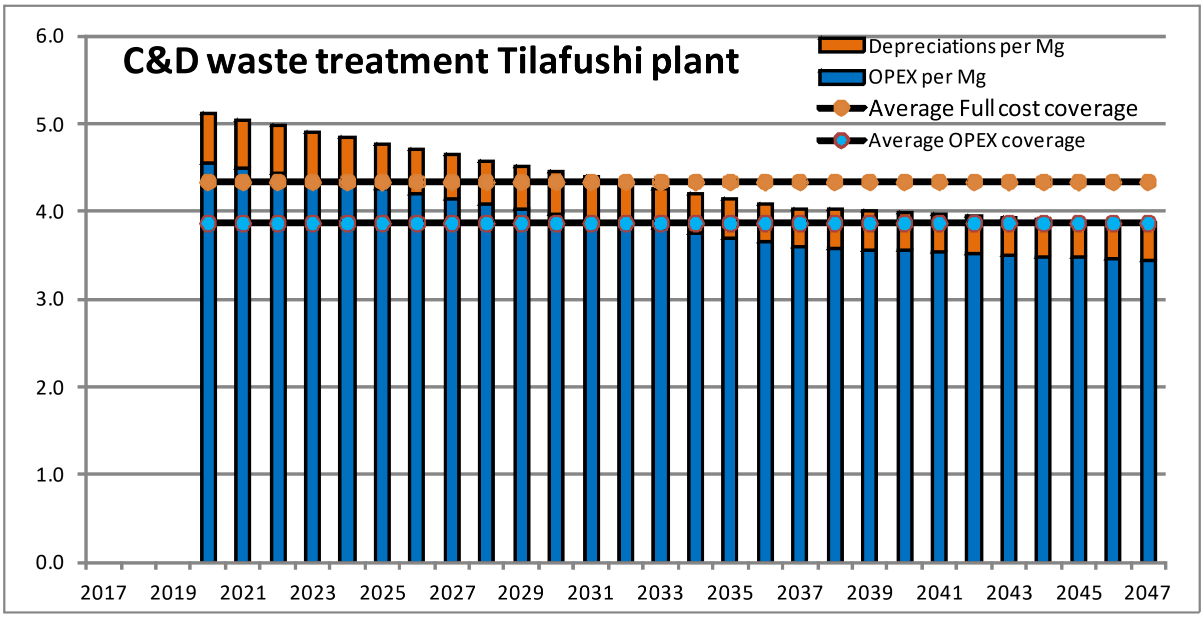


Figure 129: Expenses for C&D waste treatment Mg incoming waste (USD/Mg)

4.5. OPEX for End-of-life Vehicles Treatment

For the projection of the expenses induced by the Eol Vehicles treatment the Consultant takes in addition to the already in Subsection 4.1 discussed expenses (repair and maintenance and staff) for demonstrative purposes

[7] Regarding the mobile C&D waste processing plant the Consultant assumes here that WAMCO rents out the plant at cost price.

explicitly 1,209 EUR for the disposal of 47 Mg of residual waste to the Incineration plant into account. Like for the C&D residual waste the corresponding unit costs are 26 USD / Mg. Moreover, for the purchasing of other consumables a 10% mark-up on the above mentioned expenses is taken into account. This leads to constant total operating expenses amounting to 132 thousand USD for all years starting with the commissioning of the treatment facility at the beginning of 2021 and lasting until 2047.

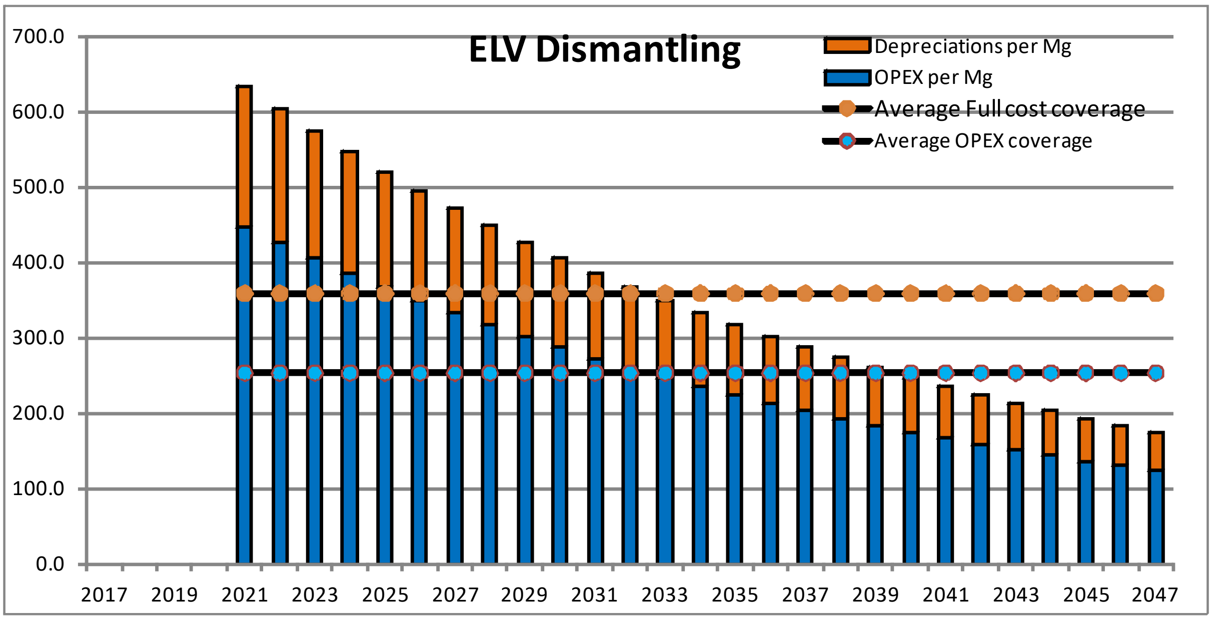


Figure 130: Expenses for Eol Vehicles Treatment per Mg incoming waste (USD/Mg)

5. Service Tariffs, Cost Coverage and Affordability

5.1. Currently valid Tariffs and Affordability

According to the received information the introduction of the currently valid service tariffs for Male by WAMCO was earmarked by the intention to request prices from the different customer groups which are competitive to the service fees requested by the informal sector.

A clear advantage of this approach is that the waste collection tariff for households amounting to 150 MVR per month (door step service) is already accepted by Male's population as appropriate and affordable.

On the other hand the approach ignores that waste management expenses are finally determined by the mass of the waste which should be applied for the determination of tariffs following the common "users pay" principle: As shown in the next table the currently valid tariffs lead for representative households with a waste generation of 3.77 kg/day to a waste collection fee amounting to slightly more than 1.300 MVR/Mg. On the other hand commercial entities have to pay for the daily collection of (estimated) 20 kg/day finally only less than 1.000 MVR /Mg. Last but not least the waste disposal fee to pay by resorts is fixed at 400 MVR/ Mg, i.e. at less than 25% of the households' fee.

	Fee incl. 6% VAT		Waste generation		MVR per Mg	USD per Mg
			kg / day	kg / month		
Households	150	MVR / month	3.77	114.61	1308.80	86.08
Commercial and similar entities	600	MVR / 60 litres dustbin	20.00	608.33	986.30	64.87
Resorts	400	MVR / Mg			400.00	26.31

Table 52: Currently valid tariffs for Male and their relations **8**

From the Consultant's point of view the currently valid tariff structure is not acceptable. For this reason and bearing in mind that the implementation of the RSWM system leads to

- significantly higher OPEX than observed in the past,
- high replacement expenditure starting in 2023 *(Figure 123*) and
- additionally to fulfil debt service obligations *(Figure 124)*

the Consultant strictly recommends increases of the service tariffs for the commercial customer group and the resorts to adjust the tariff structure. Only if the users pay principle is appropriately reflected in the tariff structure, simultaneous adjustments of the households' and other tariffs should be taken into consideration.

5.2. Waste Collection Tariffs and Sales Revenues

5.2.1. Currently valid Tariffs and Coverage of Expenditure

For the determination of appropriate waste collection tariff adjustments beside the already above projected operating expenses, replacement needs and debt service payment also the expected sales revenues for sorted recyclables, bottom ash and generated electricity have to be taken into account.

Applying for this purpose the unit sales prices listed in the following table shows that the projected sales revenues increase according to the projection continuously. First in particular due to the assumed and strictly recommended improvement of the recyclables sorting efficiency, later because of the further increases of the collected households waste. Constant amounts are listed in Table 17 for the revenues due to the applied internal cost allocation reflecting that the incineration plant is also used to burn the residual waste from the C&D and ELV treatment. Because both are operated at the design capacity, the output quantities and, as a consequence, also the related allocation amounts do not vary. The same situation is valid for the WTE plant and explains the constant revenues from its saleable outputs.

[8] Source WAMCO document received during mission june 2017

		Amounts in 1000 USD						
		2017	2022	2027	2032	2037	2042	2047
Sale of recyclables								
PET	90 USD / Mg	34	121	203	286	413	484	566
Metal	90 USD / Mg	23	81	135	190	276	322	377
Paper / Cardboard	30 USD / Mg	42	107	176	237	304	356	416
Subtotal Sale of recyclables		**99**	**308**	**514**	**713**	**993**	**1,162**	**1,359**
Internal cost allocation								
Residual C&D wast	26 USD / Mg	0	435	435	435	435	435	435
Residual ELV waste	26 USD / Mg	0	1	1	1	1	1	1
Subtotal Internal cost allocation		**0**	**436**	**436**	**436**	**436**	**436**	**436**
WTE saleable outputs								
Bottom ash /slag	20 USD / Mg	0	0	863	863	863	863	863
Electricity	69 USD / MWh	0	0	3,428	3,428	3,428	3,428	3,428
Subtotal WTE saleable outputs		**0**	**0**	**4,290**	**4,290**	**4,290**	**4,290**	**4,290**
Total Sales Revenues		99	745	5,241	5,440	5,720	5,889	6,086
OPEX (grand total)		3,429	6,945	11,695	12,329	13,040	13,836	14,718
OPEX (remaining uncovered)		3,329	6,200	6,454	6,889	7,320	7,947	8,632
OPEX reduction in Percent		3%	11%	45%	44%	44%	43%	41%

Table 53: Sales Revenues affecting the necessary Waste Collection Tariffs

However, looking in the table above at the total sales revenues it can be stated, that they cover for the assumed retail prices and the fix allocation prices in the long run about 18% of the grand total OPEX for the incinerator and the landfill. Nevertheless for the currently valid waste collection tariffs it has to be stated that they are too low: As shown in the following figure the sales plus service tariff revenues are only slightly higher than the OPEX. Consequence is for a lot of years a lack of financial means necessary to cover the debt service payments and the expenditure for replacements. Thus, a subsidization (viability gap funding) will become necessary as shown in the next but one figure. In total the necessary subsidization adds up to about 182 million USD for the currently valid waste collection tariffs.

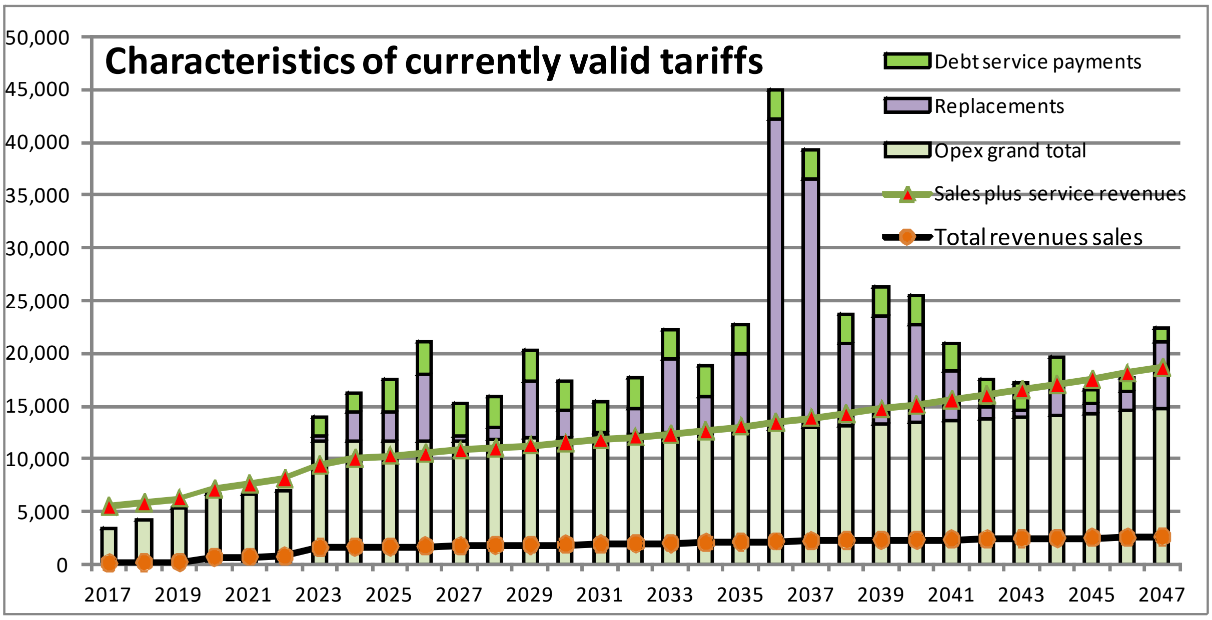


Figure 131: Relation between Revenues and Payment Obligations for currently valid Tariffs

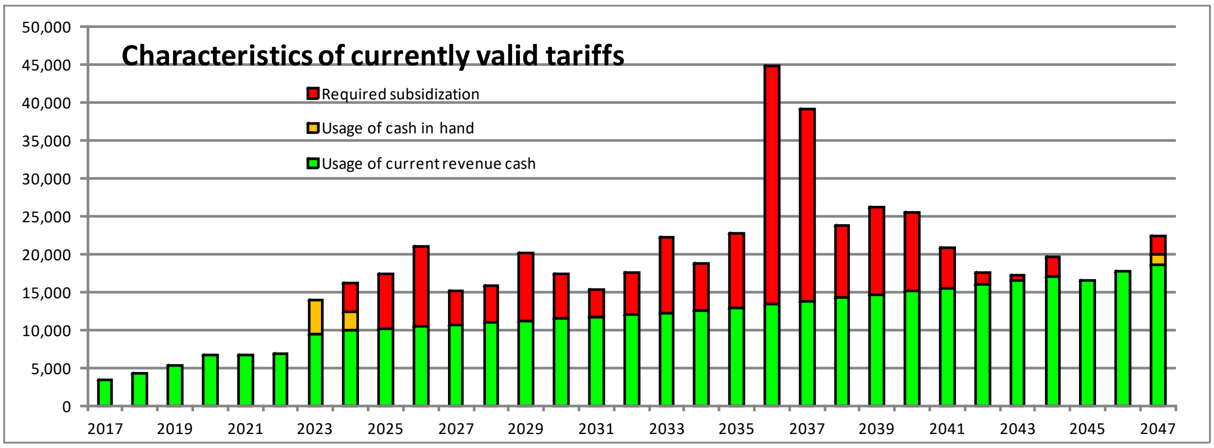


Figure 132: Required subsidization for the currently valid Tariffs

5.2.2. Proposed Adjustment of Waste Collection Tariffs

Based on the results obtained for the currently valid tariffs and bearing in mind the difficult tariff structure, the Consultant recommend to adjust the waste collection tariffs as shown in the following table.

		2018	2019	2020	2021	2022	2023	2024
Service tariff for households (incl VAT)	MVR/month	150	150	150	150	200	250	250
Service tariff for households (ex VAT)	USD / month	9.31	9.31	9.31	9.31	12.41	15.51	15.51
Service tariff (VAT excluded)	USD / Mg	87.77	82.09	72.57	68.71	88.37	107.89	105.42
Service tariff for commercial / other	USD / Mg	61.20	65.08	68.96	72.84	97.12	121.40	121.40
	MVR/Mg	930.47	989.46	1,048.44	1,107.43	1,476.57	1,845.72	1,845.72
Service tariff for resorts	USD / Mg	24.82	40.83	56.83	72.84	97.12	121.40	121.40
	MVR/Mg	377.36	620.72	864.07	1,107.43	1,476.57	1,845.72	1,845.72

Table 54: Proposed Adjustment of Waste Collection Tariffs

Applying the already above presented unit sales prices, the amended tariffs lead to significantly higher service revenues as demonstrated in the following figure. There only for two years relatively low total revenues compared to the total payment obligations become visible. But, on the other hand for the years before 2036 the figure signals that revenues surpluses are expected. As shown in the next but one figure these surpluses are high enough to build up enough cash reserves to completely cover the funding gaps in 2036 and 2037. Thus, due to the above assumed tariffs adjustment the need for subsidization can be avoided.

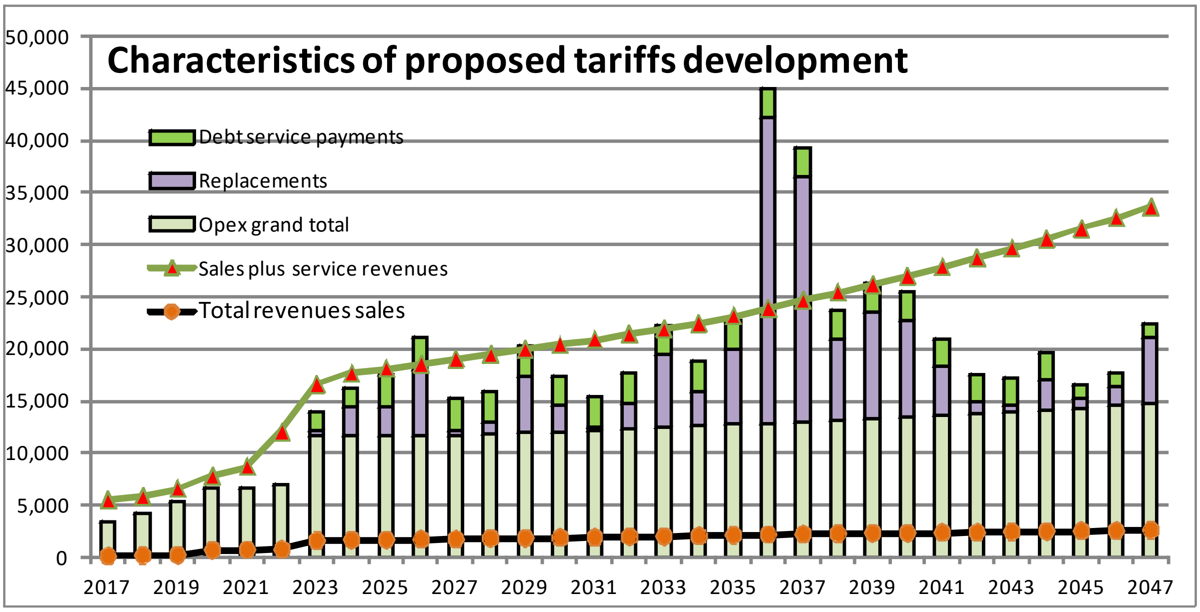


Figure 133: Proposed Tariffs Development and Coverage of Payment Obligations

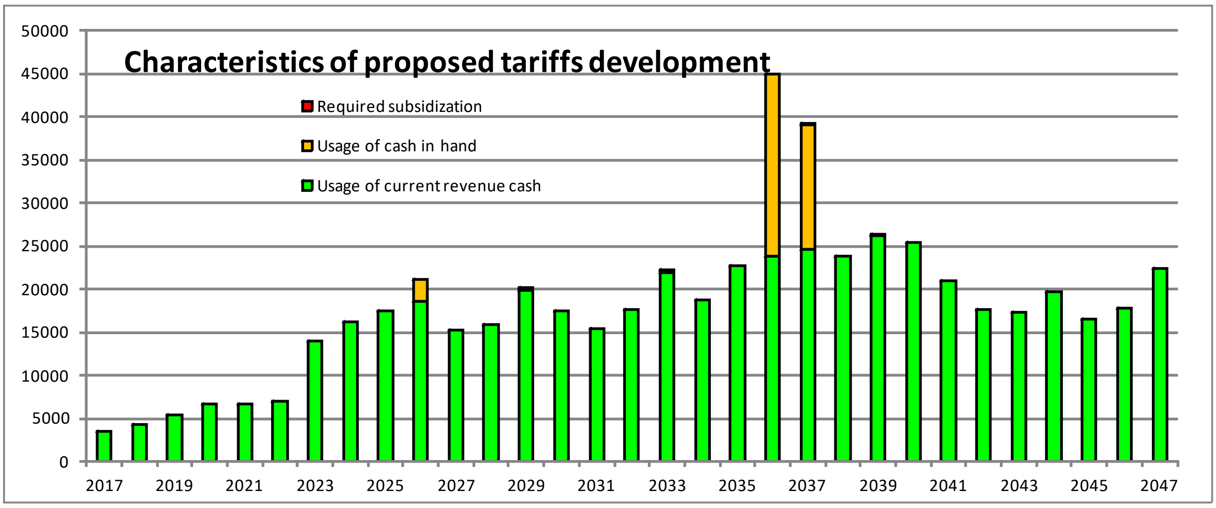


Figure 134: Adjusted Tariffs and Usage of Cash Reserves to avoid Subsidization Needs

5.2.3. Reductions in Sales Revenues (Sensitivity Analysis)

The above presented tariff proposal and the resulting cash flow development suggest that the implementation of the proposed RSWMS is very favorable. But, this result is in particular based on the assumed, high revenues from the sale of recyclables (PET, metal; P&C), bottom ash and, last but not least electricity produced at the WTE plant. For this reason in the following the impact of reductions in the sales revenues was analyzed in detail by the Consultant. The main important results are presented in the following table.

As listed there, a marginal reduction of the sales revenues has to be compensated either by a tariff increase or by the acceptance of a unique subsidization. The latter one is from the Consultant's point of view acceptable, because the remaining cash in hand at the end of 2047 after repayment of the subsidy (and the still outstanding debts) is about 82.6 million USD. This amount is a sufficiently high provision for asset replacements later than 2047.

Sales revenues reduction	Household Tariff (incl VAT)	Requires Subsidisation		Remaining cash EoY 2047	Scenrio Description (Example)
Percent	MVR / month	Amount	Years	1000 USD	
0.0%	250.00	0	0	83,029	Base case scenario
1.0%	250.00	**196**	**1**	82,605	Marginal reduction requires one-time subsidization
12.7%	250.00	2,851	1	77,638	No sale of bottom ash
33.7%	250.00	7,603	1	68,746	No sale of electricity
46.5%	250.00	10,571	2	63,355	No revenues due to WTE operating
53.5%	250.00	12,437	2	60,349	Neither sale of PET, metal nor P&C
78.2%	250.00	18,907	**3**	49,927	Only sale of PET
100.0%	250.00	**25,016**	**5**	40,676	Not any sales revenues, no tariff adjustment
100.0%	**260.00**	11,578	2	62,622	Not any sales revenues, moderate tariff adjustment
100.0%	**271.00**	0	0	86,762	Not any sales revenues, not any subsidisation

Figure 135: Different Stages of Sales Revenues Reductions

The table above shows moreover, that also significant decreases in the sales revenues, for example because the electricity produced at the WTE cannot be feed into the Maldivian electricity grid, are acceptable looking at the remaining cash at the end of 2047 and the number of subsidization years.

Even for the case that not any sales revenues can be realized, the remaining cash is still higher than 40 million USD. On the other hand, the required subsidization amounts to more than 25 million USD. For this reason increase in the waste service tariff for households and consequently for the other customers should be considered as an option for this scenario. As shown above, an increase of the household tariff for 2023 and thereafter by 10 MVR/month would reduce the needed subsidies toward “only” 11.6 million USD. Not any subsidization is required, if the corresponding tariff is increased up to 271 MVR/month for households.

5.3. Service Tariffs for C&D Waste and ELV Disposal

5.3.1. Proposed Tariff for the C&D Waste Disposal Service

For the C&D waste treatment service the Consultant’s calculations lead to the result, that the introduction of a Tilafushi gate fee for C&D waste amounting to only 2.37 USD (36 MVR) per MG C&D waste is sufficiently high to avoid the need for a subsidization. Based is this result in particular on the assumption that the C&D recyclables can be sold at 2 USD/Mg. Further reasons are the expected contents of recyclables (91%) and, last but not least the assumed delivery of the C&D waste to Tilafushi on the customers own account. Moreover, as marked by the peaks in the following figure there are only moderate replacement needs to be taken into account and not any debt service obligations were assign to this service.

However, the projected replacement needs as well as the projected OPEX are considered as sufficiently reliable by the Consultant. Contrary to that the share of recyclables which can be sorted out from the C&D waste and in particular the corresponding possible retail price are in fact unsure. For this reason, the Consultant prepared a sensitivity analysis focusing on the impact of both on the service tariff necessary to avoid the need for subsidizations. The main results are presented in the following table. As can be seen there,

- For the retail price of 2 USD/Mg a reduction of the sorted out recyclables towards 85% has to be compensated by a 50% increase of the C&D waste service tariff from 2.81 USD/Mg up to 4.21 USD/Mg.

- For a 91% sorting yield a reduction in the retail price from 2 USD/Mg towards only 1 USD/Mg has to be compensated by a 31% service tariff increase up to 3.69 USD/Mg.

Based on these results the Consultant strictly recommends that WAMCO pays special attention to the development of a market for C&D recyclables with the target to offer favorable C&D waste service tariffs to its customers.

C&D tariff sensitivity		Lower retail price		Base Case		Reduced yield recycables	
		USD / Mg			Percent		
		0.00	1.00	2.00	91%	85%	80%
Adjusted tariff	USD / Mg	4.57	3.69	2.81		4.21	5.32
Tariff increase	USD / Mg	1.76	0.88			1.40	2.51
	Percent	63%	31%			50%	89%

Table 55: Impact of C&D recyclables yield and sales price on C&D waste service tariff

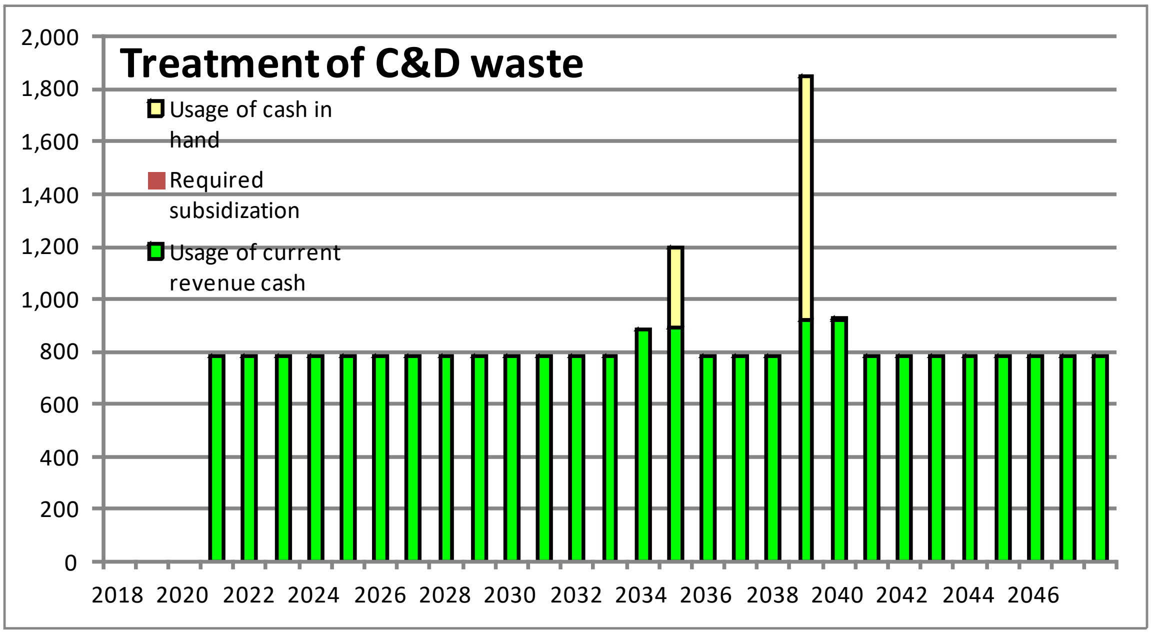


Figure 136: Coverage of Payment Obligations for the C&D Treatment Service

5.3.2. Proposed Tariff for the ELV Dismantling Service

For the ELV dismantling service the Consultant's calculations lead to the result, that the introduction of a Tilafushi gate fee for ELV amounting to 314.26 USD (4,778 MVR) per Mg ELV is sufficiently high to avoid the need for a subsidization with one exception: In 2039 a marginal support amounting to 25 thousand USD is needed to complete the replacement of the civil construction and can (in principle) be repaid already one year later. Based is this result in particular on the assumption that the applied ELV recyclables sales prices amounts to 75 USD/Mg. Further reasons are the expected contents of recyclables (90%) and, last but not least the assumed delivery of the ELV to Tilafushi on the customers own account. Moreover, as marked by the peaks in the following figure there are only moderate replacement needs to be taken into account and not any debt service obligations were assign to this service.

Accepting an about 25 thousand USD subsidization in 2039 also for variations in the recyclables yield and retail price, leads to the below listed service tariff adjustment. For ELV these adjustments are only a 2% increase if the yield rate is 85% instead of 90% and only 3% if the sales prices is reduced by 10 USD/Mg towards 65 USD/Mg. Nevertheless it is recommended that WAMCO bears in mind that a market for the recyclables needs to be developed.

ELV tariff sensitivity		Lower retail price		Base Case		Reduced yield recyclables	
		USD / Mg			Percent		
		55.00	65.00	75.00	90%	85%	80%
Adjusted tariff	USD / Mg	331.15	322.71	314.26		319.13	323.99
Tariff increase	USD / Mg	16.89	8.45			4.87	9.73
	Percent	5%	3%			2%	3%

Table 56: Impact of ELV recyclables yield and sales price on ELV disposal service tariff

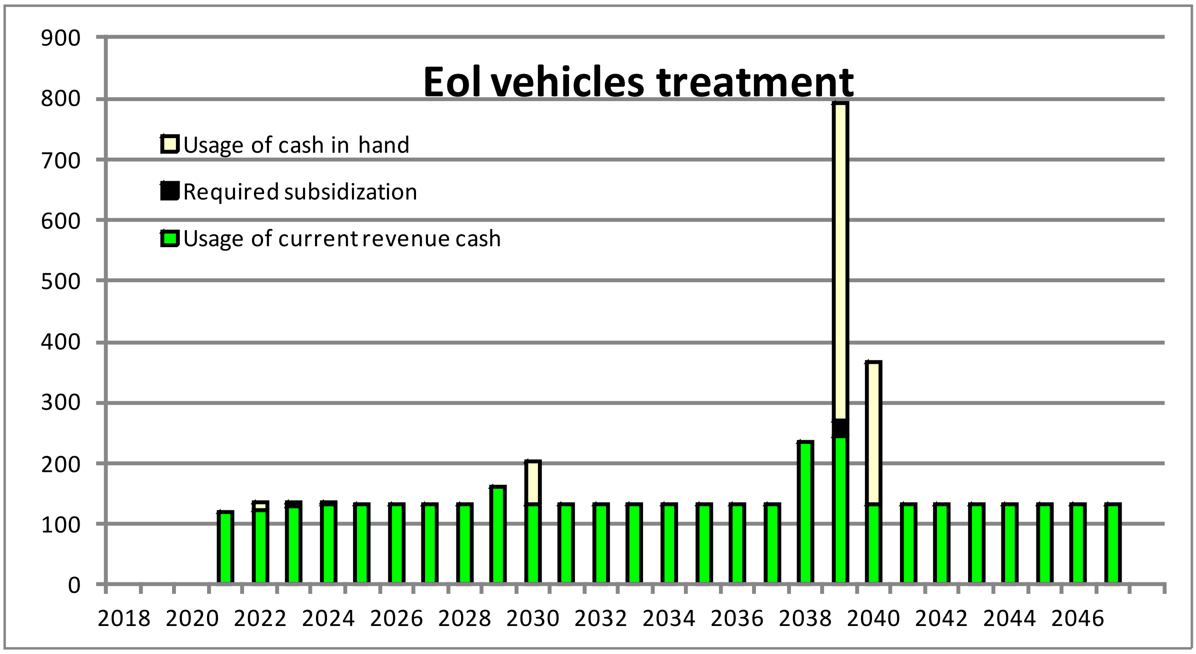


Figure 137: Coverage of Payment Obligations for the ELV Dismantling Service

CHAPTER 7: PROCUREMENT

1. Procurement Plan

The procurement plan was elaborated in coordination and cooperation with ADB's PPTA team

The following table lists goods and works contracts for which the procurement activity is either ongoing or expected to commence within the next 18 months.

Package Number	General Description	Estimated Value[9]	Procurement Method	Review	Bidding Procedure	Advertisement Date	Comments
Works							
1	Harbour rehabilitation, waste processing, administration building, and civil works (platform) for C&D plant, recycling yard, and ELV dismantling workshop.	4.4	ICB	Prior	1S2E	Q1/ 2018	Advance Contracting: Yes; Without Pre-qualification: Yes; Bidding Document: SBD Works (Large); Contract Completion period 12 months followed by Defect Liability Period.
2	2 transfer stations in Male, Villimale, and Hulhulmale waste centre (Plant contract)	6.2	ICB	Prior	1S2E	Q1/ 2018	Advance Contracting: Yes; Without Pre-qualification: Yes; Bidding Document: SBD Plant – Design, Build, Install; Contract Completion Period: 15 months followed by Defect Liability Period.
3	End of Life Vehicle (ELV) dismantling workshop (including Equipment) (Plant Contract)	1.0	ICB	Prior	1S2E	Q2/ 2018	Advance Contracting: Yes; Without Pre-qualification: Yes;

[9] Estimated values do include taxes (6% of estimated costs incl. contingencies)

Package Number	General Description	Estimated Value[9]	Procurement Method	Review	Bidding Procedure	Advertisement Date	Comments
							Bidding Document: SBD Plant-Design, build, installation; Contract Completion Period: 6 months followed by Defect Liability Period.
4	C&D waste processing plant (including equipment) (Plant Contract)	2.0	ICB	Prior	1S2E	Q1/ 2018	Advance Contracting: Yes; Without Pre-qualification: Yes; Bidding Document: SBD Plant – Design, Build, Install; Contract Completion Period: 9 months followed by Defect Liability Period.
5	Outer island waste management centres (up to 32)	2.4	NCB	Prior	1S2E	Q1/ 2019	Advance Contracting: No; Without Pre-qualification: Yes; Bidding Document: SBD Works (Large); Numbers of Contract: Multiple; Contract Completion Period: 18 month each followed by Defect Liability Period.
Goods							
6	Dumpsite equipment for immediate management measures on Thilafushi Island) Multiple Lots (5)	2.9	ICB	Prior	1S2E	Q1/ 2018	Advance Contracting: Yes; Without Pre-qualification: Yes; Bidding Document: SBD Goods; Contract (Supply) Completion Period: 9 months followed by Warranty Period.
7	Collection and transport equipment (trucks, bins) Multiple Lots (tbd)	6.2	ICB	Prior	1S2E	Q1/ 2019	Advance Contracting: Yes; Without Pre-qualification: Yes; Bidding Document: SBD Goods; Number of Contracts: Multiple;

Package Number	General Description	Estimated Value[9]	Procurement Method	Review	Bidding Procedure	Advertisement Date	Comments
							Contract (Supply) Completion Period: 9 months followed by Warranty Period.
8	Outer Island Transfer Vessels (3)	2.4	ICB	Prior	1S2E	Q1/ 2019	Advance Contracting: Yes; Without Pre-qualification: Yes; Bidding Document: SBD Goods; Contract (Supply) Completion Period: 9 months followed by Warranty Period.
9	Transfer station equipment Multiple Lots (8)	4.1	ICB	Prior	1S2E	Q3/ 2018	Advance Contracting: No; Without Pre-qualification: Yes; Bidding Document: SBD Goods; Contract (Supply) Completion Period: 9 months followed by Warranty Period.
10	Outer Island waste management centers equipment	0.9	ICB	Prior	1S2E	Q1/ 2019	Advance Contracting: No; Without Pre-qualification: Yes; Bidding Document: SBD Goods; Contract (Supply) Completion Period: 18 months followed by Warranty Period.

Consulting Services Contracts Estimated to Cost $100,000 or More

The following table lists consulting services contracts for which the recruitment activity is either ongoing or expected to commence within the next 18 months.

Package Number	General Description	Estimated Value[10]	Recruitment Method	Review	Advertisement Date	Type of Proposal	Comments
1	Project Management, Design and Construction Supervision Consultants (Firm) - Project 1	1.5	QCBS (90:10)	Prior	Q1/ 2018	FTP	Advance Contracting: Yes; Short-listing: International; Contract Type: Time Based. Contract Completion Period: 24 months.
2	Awareness building and community outreach NGO	0.35	QBS	Prior	Q1/ 2018	STP/ Bio-Data	Advance Contracting: No; Short-listing: International; Contract Type: Time Based. Contract Completion Period: 36 months.

Goods and Works Contracts Estimated to Cost Less than $1 Million and Consulting Services Contracts Less than $100,000 (Smaller Value Contracts)

The following table groups smaller-value goods, works and consulting services contracts for which the activity is either ongoing or expected to commence within the next 18 months.

Goods and Works						
Package Number	General Description	Estimated Value ($ Mn)	Method	Bidding Procedure	Advertisement Date	Notes
1	Regular office supplies and consumables.	0.50	Shopping	1S1E	2017 - 2022	Multiple Contracts Each below $100,000;
2	Fire fighting equipment (hoses, PPE, portable pumps)	0.20	Shopping	1S1E	2018-2019	Multiple Contracts Each below $100,000;

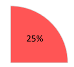
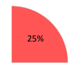
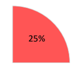
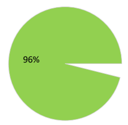
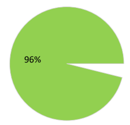
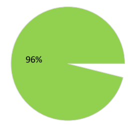
[10] Estimated values do include taxes (6% of estimated costs incl. contingencies and provisional sums

Indicative Procurement Plan – Project 2

Package Number	General Description	Estimated Value ($ Mn)	Method	Bidding Procedure	Advertisement (quarter/ year)	Notes
Civil Works						
1.	WTE facility, new landfill for residuals, and leachate treatment (SBD DBO contract – FIDIC Gold Book)	95.6	ICB	1S2E	Q4/2018	DS/OS – 15 Dec'17 EIA – 15 March'18 BD –June'18 PQ (tbd) – July 18 IFB- Dec 18 (w PQ)
2.	Dumpsite rehabilitation, remediation (BOQ based bidding document)	15.0	ICB	1S2E	Q1/2019	DD – Nov'18 EIA- Aug'18 BD – Dec'18 IFB- Feb'19
Services						
3	Project Management, Design Construction Supervision and Capacity Building Consultants (Firm) - Project 2	4.0	QCBS	90:10	Q2/2018	TOR- 1 Dec 17 EOI – Feb 18

2. Status of the procurements

	General Description	Est Value	Procurement method	PQ	Bidding Procedure	SBD	ToR	Design (actual)	Tender/bidding documents (actual status)			Advertisement	Evaluation & Awarding time	Implementation	DLP/DNP
		($ Mn)							General spec.	Technical specs	BOQ	(quarter/ year)	(months)	(months)	(months
Civil Works &Procurment of plant															
1	Harbor rehab, waste processing, admin building	2.0	NCB	No (single stage)	1S2E	Works		PD	96%	96%	96%	Q1/2018	3	12	12
2	C&D waste processing plant	1,6	NCB	No (single stage)	1S2E	Plant		PD	96%	96%	96%	Q1/2018	3	9	12
3	3 transfer stations in Male, Hulhulmale, Villamale	3,6	ICB	No (single stage)	1S2E	Works						Q1/2018	3		
3a	Lot 1: Male'							DD	75%	75%	75%			15	12
3b	Lot 2: Hulumale'								50%	50%	50%			6	12
3c	Lot 3: Vilingili/Vilimale							PD	50%	50%	50%			3	12
4	Island waste management centres (32)	2,4	NCB	No (single stage)	1S2E	Works						Q1/2018			
5	Dumpsite rehabilitation, remediation	25,0	ICB	No (single stage)	1S2E	Works						Q3/2018	3	18	
6	ELV Processing	0,5	NCB	No (single stage)	1S2E	Plant						Q3/2018			
DBO															
	Waste to Energy facility and landfill	83,0			1S2E	DBO		PD	75%	75%	50%	Q3/2018			
Goods															
5	Dumpsite and RSWMF equipment	1,3	ICB	No (single stage)	1S2E				96%	96%	96%	Q1/2018	2	9	12

	General Description	Est Value	Procurement method	PQ	Bidding Procedure	SBD	ToR	Design (actual)	Tender/bidding documents (actual status)			Advertisement	Evaluation & Awarding time	Implementation	DLP/DNP
		($ Mn)							General spec.	Technical specs	BOQ	(quarter/ year)	(months)	(months)	(months
6	Collection and transport equipment	8,5	ICB	No (single stage)	1S2E							Q1/2018	2	9	12
7	Transfer station equipment	1,8	ICB	No (single stage)	1S2E							Q1/2018	3	12	12
8	Island waste management centres equipment	3,5	ICB	No (single stage)	1S2E							Q3/2018	3	18	12
Services															
9	PMDSC phase 1	2.0	QCBS		80:20							Q4/2017			
10	Awareness building and community outreach NGO	0.2	QBS		80:20							Q1/2018			
11	PMDSC phase 2	4,0	QCBS		80:20							Q4/2017			

3. Detailed time schedule and milestone plan

See Annex 2