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# INDUSTRIAL WASTE ASSESSMENT IN THE REPUBLIC OF MAURITIUS - OPPORTUNITIES FOR INDUSTRIAL SYMBIOSIS

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## Executive summary

### Objective and activities performed

The aim of the Industrial Waste Assessment (IWA) in the Republic of Mauritius project was to stimulate industrial symbiosis through the establishment of recycling activities and a circular economy. The project also set out to review the legislative, institutional and technical framework and develop policy recommendations to support the recovery of materials and energy from industrial solid waste. Practically it meant:

- developing a methodology to identify, characterize and quantify different solid waste streams generated by industrial activities in Mauritius, thus contributing to the identification of opportunities to set up industrial symbiosis projects and programmes;
- assessing the legislative framework to identify gaps in the country's regulatory framework and propose a set of key policies to facilitate the management of industrial solid waste and the recovery of materials and energy from industrial solid waste;
- addressing capacity building by establishing a discussion forum with local experts, and provide training on conditions that promote industrial symbiosis and the building of an integrated waste management framework.

### Methodology

The methodology applied in the IWA in the Mauritius project was based on the following key elements:

1. adopt the appropriate **tools to quantify** industrial solid waste generation and identify types and amounts of waste at the national scale per year by each of the selected industrial sectors for which an industrial symbiosis project is tenable.

The tools used were:

- a. a **questionnaire**, to be filled by individual firms listing their waste, was formulated with contributions from all stakeholders participating in the Steering Committee;
- b. **on-site visits** to 23 firms of the selected industrial sectors were made;
- c. **selection of types of solid waste** which could form part of an **industrial symbiosis** approach;
- d. analysis of data available from statistics offices for each industrial sector's gross output and from the Business Registration Department for each firm's turnover. These **gross output and turnover** data were used **to estimate** the amounts of relevant waste types generated annually at the national scale in each industrial sector (**scaling-up**);

2. on the basis of the quantification performed in 1., conduct an analysis of the **legislative and institutional national framework** to identify barriers and opportunities for the development of projects to recover materials and energy from industrial waste in Mauritius;
3. identification of the **relevant actors** of industrial waste management, facilitating the sharing of different perspectives and supporting the elaboration of a common industrial symbiosis strategies;
4. addressing **capacity building**: strengthening the ability of public officers to interface with industrial management, and deepening industrial management's knowledge of the legislative framework related to waste management.

Although the questionnaire collected data on on-site wastewater production and energy consumption, the scope of the project extended only to the industrial symbiosis recovery of industrial solid waste.

### **Main types of industrial solid waste recorded in selected industries**

Based on the IWA methodology, industrial solid waste generated at industrial sites can be classified as follows:

1. solid waste that can undergo material and/ or energy recovery within the framework of industrial symbiosis projects;
2. solid waste similar to municipal waste which, following collection and transport by the firm, enter the municipal waste stream and are eventually disposed at the Mare Chicose landfill;
3. industrial solid waste (such as plastic bags containing residuals) which differ from municipal waste but are mixed with general waste and following collection, enter the municipal waste stream and are disposed at the Mare Chicose landfill;
4. solid waste already introduced into the recovery supply chain because they are collected by registered recyclers, such as: paper and cardboard, plastic films and bags, wooden pallets, used oil, etc.;
5. solid waste collected by informal recyclers and individuals, mainly for reuse, such as plastic bags and drums, carton boxes, etc.;
6. potentially hazardous solid waste stored in dedicated areas, which is transferred to the Interim Hazardous Waste Storage Facility against payment, once in operation, where it will be stored and prepared for shipment;
7. hazardous solid waste exported: the Basel Convention, which Mauritius signed, requires permits/clearance to be obtained from the relevant authorities prior to exporting such waste;
8. potentially hazardous electronic waste, currently being stored, such as neon lamps.



The different types of solid waste that have been identified in each industry and the current means of waste management for each of these are listed in greater detail in Table ES1; the different types of solid waste that are common to all industries assessed in this study are presented as well.

**Table ES1: Types of solid waste registered during IWA**

<b>SECTOR</b>	<b>SOLID WASTE</b>	<b>CURRENT MANAGEMENT</b>
<b>Food poultry</b>	- Organic waste from poultry (including offal, feathers, head, contaminated birds, feet, blood, fat)	Material recovery to produce flour for pet food Landfill
	Carton boxes / paper	Landfill: too dirty to be recycled
	Plastics	Landfill: too dirty to be recycled
	Faeces and farm waste	Composted and compost to local market
<b>Food seafood</b>	Organic waste from fish (including whole dead fish, fish bones and fish internal waste)	Landfill
	Fish food packaging (plastics)	Landfill: too dirty to be recycled
	Salt	Landfill
	Used Oil	Recycling
<b>Food bottling</b>	HDPE	Recycling
	Organic waste, including plastics	Landfill
	Carton boxes	Recycling
	Milk powder packaging (composite bag made of paper and plastics)	Recycling
	Metal drums	Recycling Reuse
	Scrap metal	Recycling
	Paper	Recycling
	Glass bottles and debris	Recycling Landfill
<b>Textile and wearing apparel</b>	Yarn and cotton fabric	Recycling
	Woollen fluff	Landfill
	Obsolete chemicals	Storage Landfill
<b>Chemical</b>	Chemical waste	Storage
	Metal drums	Reuse (after cleaning in firm)

<b>Printing</b>	Aluminium plates	Recycling
	Paper to be kept confidential	Landfill
	Plastic toner container	Storage
<b>All sectors</b>	General waste (canteen, offices, sweepings)	Landfill
	Carton boxes / paper	Recycling
	Plastics	Recycling
	Wooden pallets	Reuse
		Recycling
	Exhausted oil	Recycling
	E-waste, batteries, lighting equipment	Recycling
		Storage (if potentially hazardous)
Scrap metals	Recycling	

### **Solid waste relevant for industrial symbiosis by industry**

The IWA project revealed that among the industries investigated, the only industries which generate waste of a sufficiently high grade that could be incorporated into this first industrial symbiosis project were:

- food and
- textile and wearing apparel

The results of the estimate of amounts generated nationally by type of waste are presented in Table ES2.

Table ES2: Estimate of waste amount generated nationally by type of waste

<b>SECTOR</b>	<b>SOLID WASTE TYPE</b>	<b>AMOUNT FOR THE 23 INDIVIDUAL FIRMS (t/year) (data from the questionnaires)</b>	<b>ALREADY RECOVERED IN THE 23 FIRMS (data from the questionnaires)</b>	<b>AMOUNT ESTIMATED FOR IS PER ENTIRE INDUSTRY (t/year) (results of the scaling-up exercise)</b>	<b>INDUSTRIAL SYMBIOSIS OPPORTUNITIES</b>
<b>Food (poultry)</b>	Organic waste from poultry (including offals, feathers, head, contaminated birds, feet, blood, fat)	6,855	3,000 (estimated)	7,300	Production of pet food  Anaerobic digestion with energy recovery
<b>Food (seafood)</b>	Organic fish waste	35	No recovery at present	1,400	Production of pet food Omega oil production
<b>Textile and wearing apparel</b>	Cotton, yarn and fabric, woollen fluff	1,265	Almost all yarn and fabric waste is currently recycled, a small fraction is recovered as energy.	8,000	Energy recovery Material recovery in the building industry
<b>Poultry Textile Chemical</b>	Wooden pallets	60 (this estimate is affected by high uncertainty)	Wooden pallets are always reused, repaired and only when needed are sent for recycling, or occasionally used as an energy source.	300	Energy recovery Artisanal re-use and recycling

## Opportunities

The results of the IWA study highlight that specific types of industrial waste R&D projects could be carried out in the industries investigated to assess the feasibility of expanding or creating production lines of new materials from the following solid waste:

- **Textile material:** an R&D project could be initiated to investigate the fuel characteristics of textile waste with regard to the impact on air emissions and energy recovery equipment (e.g. boiler): the effectiveness of fume abatement systems must be verified when the fuel composition is modified; the corrosion or slagging problems caused to the boilers must also be determined to ensure lasting operation;
- **Textile material:** the possibility of using cotton and wool fabrics to domestically produce building materials for thermal and/or noise insulation could be investigated in an R&D project. The recycling industry could also be involved in this type of project.
- **Organic food waste:** the recovery of organic waste for pet food production could be increased by connecting specific firms with the industries already producing pet food and operating in Mauritius.
- **Organic food waste:** the possibility of producing omega oil from seafood waste was also investigated and it appears that this industry opens up promising prospects for further R&D projects.
- The IWA project has initiated discussions between firms involved in the seafood industry where waste from one firm can be used as raw material by another. The firms preliminarily agreed to collaborate, however, further assessments need to be carried out to verify the future amount of waste generated.
- **Organic food waste:** the technical and commercial feasibility of using organic food waste in energy recovery projects in connection with other types of organic waste, such as municipal waste collected separately, mainly using anaerobic digestion technologies, could also be investigated in specific research projects, with a medium-term time reference.
- **Wooden pallets:** when wooden pallets reach their end of life, they could be used in energy recovery projects. A technical and commercial feasibility project is necessary to define the amount available in the entire industrial sector and the possibility of using them in energy recovery projects.

It must also be mentioned that the reuse of wooden pallets for the production of household objects in Mauritius has recently been initiated by a recycling enterprise.

## **Constraints**

In the course of the IWA project, the technical expertise of the staff of firms visited was high and fully proficient to understand the different waste streams and how to quantify and qualify them. Similarly, no specific institutional or legislative obstacles that could potentially hamper these industrial symbiosis projects in its initial stages were identified. Technical knowhow and capacity among the workforce of the firms visited were also considerably high enough to undertake the waste assessment required for industrial symbiosis. The overall policy context could nonetheless be made more conducive to industrial symbiosis; the necessary measures to address the constraints can be summarized as:

- strengthening the overall framework for the recovery of material and energy from every type of waste;
- furthering the investigation on type, amount, and characteristics of industrial waste and making the best use of information already available.

These constraints not only require the initiation of industrial symbiosis projects to be supported by private industrial actors, but also that the framework conditions which could improve the overall recovery of these types of industrial waste be put in place by the public sector.

## **Recommendations**

The assessment of the effectiveness of Mauritius' current legislative and institutional conditions that are relevant for waste management and environment protection underscores the need to homogenize the different acts that have been introduced in the last few years by different ministries.

In addition to this assessment, the description of the current conditions of waste management highlight that landfilling is the prevailing solution for municipal waste, and that recovery of industrial waste is voluntarily being carried out by individual firms.

To address these concerns and support the implementation of recovery activities of both materials and energy from industrial waste and the development of industrial symbiosis projects, a set of recommendations was issued:

Recommendation		Responsible WM actor	Time frame	
<b>Legislation</b>	1	Analysis of the lessons learnt in implementing WMS 2011: difficulties encountered and selection of positive factors	MoE MoLG Local authorities	Short term
	2	Assess the feasibility of adopting extended producer responsibility to packaging aside from weee	MoE MoFinances	Medium term
	3	Provide for a unique legal definition of waste	MoE	Short term
	4	Provide for a clear legal definition of each wm phase	MoE MoLG	Short term
<b>WM strategy</b> <i>please note that these recommendations also require R&amp;D projects to be carried out</i>	5	Integrate the WM strategy with the energy strategy and assess the role of efficient wm in reducing greenhouse gas emissions	MoE MoE and PU	Short term
	6	Integrate industrial flows of similar characteristics with flows of municipal waste in recovery and treatment processes	MoE	Medium term
	7	Feasibility study for the introduction of separate collection of organic waste, of municipal waste and in selected industries	MoE MoLG BM	Short term
<b>Institutional setting</b>	8	Homogenize waste legislation and better define institutional responsibilities Consider the possibility of creating a single enforcing agency	MoE MoLG MoH	Medium term
	9	Monitoring of policies based on specific indicators	MoE	Short term
<b>Industrial waste audit and database</b>	10	Revise industrial waste audit procedures and forms	MoE	Short term
	11	Set-up a database on industrial waste	MoE	Medium term
<b>Industrial organizations' proactive involvement in capacity building and R&amp;D projects</b>	12	The SC will remain operational to support R&D and implement recommendations	MoI / BM	Short and medium term
	13	Capacity building towards other firms and sme <sub>s</sub> support further research & development projects	MoI/MoE /MoB BM Research institutions	Short and medium term
	14	Establish a recyclers association	Recyclers /BM MoI / MoE	Short term
<b>Cost and finance of WM</b>	15	Define the structure of wm costs and the cost of managing industrial waste incurred by the public sector separate wm taxes from other taxes	MoE MoLG MoFinance	Short term
	16	Clarify mechanism for feed-in tariffs	MoEnergy&PU MoFinance MoE	Medium term

# **1 Introduction**

## **1.1 Key issues and questions addressed**

The PAGE initiative was launched in Mauritius in April 2014, with a follow-up joint inception mission in July 2014 that brought together various parts of government, including environment and sustainable development experts, economy and finance, industry, employment as well as social partners, academia and development agencies. Working at the policy and strategic levels, PAGE in Mauritius aims to support government policy objectives under the Green Economy Action Plan (GEAP). It is in line with the Government Vision 2030 which addresses complementary dimensions of stimulating green investments and policy reforms to deliver sustainable growth, job creation and poverty eradication.

As part of the inception phase, there was strong private sector demand for an industrial symbiosis project. In response to this request, UNIDO in collaboration with the Ministry of Industry, Commerce & Consumer Protection (Industry Division), henceforth referred to as MoI, designed an Industrial Waste Assessment to determine the feasibility of industrial symbiosis in Mauritius. In January 2016, the Government of Mauritius, through the Cabinet, took note of the implementation of the IWA project which was launched in February 2016.

A national Project Steering Committee (PSC), co-chaired by the Ministry of Industry, Commerce & Consumer Protection and Business Mauritius (BM), was set up in January 2016 to supervise the implementation of the Industrial Waste Assessment (IWA) project and to endorse the scope of the study. The Project Steering Committee consists of:

- Ministry of Finance & Economic Development
- Ministry of Environment, Sustainable Development, Disaster and Beach Management
- Ministry of Energy & Public Utilities
- Wastewater Management Authority
- United Nations Resident Coordinator's Office
- Mauritius Chamber of Commerce & Industry
- Mauritius Export Association (MEXA)
- Business Mauritius.

A Technical Working Group (TWG), a sub-committee of the Steering Committee, was set up and is chaired by the Ministry of Industry, Commerce & Consumer Protection. The TWG consists of:

- Ministry of Environment, Sustainable Development, Disaster and Beach Management
- Wastewater Management Authority
- Business Mauritius
- UNIDO local team.

The aim of the project is to stimulate industrial symbiosis through the establishment of a recycling industry and a circular economy in Mauritius. The project also envisages a review of the legislative framework to develop specific industrial waste policy recommendations, which have been validated by stakeholders to help Mauritius shift towards a greener and more competitive economy.

The main objectives of the Industrial Waste Assessment (IWA) project are to:

- develop a methodology to identify, characterize<sup>1</sup> and quantify different waste streams generated by industrial activities in Mauritius, thus supporting the identification of opportunities for the launch of industrial symbiosis programmes;
- assess the legislative framework to identify gaps in the country's regulatory framework and propose a set of key policies to facilitate the management of industrial solid waste and the recovery of materials and energy from industrial solid waste;
- address capacity building by setting up a discussion forum in collaboration with local experts and provide training on conditions that favour industrial symbiosis and the building of an integrated waste management framework.

The IWA in Mauritius project also considered the establishment of a waste databank and the development of performance indicators to facilitate the monitoring and evaluation of any subsequent industrial waste management schemes which may follow from this study.

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<sup>1</sup> In the context of this project, waste characterization does not involve sample collections or laboratory analysis: here, it involves classifying the type of waste on the basis of its industrial production process and estimating the amount produced annually by the firms visited and the yearly amount generated by the industrial sector as a whole (if possible, on the basis of available statistical data).



## 1.2 Differentiation/Linkage to other assessments

Below is a review of previous studies that have addressed the quantification of waste in Mauritius.

### 1.2.1 Waste in the region

The “Etude de Diagnostic pour une gestion optimisée des déchets dans l’océan indien” carried out by the Indian Ocean Commission in 2014, covered hazardous waste (such as batteries, E-waste, PCBs) and waste with a high valorisation potential in terms of material recovery to define the feasibility of establishing regional policies.

The study positions Mauritius among the countries in the region as having a *structured* waste management framework characterised by:

- the presence of specific regulations on solid waste
- the fact that local authorities have a specific role in waste management
- the existence of a mechanism for funding costs and investments
- specific techniques that have been adopted: this refers to the presence and management of transfer stations
- involvement of the private sector, but only to a limited degree
- the service is managed as a public service, thus attention is given to the quality of the service being provided.

The study underlines the economic role of several actors and highlights the role of the informal sector in the waste valorisation chain. Even though the analysis mainly refers to the situation of Madagascar and Comoros, where the WM system is only in the *emergent* state and the informal sector therefore plays a greater role in it, this PAGE study found that the informal sector operating in WM in Mauritius is involved in the recycling of certain types of industrial waste (e.g. carton boxes) and is also involved in some good practice of reuse (e.g. plastic drums, after cleaning, for gardening in community buildings).

The study showed that Mauritius has already established a supply chain for the valorisation of waste oil.

The study’s major recommendation was to strengthen the institutional framework and the collection and recovery activities for electronic waste, car batteries, pesticides, tyres, as well as setting up appropriate framework conditions for the valorisation of paper, plastics and ferrous metals.

The study concluded that the lack of knowledge with respect to the management of hazardous industrial waste.

### ***1.2.2 Hazardous Waste Inventory (HWI)***

The study “Hazardous Waste Inventory report for Mauritius” carried out by the Ministry of Local Government and Outer Islands and the Africa Institute for the Environmentally Sound Management of Hazardous and Other Waste in 2012, compiled a national inventory of hazardous waste generation—of both solid and liquid waste—in Mauritius. The objectives of the Inventory were to:

- identify industrial and non-industrial hazardous waste generating industries in Mauritius;
- collect and compile data to estimate hazardous waste generation by source and type, as listed in the European Waste Catalogue, prepare inventories of hazardous waste generated annually in Mauritius with forecasts on the trend of waste generation;
- collect and compile data to estimate hazardous waste stored by industrial and non-industrial facilities in Mauritius;
- assess current levels of hazardous waste handling and management practices in Mauritius and quantify the amount of hazardous waste being treated/disposed;
- characterize and classify hazardous waste generated/stored by industrial and non-industrial facilities based on the Basel Convention classification scheme;
- classify and group hazardous waste generated/stored in categories based on considerations of similar recycling, treatment and disposal methods;
- establish a list of hazardous waste generators and hazardous waste considered a priority for sustainable hazardous waste management.

The HWI study was based on a questionnaire which was sent to different companies and organizations, field visits carried out to collect data and consultation of Industrial Waste Audit reports.

The study produced a table summarizing the amount of potentially hazardous waste estimated to be generated by each industry.

Conclusions that are relevant for this IWA study relate to:

- used oil - “the recovery of used oil generated island-wide should be improved with a more effective collection system. Some large generators of used oil (e.g. CEB, large vehicle maintenance facilities, textile manufacturing, sugar industries, edible oil refineries, and petroleum companies) have already set up storage and collection systems at their premises”; and
- e-waste: “To increase the recycling rate of e-waste, several alternatives can be considered:

- a recycling fee to be charged by the vendors to customers up front when they purchase the electronic equipment or its accessories. The vendors should have a storage facility for these e-wastes where customers can deposit them at no cost when they are no longer used or functional. The vendors can then contact and pay the recycling company for the collection of e-waste.
- the government can plan to collect e-waste on specified dates in the country at no cost to the generators, with the support from some companies in the private sector and then pay the recycling company for collection”.

### **1.2.3 The IWA in Mauritius**

This PAGE study differs from previous ones as it investigates the feasibility of setting up an industrial symbiosis framework with existing industrial waste.

The main objectives are, therefore, to conceptualize and implement a methodology to:

- identify and quantify the different waste streams generated by the main industrial processes in each industry: by means of reconstructing a process flow diagram;
- discuss uncertainties associated with the quantification of the flows of different industrial waste types, in particular those that can undergo industrial symbiosis;
- identify the technical conditions and governance framework required to support the recovery of materials and energy from waste;
- identify the relevant actors and provide a basis for discussion as well as for the identification of necessary measures.

Having performed on-site visits for firms from five selected industrial sectors, this IWA study is able to:

1. identify the specific types of waste generated in industrial activities in five selected industries, which could undergo material and energy recovery;
2. estimate the available annual amount of each type of waste;
3. identify which industrial waste from these five industries is already, even if only partially, being recycled and reused;
4. identify other waste flows which can undergo different material and energy recovery and suggest integration with municipal waste management.

## **2 Policy context and governance structure**

### **2.1 Institutional setting and coordination**

#### ***2.1.1 Ministry of Environment, Sustainable Development, and Disaster and Beach Management***

The **Solid Waste Management Division** of the Ministry of Environment, Sustainable Development, and Disaster and Beach Management is responsible for environmental protection and public health through proper management of solid and hazardous waste. Its major functions are:

- formulation of policies and strategies for the environmentally sound management of municipal solid waste and other waste streams, including hazardous waste;
- implementation of projects and programmes for the environmentally sound management of municipal solid waste and other waste streams, including hazardous waste;
- operation and management of waste management facilities, namely transfer stations, sanitary landfills and interim hazardous waste storage facilities;
- enforcement of the Environment Protection (Standards for Hazardous Waste) Regulations of 2001, the Environment Protection (Collection, Storage, Treatment, Use and Disposal of Waste Oil) Regulations of 2006 and the Local Government (Dumping and Waste Carriers) Regulations of 2003;
- control over the activities of private operators in the field of waste management.

The **Pollution Prevention and Control Division**, which ensures proper implementation of the Industrial Waste Audit regulations, operates within the Ministry of Environment (refer to section 0 for more detail).

#### ***2.1.2 Local authorities (under the Ministry of Local Government)***

**Local authorities** play a pivotal function in waste management. In fact, the Local Government Act of 2011 establishes that “A Municipal City Council, Municipal Town Council or District Council shall, subject to its financial capability and within the limits of its administrative area, be responsible [....]

...for the collection and conveyance of waste from households and public places to disposal sites or waste management facilities”.

A local authority shall:

- “(a) implement programmes and put in place mechanisms for waste minimisation, storage, collection and conveyance of waste to waste disposal sites or waste management facilities;
- (b) ensure that waste is put in appropriate storage receptacles for collection;
- (c) arrange for the regular collection of waste in its jurisdiction area and transfer to disposal sites or

waste management facilities, as appropriate.”

Thus, adopting the most globally widespread approach to waste management, local authorities in Mauritius are responsible for the collection of waste.

It must be noted that local authorities are not involved in the collection of industrial waste.

Given the broad definition of waste in the current legislation, local authorities currently collect waste which can be identified as:

- household waste,
- commercial waste (such as from shops and restaurants),
- business waste (such as from offices).

Moreover, the responsibilities of local authorities extend to the “removal of any type of waste that has been deposited on any premises or take other steps such as:

- (a) where it considers that such waste should be removed to eliminate or reduce the consequences of the deposit of it and take action to prevent pollution of the environment or which may represent danger to human, animal or plant life; or
- (b) where the owner of the premises in question is untraceable”.

Local authorities may introduce regulations to provide for:

- “the levying of fees and charges, including different charges for
  - the removal of any type of waste;
  - the removal of waste from properties or part of properties used for residential, commercial or industrial purposes;
- the supply of storage receptacles for different categories of wastes;
- the removal of waste unlawfully deposited, clearing of bare lands and the recovery of expenses incurred.”

### ***2.1.3 Ministry of Industry, Commerce & Consumer Protection, Commerce & Consumer Protection***

According to current legislation, the Ministry of Industry, Commerce & Consumer Protection, has no direct responsibility in the management of industrial waste.

### ***2.1.4 Ministry of Health and Quality of Life***

The Ministry of Health is responsible for controlling health-related aspects of waste. The Public Health Act defines problems and empowers health inspectors to issue sanitary notices for offences relating to solid waste and wastewater not connected to the sewer networks.

The Ministry of Health is also a member of the Industrial Waste Audit Committee at the Ministry of Environment.

## **2.2 Legal framework**

The main legal acts defining the framework for waste management in Mauritius are the Environment Protection Act (EPA) of 2002, amended in 2008, and the Local Government Act (LGA) of 2011. Specific regulations made under EPA 2002 and LGA 2011.

### ***2.2.1 Environmental Protection Act 2002 (as amended in 2008)***

Embracing the principles of sustainable development, the overall goal of EPA 2002 is “to provide for the protection and management of the environmental assets of Mauritius“ and ”more specifically, to provide for the legal framework and the mechanism to protect the natural environment, to plan for environmental management and to coordinate the inter-relations of environmental issues, and to ensure the proper implementation of governmental policies and enforcement provisions necessary for the protection of human health and the environment of Mauritius.”

Under EPA, the Permanent Secretary shall make arrangements for:

- (a) the collection and disposal of waste;
- (b) the operation and management of disposal sites.

Part VI – National Environmental Standards cover waste and state that the Minister of Environment:

- (42) “may, by regulations, declare what wastes are to be considered as **hazardous wastes**.

In determining what wastes shall be declared hazardous, the Minister [of Environment] shall have regard to such special circumstances as he considers appropriate, including quantity, location, and climatic conditions, relating to discharges.

The Minister shall prescribe standards for hazardous wastes to control pollution of the environment and to promote public health and welfare.

The Minister may make regulations for:

- (a) the control of the import, export, collection, movement, transit, transportation and disposal of hazardous wastes;
- (b) the licensing of waste disposal sites, waste management systems and other facilities relating to the disposal of hazardous wastes in an environmentally sound manner.”

The Minister shall specify standards for the collection, transportation, storage, processing, disposal and recycling of non-hazardous wastes.

As regards waste management plants, a **preliminary environmental report** describes the proposed facility and provides all necessary information to identify and assess the impacts the plants are likely to have on the environment and on society, and the measures proposed to avoid, reduce and, where possible, remedy any significant impact on the environment is required for:

- recycling plants, and
- rendering plants.

With respect to waste management, an **environmental impact assessment** is required for:

- incineration of municipal solid waste, quarantine waste, medical and clinical waste
- landfill
- municipal wastewater treatment plant
- transfer stations for solid waste
- used or waste oil treatment and disposal.

Fixed penalties are foreseen for the following **offences**:

discarding, placing, throwing away, leaving behind or causing any litter to be dropped or waste generated from any trade, business, industry, office or any service provider, in any:

- lake, reservoir, stream or watercourse or upon the bank of any of the same or beach or any part of sea; and
- canal, drain or public place.

The EPA Act also establishes that “an authorised officer may serve an **eyesore abatement notice** on the owner or occupier of any land, building or structure on which any eyesore [...] is detected”. Among these eyesores there is the “**depositing or dumping** of household, commercial or trade refuse, vehicle wrecks, agricultural, building or excavation waste, animal carcasses or any other waste materials on any premises”.

An enforcing agency shall:

- supervise the enforcement of national environmental standards and notices, orders and directives issued under an environmental law;
- verify compliance with environmental laws;
- conduct regular monitoring, sampling, test and analyses to ensure compliance with environmental laws; provide such assistance as may be required for reviewing an EIA and in case of a spill or an environmental emergency;
- carry out directions issued by the Minister.

An enforcing agency shall:

- (a) have all the powers conferred on an authorized officer under sections 79, 80, 81,88 and 89, and delegate its powers in writing to any officer of the Ministry, authority, corporate body or Department, as the case may be;
- (b) make available all facilities required for carrying out environmental monitoring, laboratory analyses and tests to other enforcing agencies and to the Department;
- (c) keep a record of all inspections and compliance monitoring exercises as well as information and environmental data obtained from such monitoring;
- (d) upon request, provide the Director with a copy of the record.

The EPA 2002 also establishes the scheduled industries under the IWA Regulations 2008 to perform an **industrial waste audit** which covers the inventory of waste generated in the industry and provides for the development and implementation of an environmental management plan.

### **2.2.2 Public Procurement Act**

The Public Procurement Act defines the procurement procedures to be adopted, and standard bidding documents are available for scavenging services and works.

The conditions of contract are well detailed. Enforcement officers of the SWMD carry out regular inspections to ensure compliance with the scope or works. Any shortcomings noted are reported to the



project officers who, in turn, apply the necessary penalties or liquidated damages for lack of performance. Meetings are held with the contractors to ensure that they take the necessary remedial measures.

### **2.2.3 Local Government Act (LGA) of 2011**

This Act provides “the legislative framework for a democratic, efficient, effective, inclusive and accountable system of local government permitting local communities to manage autonomously, through elected local authorities, the economic and social well-being of their areas”.

It defines the functions of the Ministry of Local Government and Outer Islands and the functions and services of the local authorities on waste management.

It establishes that

“no person shall deposit, or cause, or allow to be deposited, any household or commercial waste, litter, vehicle wreck, excavation or builder’s rubble, household furniture, animal carcass or any other material whether liquid or solid, on any street, pavement, bare land, vacant premises, drain, canal, rivulet, river, stream, reservoir or any public place.”

### **2.2.4 Ministry of Environment Environmental Protection (Standards for Hazardous Waste) Regulations 2001 (Government Notice No. 157 of 2001)**

The aim of the “Environmental Protection (Standards for Hazardous Waste) Regulations 2001” is to control the export, collection, on-site treatment, transportation and disposal of hazardous waste (HW).

HW regulations postulate that the waste generator must minimize HW generation and ensure that HW is properly stored, treated on site or disposed of; HW must be safely stored and transported and containers must be labelled with all necessary information to identify their HW characteristics.

Every three months, HW generators must draw up an inventory of the HW generated and to notify the enforcing agency.

Storage of HW must receive prior approval by the enforcing agency.

An HW tracking system based on **consignment notes** is in place, which gives responsibility to all actors involved: the generator, the consignor, the carrier and operator of treatment or disposal plants.

HW can only be disposed of at a disposal site approved by the enforcing agency and after the necessary pre-treatment which may be imposed by the enforcing agency prior to disposal.

HW can only be exported upon written approval by the enforcing agency. Imports of HW are prohibited.

### **2.2.5 Ministry of Environment - Guidance Notes for the Implementation of Environmental Protection (Standards for Hazardous Waste) Regulations 2001**

These Guidance Notes elaborate the duties and obligations of the persons involved in hazardous waste management (generators, carriers, persons carrying out treatment or disposal, and government officials) under the Hazardous Waste Regulations 2001.

### **2.2.6 Ministry of Environment – Environmental Protection (Industrial Waste Audit) Regulations 2008 (Government Notice No. 255 of 2008)**

Section 48 of the Environmental Protection Act 2002 provides for pollution control by means of an Industrial Waste Audit. With a view to promoting a clean and green environment, the then-Ministry of Environment and NDU promulgated the Environmental Protection (Industrial Waste Audit) Regulations 2008 (GN No. 255 of 2008), which came into force on 01 April 2009.

The objectives of the Environmental Protection (**Industrial Waste Audit**) Regulations 2008 are to:

- prompt industries to adopt a proactive attitude rather than the traditional end-of-pipe approach;
- develop a sound understanding of all sources of waste streams in an industry;
- optimize use of resources;
- facilitate elimination of waste and associated disposal problems;
- develop a waste management system and hence comply with discharge/emission regulations;
- develop a culture of industrial environmental compliance through an EMP, which:
  - includes adoption of clean technology and waste minimization benefits;
  - leads to significant savings in the medium to long term; and
- induce industries to adopt international environmental standards such as ISO 14001.

The obligations under the Industrial Waste Audit Regulations 2008 are as follows:

- i. According to these Regulations, existing industrial activities (prior to the IWA regulations entering into force) listed in the First Schedule of the Regulations had to fill in an IWA form and submit it to the Director of Environment within a 3-month period (from the date of the Regulations' coming into force). The IWA form inquires about general information on the given activity and specific information relating to the various environmental aspects of the activity;
- ii. Section 3 of the Regulations requires new industries to submit an IWA form no later than 12 months from the date of commencement of the activity;

- iii. Based on information included in the IWA form and taking account of the nature, significance and impact of the waste generated on the environment, the industries/activities may be further required to:
- Submit an IWA report within a period of 6 months;
  - Develop an Environmental Management Plan (EMP) and submit it within a period of 9 months; and
  - Implement the EMP following its approval by the Department of Environment.
- iv. An IWA report contains, *inter alia*, information on the features of the industrial site, a description of inputs and outputs of the processes, a description of all process discharges, flow diagrams and the operational performance of the industry;
- v. The EMP contains, *inter alia*, statements by top management on their organizations' environmental policy and commitment, a description of the objectives and targets, the structure put in place to implement it and a description of how the organization addresses environmental issues such as air pollution, water pollution, solid waste (hazardous and non-hazardous), noise, as well as the record-keeping system put in place; and
- vi. Failure to comply with the Regulations shall constitute an offence and the offender shall, on conviction, be liable to a fine not exceeding INR 50,000.

Section 7 of the IWA Regulations provides for an **IWA Committee** to be set up to ensure proper enforcement and implementation of the said Regulations.

The role of the Committee consists of:

- Developing criteria or guidelines for the evaluation of the IWA form and to decide whether an IWA Report is required;
- Making recommendations to the Director for the approval of the EMP;
- Establishing a monitoring programme and developing reporting formats to ensure compliance with the Regulations;
- Ensuring proper implementation of measures mentioned within an EMP;
- Preparing and submitting annual progress reports to the Director; and
- Determining appropriate enforcement measures in case of non-compliance with the Regulations.

The Committee is comprised of representatives from the following organizations:

- Ministry of Environment, National Emergency Centre & Beach Authority;
- Ministry of Local Government & Outer Islands;
- Ministry of Health and Quality of Life;
- Ministry of Housing and Lands;
- Ministry of Energy and Public Utilities (Wastewater Management Authority);
- Ministry of Energy and Public Utilities (Water Resources Unit);
- Police de l'Environnement and other members co-opted as and when required.

#### ***2.2.7 Local Government (Registration of Scavenging Contractors) Regulations 2004***

These Regulations define the conditions for registration of scavenging contractors (defined as persons who offer services to collect and transport waste).

#### ***2.2.8 Local Government (Registration of Recycling and Exporting) Regulations 2013***

These Regulations are particularly relevant for the IWA project because they define conditions for the safe operation of a recycling facility.

They also establish that “no person shall:

- dismantle waste;
- recycle waste;
- export waste,

unless he/she is registered in accordance with these Regulations with the Ministry of Local Government.

Every year, the amount of different types of waste received, recycled, dismantled, delivered off-site or exported for recycling must be reported by filling out the provided forms and submitting them to the Ministry of Local Government. The categories of waste included are:

- Carton
- Construction and demolition waste
- Electrical and electronic-waste (e-waste)
- Fluorescent lamps

- Glass
- Green waste
- Municipal waste (mixed waste)
- Paper
- Photographic and printing waste
- Plastic
- Textile waste
- Timber/wood
- Used batteries
- Used tyres
- Waste oil.

#### **2.2.9 Local Government (*Dumping and Waste Carriers*) Regulations 2003**

These Regulations establish the conditions for issuing a waste carrier licence and for transport that is safe in terms of public health and the environment. Moreover, any person carrying waste in a waste carrier shall have written authorization from the Ministry to use a transfer station or waste disposal site or any other site approved by the Minister for that purpose.

These Regulations establish that “no person shall:

- deposit, cause or allow waste to be deposited at a place other than a transfer station or a waste disposal site or any other site approved for that purpose;
- throw, drop or otherwise deposit or cause any littering in any street, road, drain, river or other public place other than in a space or bin specially provided for that purpose”.

### ***2.2.10 Wastewater (Standards for Discharge of Industrial Effluent into a Wastewater System) Regulations 2004***

These Regulations are relevant for the IWA project because they establish that “no person shall discharge or cause to discharge industrial effluent into a wastewater system unless he holds a licence with a three-year period of validity, issued under these regulations”. Upon obtaining a licence, the person responsible will have to:

- (a) take a composite sample of industrial effluent at intervals specified in the Second Schedule;
- (b) analyse the composite sample of industrial effluent for the purpose of determining the level of pollutant as specified in these Regulations; and
- (c) submit a monthly report of the result of the analysis to the Authority.

Several industries covered by the IWA project produce effluent and are thus subject to the specifications defined by these Regulations.

The Regulations also require a pre-treatment system to be installed, approved by the Authority, to ensure that any discharge of industrial effluent is in compliance with the permissible limit of pollutant as specified.

The relevant substance in each industry and the permissible limits of pollutants to be discharged as industrial effluent are provided in these Regulations, together with the penalties associated with each pollutant.

Moreover, the industry shall notify the authorities of any accidents or spills resulting from an increase in the concentration or load of pollutants contained in the industrial effluent and take immediate corrective action to reduce the level of pollutants to comply with the permissible limits.

To ensure good quality of control, the authorities may access the industrial premises any time for the purpose of inspecting and maintaining the public wastewater network, inspecting and verifying any meter and sampling device used, and collecting samples for the analysis of industrial effluent discharged.

### ***2.2.11 Environmental Protection (Effluent Discharge Permit) Regulations 2003, amended in 2004***

These Regulations establish that no person shall discharge or cause to be discharged any effluent from any of the main industries and production plants into a watercourse, waterbody or onto any land, unless it has an Effluent Discharge Permit from the appropriate enforcing agency upon payment of a fee specific for each industry. This permission is never granted for watercourses or waterbodies in which water is abstracted for domestic purposes.

Effluent is defined as “water sullied or contaminated by any matter, in solution or suspension and derived from the use of the water in connection with domestic, industrial or other activities”.

The application for a discharge permit must be accompanied by a contingency plan specifying which measures the applicant will take in case of a breakdown or failure in the treatment works or processes. The permit specifies the maximum volume of effluent that may be discharged daily; the maximum rate at which any effluent may be discharged at any time; the method of sampling and location of effluent sampling points; and the frequency at which such analysis is to be conducted. The list of parameters is industry-specific and effluent analysis results shall be forwarded to the enforcing agency on a monthly basis.

### ***2.2.12 Consumer Protection (Scrap Metal) (Amendment) Regulations 2016***

The Consumer Protection (Scrap Metal) (Amendment) Regulations 2016 have recently been amended. Licences to carry on scrap metal exporting expired on 30 June 2016.

### ***2.2.13 Further regulations***

The Environmental Protection (Collection, Storage, Treatment, Use and Disposal of Waste Oil) Regulations 2006 define the conditions for safe separation, storage, transport, treatment and disposal of waste oil (which includes engine and gear oil; lubricating oil; bilge oil; brake oil; mineral insulating and heat transmission oil; non-chlorinated insulating and heat transmission oil; synthetic insulating and heat transmission oil; and cooking oil, but does not include waste thermal oil and waste oil containing polychlorinated biphenyls or polychlorinated terphenyls in excess of 50 parts per million). These Regulations also define the conditions for obtaining a licence for the treatment of waste oil.

Industries that are connected to the sewer network are regulated under the Wastewater Regulations; for those not connected to the sewer network, the Environmental Standards apply through the Effluent Discharge Permit Regulations.

The Wastewater (Registration of Wastewater Carriers and Disposal of Wastewater) Regulations 2006 define the conditions for the transport of wastewater by carriers registered with the enforcing authority.

## **2.3 National energy strategies**

Integration with the national energy policy is relevant for solid waste management and industrial symbiosis because it can create the appropriate framework to integrate the recovery of energy with the recovery of materials from waste.

The Long Term Energy Strategy (LTES) covering the period 2009-2025 is currently being reviewed under the supervision of the Ministry of Energy and Public Utilities. Discussions with major stakeholders are ongoing and the updated LTES will cover the period 2016-2030.

This document will include a renewable energy action plan and master plan to achieve the targeted 35 per cent of electricity generation mix from renewable energy sources by 2025. This target will remain in place until 2030.

Bagasse, waste from the sugar cane industry (an industry not covered by this report), is currently being used for the generation of electricity. It contributes approximately 18 per cent of total production in Mauritius.

Studies are also being carried out on the use of other types of waste from wood and other agricultural products to complement bagasse.

#### **2.4 Waste Management Strategy 2011-2015**

Through concerted institutional efforts—including the local authorities, the waste management industry and the community—significant advancements in the implementation of the first national solid waste management plan of 1994 have already been achieved, including:

- Closure of open dumps
- Construction of the sanitary landfill at Mare Chicose
- Construction of additional transfer stations and upgrading of existing ones
- Increase in collection coverage and frequency
- Disposal of specific types of solid hazardous waste in specially designed cells
- Public awareness.

The document “Solid Waste Management Strategy 2011-2015” prepared by the Solid Waste Management Division of the Ministry of Local Government and Outer Islands was released in September 2011.

The long-term vision described in the WMS is particularly relevant for the IWA project, because it states that “the majority of waste being generated would either be reintroduced into the economic cycle, especially by recycling, or returned into the environment in a useful (e.g. composting) or harmless form, thereby substantially decreasing quantities that have to be disposed.”

“The aim for 2015 is to recycle 40 per cent and dispose a maximum of 60 per cent of waste being generated.”

The strategy did not distinguish between municipal, commercial and industrial waste and the overall estimate was that “if waste continues to grow at the present rate, the total amount of waste requiring management and disposal would be around 472,500 tonnes by the year 2015”.



The WMS 2011-2015 identifies the critical elements of the present solid waste management as:

- Inefficiencies in waste collection
- Waste reduction, reuse and recycling
- Capacity at the institutional level
- Enforcement
- Lack of a database on solid waste
- Hazardous waste disposal facility
- Information/education and awareness
- Financing and cost recovery.

On the basis of these critical elements, the strategic areas and the actions required were identified as:

1. Improvements in waste collection:

- a. Assessing requirements for additional waste collection lorries, storage receptacles and labour force; this analysis was already performed by the Solid Waste Management Division and it is going to be used as a basis for the upcoming WM Strategy.
- b. Comparison of public and private waste collection costs: this analysis was performed and is currently under revision.
- c. Setting up of an appropriate accounting and financial management system for waste collection

2. Increased resource recovery:

- a. Segregation schemes at local authority level
- b. Tender for redesigning transfer stations into Material Recovery Facilities (MRF), the operation of MRFs and the transfer of non-recyclables at la Chaumiere, La Brasserie and La Laura
- c. Launching of request for proposal for the construction of two composting plants
- d. On-site composting by local authorities
- e. Distribution of home composters by local authorities

- f. Introduction of a waste disposal fee at transfer stations and landfill for industrial and commercial operators
  - g. Ban on disposal of waste that can be valorised
  - h. Registration of recyclers.
3. Provision of adequate disposal infrastructure for the short to medium term and selection of appropriate treatment technologies for the long term
- a. Construction of additional cells at Mare Chicose (extension)
  - b. Feasibility study to analyse various alternative technologies to cater for the long term; the following will be explored: anaerobic digestion and thermo-chemical processes, such as gasification and pyrolysis.
4. Wider community involvement
- a. Encourage consumers to purchase products with a longer duration and products made from recycled materials
  - b. New ways of purchasing
  - c. Avoid and reduce waste at government level and improve markets
  - d. Development of local Annual Action Plans
  - e. Publication of pamphlets on proper waste handling
  - f. Audio-visual programmes on solid waste
  - g. Deployment of resource persons for delivery of talks
  - h. Inclusion of the topic of solid waste management in primary and secondary school curricula
  - i. Waste characterization study
  - j. Best local authority award
  - k. Competitions at local authority level
  - l. Workshops
  - m. Waste statistics

5. Improvement of hazardous waste management
  - a. Investigating the feasibility of on-site recycling at selected hazardous waste generators
  - b. Exportation of hazardous waste
  - c. Enforcement
  - d. Segregation of household hazardous waste
  - e. Extended Producer Responsibility study
  - f. Construction of storage facility for hazardous waste.

The WMS 2011-2015 also advocates institutional strengthening claiming that “successful implementation of this Strategy will depend crucially on there being in place a fully equipped technical Solid Waste Management Division”, which will require strong technical expertise to ensure implementation of the strategic plan and proper harmonization and coordination with the local authorities.

This requires an appropriate capacity and organizational structure. The functions of the SWMD with regard to the plan to implement the WMS 2011-2015 were listed as follows:

1. Administrate the implementation of SWM projects of the strategic plan in order to ensure satisfactory performance in all stages of execution;
2. Promotion of national awareness about solid waste management through community participation activities and stakeholder consultation;
3. Improvement and strengthening of solid waste service delivery at local authority level;
4. Enforcement of legislation;
5. Development of a National Solid Waste Information System to support the decision making process of policies, regulations and projects;
6. Promote positive behaviours on the part of citizens towards reducing waste, recycling and reduction of littering.

## 2.5 Revision of Waste Management Strategy

The Solid Waste Management Strategy 2011-2015 is being updated in line with the government’s aim to focus on waste reduction, recycling and recovery.

The new policy being defined aims at implementing measures for waste prevention, reduction, source separation, fiscal and other incentives, information and sensitization campaigns; the WM Strategy will include an analysis of the relevance of building new WM infrastructures, including technologies such as

composting and material recovery facilities (MRF). The overall goal is to reduce dependence on landfill disposal to move towards resource conservation and recovery of materials from waste.

The WM Strategy under development is also considering the relevance of job creation in green economy sectors, and investment in green industries will be promoted.

## 2.6 **Extended producer responsibility**

The National Environmental Policy 2007 established that the government will:

“provide a legal framework for establishing a recycling-based society to promote waste recycling measures. Centred on this legislation, individual regulations will be established to include the following: effective utilization of resources, container and packaging, **Extended producer responsibility**, construction material recycling, food recycling, green procurement, etc.

At present, legislation to introduce the extended producer responsibility approach for e-waste is under elaboration at the Ministry of Environment.

## 2.7 **Basel Convention**

Mauritius is a signatory to the Basel Convention, which regulates the import and export of hazardous waste.

In accordance with the Basel Convention, the Mauritian legislation in the Local Government (Registration of Recycler and Exporter) Regulations 2013 requires registration of waste exporters and stipulates that the export of waste can only be carried out by registered persons.

Every registered exporter “shall, every year, submit a report to the Permanent Secretary, [by a provided form], on the total amount:

- (a) of waste received for exportation under these regulations by reference to each of the categories [for which the exporter is registered];
- (b) and types of waste delivered to another facility for recycling under these regulations by reference to each of the categories [for which the exporter is registered];
- (c) of waste exported for recycling under these regulations by reference to each of the categories [for which the exporter is registered]; and
- (d) types of residuals for ultimate disposal”.

## 2.8 **Minamata Convention on Mercury**

Mauritius is a signatory to the ‘Minamata Convention on Mercury’ and ratification is expected in 2017.

According to the Convention, CFL lamps that exceed 5 mg per lamp will have to be phased out by 2020.

Preliminary findings indicate that most CFL lamps used in Mauritius contain less than 5 mg of mercury; a further detailed inventory is currently being conducted.

## **2.9 Existing initiatives for material efficiency**

The PAGE IWA is providing baseline data for the implementation, since January 2016, of the Industrial Symbiosis Project by Solid Waste Management Division (SWMD). The project, which started in January 2016, is funded by the European Union under the SWITCH Africa Green Programme led by UNEP in collaboration with UNDP and UNOPS and will be completed by June 2018.

## **3 Industrial and municipal waste management (review of status quo)**

### **3.1 Industrial structure**

Since its independence in 1968, Mauritius' economy has developed from a low-income, agriculture-dependent one to a middle-income diversified economy with growing industrial, financial and tourism industries. Between the 1980s to 2000, annual economic growth averaged 6 per cent. Since then, economic growth has remained in the range of 5 per cent to 3.5 per cent, improving the general economic welfare.

Mauritius now ranks as an upper middle-income country and is characterized by socio-economic stability, which has been ensured through prudent fiscal policies and dynamic trade and investment policies. This is a remarkable feat in the region as Mauritius is only endowed with resources such as fisheries and forests. Moreover, Mauritius has successfully met the Millennium Development Goals (MDGs), including those related to the environment.

Mauritius is dependent on imported fossil fuel for its energy needs and is therefore exposed to global fuel price shocks. Also, as a small-island developing state, Mauritius is vulnerable to the impacts of climate change, including rising sea levels and flooding<sup>2</sup>.

Strong growth driven by economic diversification has led to an increase in per capita income from USD 200 in 1968 to USD 12,128 in 2015. Moving to an industrial and a service-oriented economy, the contribution of agriculture to GDP has shrunk from 23.1 per cent in 1968 to 3.5 per cent in 2015. Tourism, financial services and ICT sectors constitute the main drivers of the service sector<sup>3</sup>. The following table summarizes the main economic trends in GDP per sector over the last four decades.

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<sup>2</sup> UNEP, 2014, "Green Economy Fiscal Policy Scoping Study – Mauritius".

<sup>3</sup> University of Mauritius, 2015. "Green economy assessment Mauritius".

**Table 1: Industrial distribution of GDP, 2010-2016, Mauritius**

Industry	2010	2011	2012	2013	2014	2015	2016
Agriculture, forestry, fishing	4.1	4.2	4.2	3.8	3.7	3.5	3.4
Manufacturing	16.0	15.7	15.5	15.8	15.4	14.8	14.4
Construction	6.8	6.5	6.2	5.5	4.8	4.4	4.2
Wholesale and retail, restaurants and hotels	18.1	18.4	18.7	18.0	18.3	18.6	18.5
Transport, storage and communication	11.0	10.9	10.6	10.4	10.4	10.5	10.4
Financing, insurance, real estate & business services	17.7	17.6	17.6	17.5	17.6	17.7	17.7
Others*	26.3	26.7	27.2	29.0	29.8	30.5	31.4
Total	100	100	100	100	100	100	100

\* Others include: mining and quarrying, electricity, gas and water, producers of government services and community, social and personal services

Source: National Accounts, Mauritius (2010)

These overall characteristics were considered relevant for the IWA project and were given full consideration in the analysis of industrial waste generation and in formulating recommendations in terms of both reducing the environmental impact of industrial waste management and increasing the contribution to energy security by considering an array of energy from waste possibilities.

What is of relevance to the IWA project is that over the years, manufacturing has played an increasingly important role in the structural transformation of the economy. In Mauritius, the manufacturing sector amounted to 16.7 per cent of GDP in 2012<sup>4</sup> and 16 per cent in 2014<sup>5</sup>.

Based on data from the UNIDO INDSTAT database, Table 2 shows the relevant growth of the food, beverages and tobacco industry, as well as the changes in specific production industries, e.g. the growth of machinery and equipment and the diminishing of electrical machinery and apparatus and wood products.

In recent years, manufacturing value added has increased, but overall growth has been slowing. The growth rate of the manufacturing sector averaged 2.1 per cent from 2008 to 2012 compared to 6 per cent during the 1990s.

Textiles and apparel contributed nearly 30 per cent of manufacturing GDP, while the food and beverages industry accounted for 32 per cent<sup>6</sup> (amounting to 46 per cent if tobacco is also included). Fish and fish preparation are an increasingly important part of this industry, accounting for 25 per cent of exports. Figure 1 presents the contribution of the different manufacturing industries to the overall value added for 2012.

<sup>4</sup>Ministry of Health, SAICM, UNEP, UNDP, 2014. National Chemical profile of the Republic of Mauritius.

<sup>5</sup>The Central Bank of Mauritius Annual Report 2014-2015.

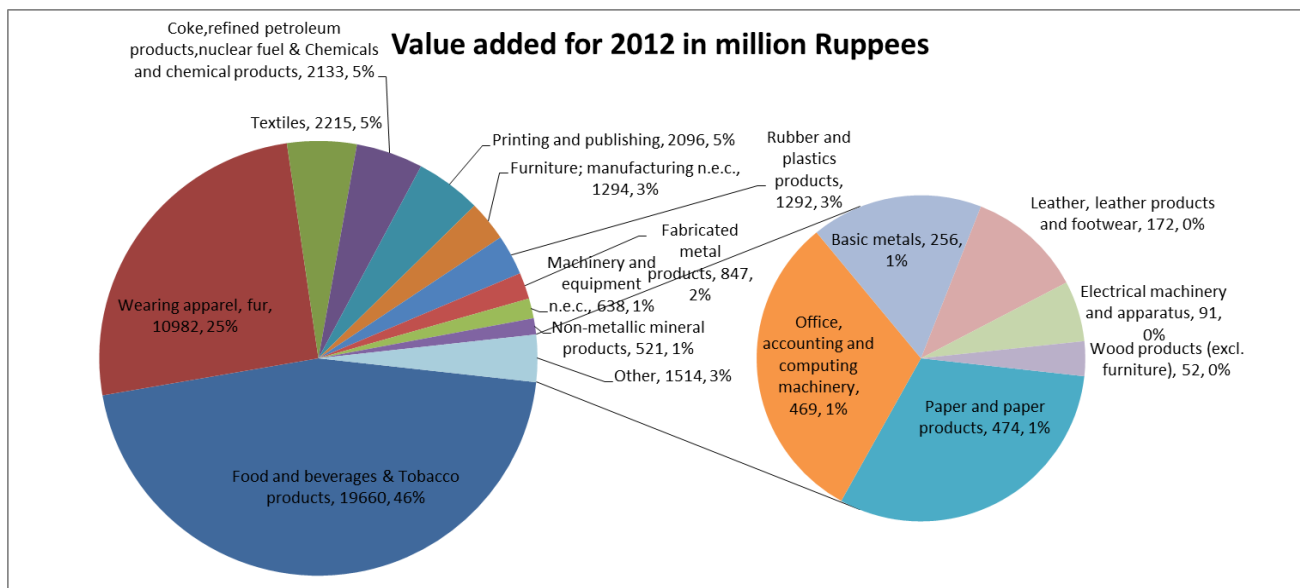
<sup>6</sup>Statistics Mauritius 2014.

**Table 2: Cumulative annual growth rate (2000-2012) for Mauritius' manufacturing industries**

ISIC	ISIC description	Value added	Output	Establishments	Employees
15-16	Food and beverages & tobacco products	14%	11%	0%	1%
17	Textiles	2%	0%	-5%	-6%
18	Wearing apparel, fur	1%	0%	-7%	-6%
19	Leather, leather products and footwear	1%	2%	-4%	-5%
20	Wood products (excl. furniture)	-11%	-12%	-1%	0%
21	Paper and paper products	4%	6%	-2%	-2%
22	Printing and publishing	8%	7%	-1%	-2%
23-24	Coke, refined petroleum products, nuclear fuel & chemicals and chemical products	6%	7%	0%	1%
25	Rubber and plastics products	0%	2%	-7%	-7%
26	Non-metallic mineral products	-5%	-5%	1%	0%
27	Basic metals	-2%	3%	-3%	1%
28	Fabricated metal products	6%	5%	3%	1%
29	Machinery and equipment n.e.c.	13%	14%	-2%	-1%
30	Office, accounting and computing machinery	0%	-1%	1%	0%
31	Electrical machinery and apparatus	-7%	-3%	-7%	-6%
33	Medical, precision and optical instruments	5%	5%	-4%	-3%
34	Motor vehicles, trailers, semi-trailers	8%	14%	-3%	3%
36	Furniture; manufacturing n.e.c.	5%	7%	-2%	-2%
37	Recycling	-1%	-1%	NA	NA

Source: Own calculation based on UNIDO INDSTAT database

**Figure 1: Value added distribution across Mauritian manufacturing industries**



Source: Own calculation based on UNIDO INDSTAT database

The population of Mauritius is approximately 1.29 million, and is growing at an estimated rate of 0.5 per cent per year. The country will be facing an ageing population in coming years<sup>7</sup>.

Total employment in 2010 was estimated at 558,100<sup>8</sup>. The employment characteristics have also changed, with agricultural employment falling from 27 per cent in the mid-1970s to 8 per cent in 2012<sup>9</sup>. Aggregate employment in the manufacturing sector was 73,414 units in 2014 (data from the Digest of Industrial Statistics 2014 – June 2015), with textiles and wearing apparel accounting for 43,176 employees and food and beverages for 14,103 employees. A breakdown of manufacturing employment is depicted in Figure 2.

Mauritian enterprises value the principles of sustainability. According to a survey conducted by the International Labour Organization (ILO) in 2012, Mauritian enterprises are aware of the need to improve the sustainability of their production processes, including the importance of sustainable practices such as energy saving, more efficient use of materials, reduction of wastewater and adoption of pollution control and cleaner production methods.

In 2010-2011, green and decent jobs in Mauritius stood at around 35,000, representing 6.3 per cent of total employment. Around 14 per cent of employment in the primary sector (non-sugar agriculture, sugar agriculture, forestry and fishing) can be considered green. In the secondary sector and notably the textile industry, only around 5 per cent of employment were green. Some textile companies have been greening their production processes with, for example, solar water heating systems, grey water use, recycling and natural air cooling practices. Such investments have created job opportunities and can reduce energy use

<sup>7</sup>Mauritius Ministry of Environment and Sustainable Development, 2013.

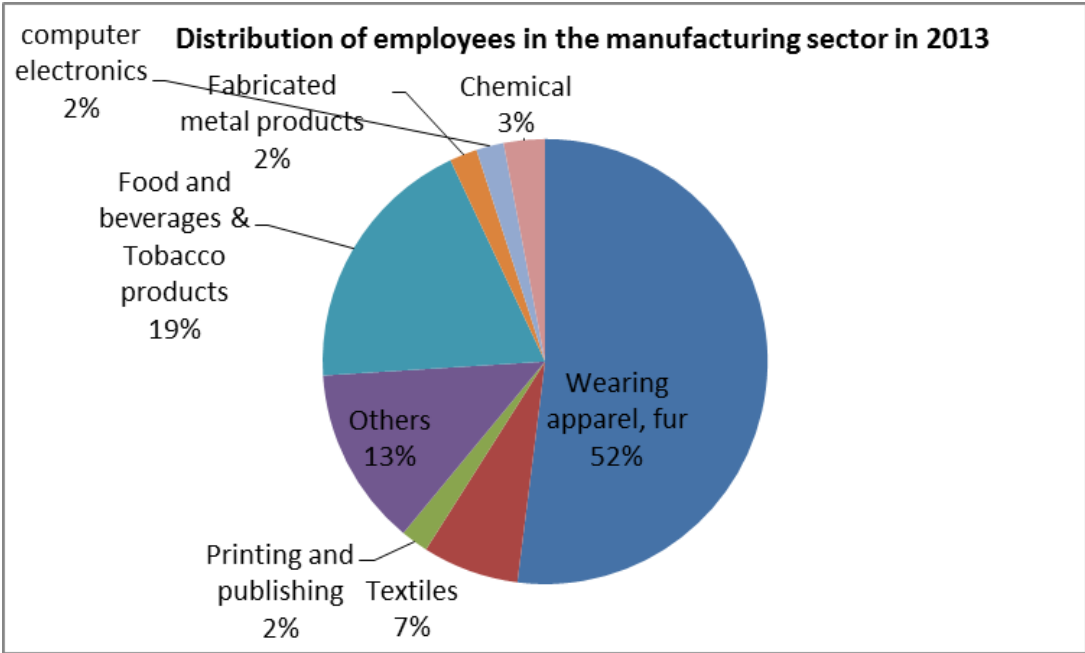
<sup>8</sup>ILO, 2013. "Green Jobs in Mauritius. Experiences from a Small Island Developing State. Synthesis Report".

<sup>9</sup>University of Mauritius, 2015. "Green economy assessment Mauritius".



by up to 30 per cent. Similar technologies have been introduced in the hotel industry where roughly 3 per cent of the jobs were found in highly energy and water efficient tourist resorts<sup>10</sup>.

**Figure 2: Employment distribution across the Mauritian manufacturing industries**



Source: Ministry of Finance and Economic Development, 2015. “Digest of industrial Statistics 2014”

**3.2 Mauritius’ waste management in the regional and global context**

Waste from which value can be recovered has been exported in the last decades. Table 3 provides details on exports of cotton and yarn waste and fish/shellfish waste, expressed as USD and kg.

It is well known that both the generation and trade of waste are directly correlated with a country’s GDP. An analysis of the trend of the amounts of cotton and yarn waste exported in tonnes are presented in Figure 3 and clearly shows that the trend can be coupled to Mauritius’ and global economic trends: the values were relatively stable up to 2004, followed by a significant increase and then a clear decrease beginning in 2008; the recovery of textile exports started in 2012.

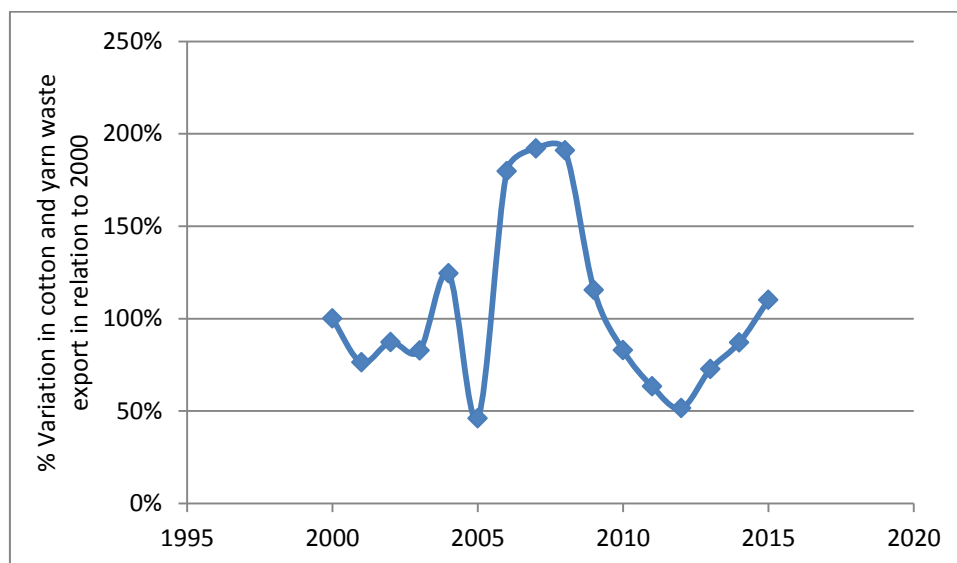
<sup>10</sup>FROM ILO green jobs opportunity, 2014.

**Table 3: Mauritian export values in USD and quantities in kg**

	Mauritian export values in USD			Mauritian exports quantity in kg		
	Cotton waste n.e.c.	Cotton yarn waste	Fish/shellfish waste	Cotton waste n.e.c.	Cotton yarn waste	Fish/shellfish waste
<b>2000</b>	937479	49853		2950044	67128	
<b>2001</b>	692973	19815		2277748	27475	
<b>2002</b>	923978	27238		2574044	59798	
<b>2003</b>	958286	37065		2343673	150214	
<b>2004</b>	1921008	4671	20757	3723676	29771	15797
<b>2005</b>	1012214	15912	0	1362240	24740	0
<b>2006</b>	3042083	10786	636178	5393831	29001	591246
<b>2007</b>	3248289	186748	1286377	5378397	416133	952338
<b>2008</b>	4504422	291383	1796695	5380759	383259	0
<b>2009</b>	1590401	205159	3064686	3162377	320701	2429028
<b>2010</b>	1212801	177867	0	2210646	292213	0
<b>2011</b>	1264431	96575	0	1774280	137384	0
<b>2012</b>	948374	173612	98	1366540	188825	602
<b>2013</b>	1752947	87800	0	2056942	134234	0
<b>2014</b>	2170362	110172	198	2381179	246427	112
<b>2015</b>	2689881		0	3321517		0

Source: COMTRADE database

**Figure 3: Variation in cotton and yarn waste export in relation to 2000**



Source: Own calculation based on COMTRADE database

Data on the export of recyclable waste are available from registered recyclers who must provide data on the amounts and types of waste exported; the possibility of establishing a database on industrial waste would facilitate an analysis of those data.

In Mauritius, the import of hazardous waste is prohibited.

### 3.3 Analysis of waste streams management

Even if industrial waste is generally not collected by local authorities, but is carted away under the responsibility of each firm, the management of such waste overlaps with the management of municipal waste, because waste management does not distinguish waste by origin. According to the 2014 annual report on waste disposed at the Mare Chicose landfill (provided by the operating company Sotravic), industrial waste constitutes less than 3 per cent of the total amount.

During the on-site visits, we observed that for similar waste groups, such as paper, plastics, metal scraps, e-waste, the same recyclers operate in both supply chains: they collect from both industrial premises as well as from local authorities.

Given that, excluding hazardous waste, all other types of waste become part of the same waste management system, an analysis of municipal waste management appeared relevant and it was undertaken as part of the IWA in Mauritius project.

### 3.3.1 Definition of waste and waste management

The EPA Act 2002 amended 2008 defines

**waste** as solid waste other than hazardous waste, clinical waste and pharmaceutical waste

and

**hazardous waste** as “waste, natural or artificial, whether in solid or liquid form, or in the form of gas or vapour, declared as hazardous waste under section 42” regulations and includes clinical waste.

A first observation is related to the definition of municipal solid waste issued by the Ministry of Environment:

**municipal solid waste** comprises waste from households, commercial centres and industries\*.

\*<http://environment.govmu.org/English/Pages/swmd/SWMD-Solid-Waste-In-Mauritius.aspx>

This definition differs from those given in other normative contexts, such as, for instance, in the European Union Directive, because it includes industrial waste in municipal solid waste.

The implications for the IWA in Mauritius project deriving from these definitions are relevant and will be thoroughly analysed in the following sections.

In the Local Government Act 2011:

**waste** includes any solid matter, other than hazardous waste, which is discarded, rejected, abandoned, unwanted or surplus matter, including any such matter intended for:

- (a) recycling, reprocessing, recovery or purification by a separate operation from that which produced the matter;
- (b) sale; or
- (c) export.

Waste is also defined in the Local Government (Dumping and Waste Carriers) Regulations 2003:

**waste** includes anything which is discarded or otherwise dealt with as if it were waste and includes any substance or article that requires to be disposed of as being broken, dilapidated, contaminated or otherwise spoiled other than hazardous waste.

In the Environmental Protection (Industrial Waste Audit) Regulations 2008:

**waste** includes:

- (a) any matter, whether solid, liquid, gaseous or radioactive, which is discharged, emitted or deposited in the environment;
- (b) noise and vibration;
- (c) any discarded, rejected, abandoned, unwanted or surplus matter, including any such matter intended for:
  - >recycling, reprocessing, recovery or purification by a separate operation from that which produced the matter;
  - >sale and export.

The definition of hazardous waste is further specified in the Environmental Protection (Standards for Hazardous Wastes) Regulations 2001 which defines:

**hazardous waste** – with respect to its origin or composition – as any waste

- (a) specified in the third column of the First Schedule in respect of the corresponding waste stream specified in the second column of that Schedule; or
- (b) having as constituents one of the substances specified in the Second Schedule, and displaying any of the hazardous properties specified in the Third Schedule.

The Local Government Act 2011 defines that:

**disposal**, in relation to waste, includes its sorting, carriage, transportation, treatment, storage, tipping above or underground, incineration and the transformation operations necessary for its recovery, re-use or recycling (definition given in the EPA Act 2002 as amended in 2008).

and

**disposal site** means a disposal site designated under section 60(2) of the LG Act 2011 and includes a landfill or other final disposal site

and

**waste management facility:**

- (a) means any site which is used for the transfer, treatment or disposal of waste; and
- (b) includes a landfill, transfer station, composting plant, recycling facility or any other facility designated by the Minister under section 60(2).

The definition of disposal includes all phases and operations of waste management, without distinction, such as their technical feasibility, cost or environmental impact.

The Local Government Registration of Recycler and Exporter Regulations 2013 separate recycling from disposal and define:

**recycling** as any recovery operation by which waste is reprocessed into products, materials or substances, whether for the original or other purposes.

### ***3.3.2 Types of industrial waste and current management***

On the basis of the data and information collected by applying the methodology adopted in this IWA project, the industrial waste generated at the industrial premises can be classified into the following types:

- 1) waste relevant for the IWA project because they can undergo material or/and energy recovery within the framework of industrial symbiosis;
- 2) waste similar to municipal waste, which is collected by the local authorities, enter the municipal waste stream and are thus disposed at the Mare Chicose landfill;
- 2) industrial waste (such as plastic bags containing residuals) which are not similar to municipal waste but that are treated as general waste and, after collection, enter the municipal waste stream and are disposed at the Mare Chicose landfill;
- 3) industrial waste which has already been inserted into the recovery supply chain because they are collected by registered recyclers, such as:
  - paper and cardboard
  - plastic films and bags
  - wooden pallets
  - waste oil;
- 4) waste collected by informal recyclers, such as plastic bags, drums and carton boxes;
- 5) hazardous waste stored in dedicated areas which will be conferred to the Interim Hazardous Waste Storage Facility, when operational;
- 6) hazardous waste exported: export requires approval of an enforcing agency (e.g. sludge from chemical recycling of solvents in the chemical industry);
- 7) hazardous electrical and electronic waste currently being stored: in general, electronic waste will not be received at the Interim Hazardous Waste Storage Facility. However, some e-waste, such as compact fluorescent lamps, may be received against payment.

The analysis of waste management in the firms of the selected industries confirms that even when collection is performed by different agents, industrial waste management merges with municipal solid waste management in several operations as a consequence of the fact that it is not legally provided for otherwise. These operations can be summarized as:

- types of waste that could be included in an industrial symbiosis programme but are not yet being recovered by the firms (e.g. textile or industrial organic residues are not collected separately) and end up in the general waste stream, i.e. they are landfilled;
- waste which is similar to municipal solid waste (same characteristics with respect to treatment and recovery, such as carton boxes used for industrial storage) and industrial waste with different characteristics and compositions can be deposited in the same collection truck and brought to the landfill;
- the informal sector collects and reuses industrial waste (such as plastic drums or plastic bags that could potentially contain residues of industrial chemicals), which at the end of their use enter the municipal waste stream.

Thus, several types of industrial waste, even if they are being collected and transported at the firms' cost, are managed in the same publicly run waste facilities. This element of the WM organization made it difficult for the IWA project to separate and estimate the cost of industrial waste disposal, since both municipal and industrial waste are managed in the same flows. The economic weight of industrial waste disposal on the public budget could therefore not be estimated.

The fact that the management of municipal and industrial streams of *residual waste*<sup>11</sup> is not separated makes it relevant for this report to deal with the issues related to the overall municipal solid waste management strategy and to describe the facilities used for municipal waste management.

### **3.3.3 Total amount of solid waste generated**

In 2012, the total amount of waste generated and managed in Mauritius was reported as 430,000 tonnes. The graph shows the linear projection for waste generation in a BaU scenario: it was estimated that if waste had continued to grow at the same rate (2 per cent), the total amount of waste to be managed by 2015 would reach 460,000 tonnes<sup>12</sup>.

The total amount of waste generated in Mauritius in 2015 was actually 480,000 tonnes, of which 450,000 (94 per cent) were disposed at the Mare Chicose landfill and 30,000 tonnes (6 per cent) were treated in the composting plant.

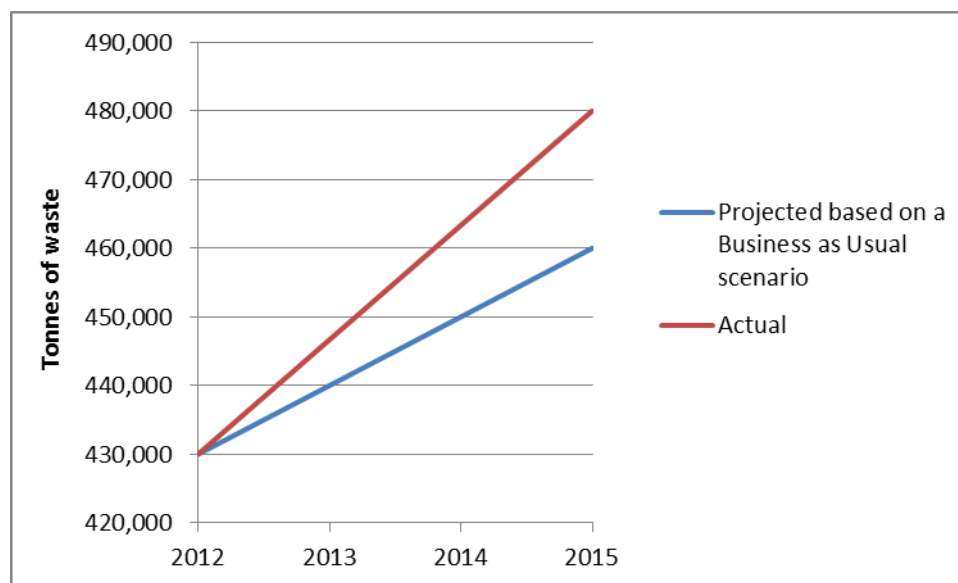
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<sup>11</sup> Residual waste is the amount of waste that remains following reuse, domestic composting and segregated collection and different waste fractions have undergone material and/or energy recovery.

<sup>12</sup> P. Kowlessar "Solid Waste Management in Mauritius", 10 September 2012. All data obtained from the Annual Report provided by Sotravac, the company operating the landfill site.

Figure 4 compares the projected and actual total amount of waste generated in Mauritius.

**Figure 4: Total amount of waste generated in Mauritius**



Source: Presentation by P. Kowlessar “Solid Waste Management in Mauritius”, 10 September 2012

### 3.3.4 Composition of solid waste

Obtaining data on the composition of waste is quite challenging for the majority of countries, independently of national income. Several campaigns have been run in Mauritius, and the graph summarizes the composition of municipal waste (percentage of the main waste fractions)<sup>13</sup>.

The largest fraction is organic waste, i.e. food and garden waste. Plastic is the second largest fraction. Figure 5 presents a breakdown of municipal waste composition.

### 3.3.5 Source segregation

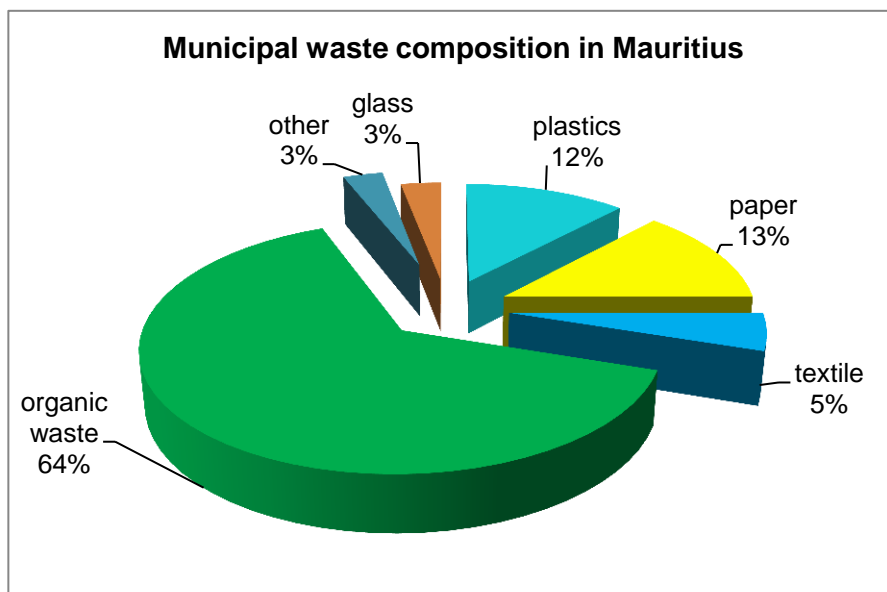
According to Mauritian legislation, waste separation is not required for industrial waste. In fact, separation is also not required for solid municipal waste and is therefore not carried out. In the case of municipal waste, cost has been indicated in policy documents as the main reason for not setting up separate collection schemes which, according to international benchmarking practices, are considered fundamental for obtaining waste in the quality required for efficient materials recovery.

The firms participating in the IWA project carry out separation of waste types for which further use has already been identified: these types could be reused for material recycling or energy production, such as textile discards, plastics discard and waste mineral oils. However, other types of waste deriving from industrial activities are not collected separately and waste such as paper boxes, plastic bags (even those potentially containing chemical residues) and plastic films might be mixed with other waste originating on the premises, such as food waste from the canteen, not recyclable paper or sweeping dust, and are ultimately disposed in the landfill.

<sup>13</sup>Data from <http://environment.govmu.org/English/Pages/swmd/SWMD-Solid-Waste-In-Mauritius.aspx>



**Figure 5: Municipal waste composition in Mauritius**



Source: <http://environment.govmu.org/English/Pages/swmd/SWMD-Solid-Waste-In-Mauritius.aspx>

The disposal of wastewater sludge is relevant for several of the firms included in this study, but mainly those not connected to the sewer network. There is no detailed regulation on sludge quality, the only established standard for sludge disposal in Mauritius is that the water content must be <70 per cent when it is disposed in the landfill.

The IWA project found that industrial sludge is dried and either disposed through the municipal waste collection service or deposited on small plots of private land available on the premises.

### **3.3.6 Storage**

There is no provision for industrial waste storage, only for hazardous waste storage (under the Environmental Protection - Standards for Hazardous Waste Regulations 2001). Due to the lack of recycling possibilities and the constraints on export transport (e.g. a full container is required for export), a few types of industrial hazardous waste, such as electronic waste (mainly light tubes) and contaminated containers (e.g. toner plastic tubes) are stored in the firms' in dedicated areas.

The Ministry of Environment is in the process of constructing an Interim Hazardous Waste Storage Facility at La Chaumière, which is expected to be operational by October 2016. Hazardous waste will be received, sorted, packaged, labelled, stored and prepared for subsequent authorized export for treatment. Firms will be able to deposit their hazardous waste against payment. The fees will be determined when the facility becomes operational. E-waste will not be included among the waste that is accepted.

### **3.3.7 Re-use on-site and off-site**

It is common practice for firms to reuse containers and bags after washing, which may still be useful in production operations.

Waste can also undergo reuse off-site, such as plastic drums and plastic bags which are collected by nearby residents or communities that privately reuse the discarded items, often as containers or carrying equipment.

A company initiated a project for reuse and recycling education which involves local residents and a school to reuse plastic drums as pots for flowers and ornamental plant cultivation.

### **3.3.8 Collection**

The collection of municipal solid waste is performed by the twelve local authorities, and is carried out either in-house, outsourced or both for household, commercial and business waste only.

Local authorities do not collect hazardous waste.

Industrial waste is not collected by the local authorities; this is the responsibility of firms:

- the collection of residual waste falls under the responsibility of each firm which must transport and dispose it at transfer stations or directly at the Mare Chicose landfill;
- waste that has a recycling market is either collected by:
  - registered recyclers; or
  - the informal sector.

### **3.3.9 Transportation**

The transport of industrial waste is carried out at the cost of each firm that generates waste. Some firms organize their own waste transport; the vehicle used for the transport of waste must possess a carrier license issued from the Ministry of Local Government.

The Wastewater Management Authority is responsible for the treatment of effluents including domestic and industrial wastewater. Wastewater is collected from industrial premises where no sewage system is in place. The sludge is disposed in the landfill.

### **3.3.10 Transfer stations**

To optimize waste transport to the sanitary landfill of Mare Chicose, five strategically located transfer stations (see Figure 6) operate in the intermediate banking of waste. Table 4 summarizes their respective characteristics.

**Table 4: Waste transfer stations**

<b>Transfer stations</b>	<b>Starting year of operation</b>	<b>Design capacity (tonnes per day)</b>	<b>Average quantity transferred (tonnes per month)</b>
La Brasserie	1991	250 to 300	7,600
Roche Bois	1992	300 to 400	7,500
Poudre D'Or	2000	170 to 200	5,500
La Laura	2005	125 to 150	4,100
La Chaumiere	2011	350 to 450	8,000

*Source:* Data from the operators of transfer stations

The Solid Waste Management Division of the Ministry of Environment is responsible for tenders for operation of the transfer stations, including the transfer of waste from the stations to the landfill.

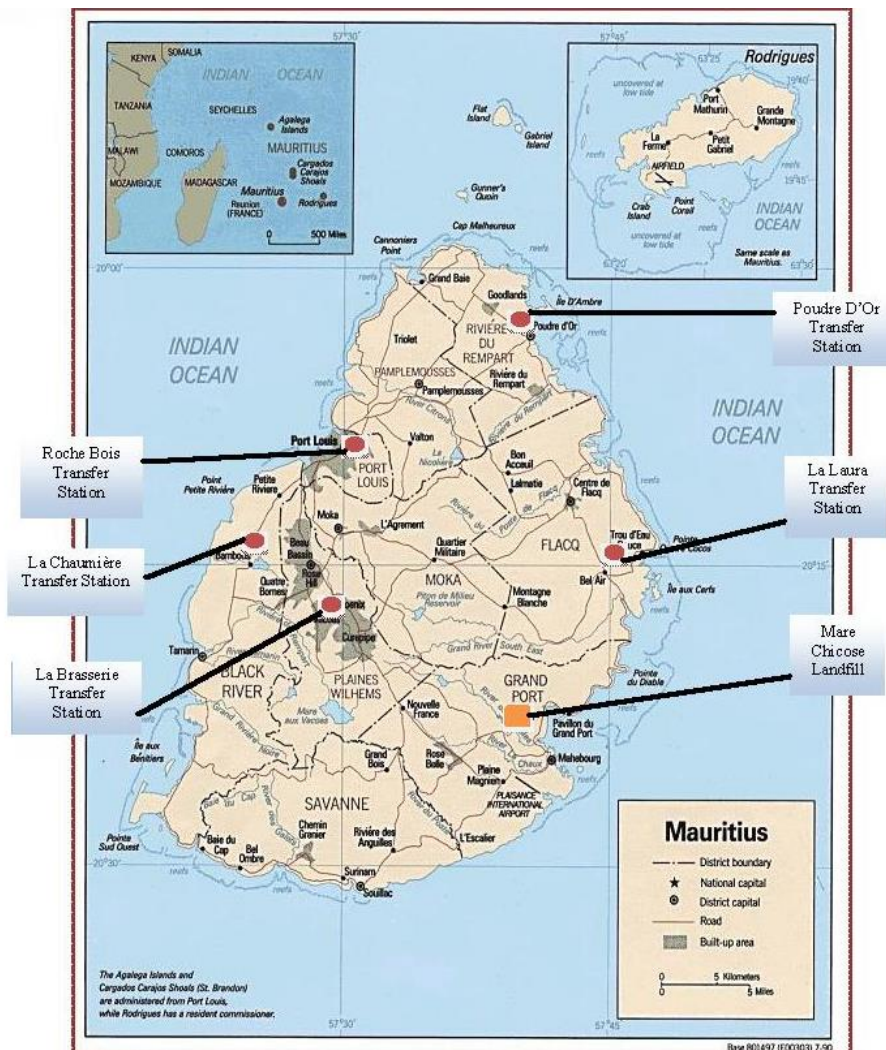
Waste collected by the local authorities and other waste generators transit through the transfer stations where waste is loaded to bigger truck trailers and transported for disposal at Mare Chicose.

The new contract concluded for the management of the transfer station with the contractors at Roche Bois and Poudre d'Or postulates that at least 2 per cent of the waste deposited at this facility must be recovered for recycling.

Aside from formal operators, which are private enterprises, informal waste pickers also operate at a few transfer stations. They focus primarily on waste fractions such as plastics and metal wires and the dismantling of electrical and electronic waste.

Figure 6 shows the location of the transfer stations and of the Mare Chicose landfill.

Figure 6: Location of waste transfer stations and landfill site in Mauritius



Source: Presentation by P. Kowlessar "Solid Waste Management in Mauritius", 10 September 2012

### 3.3.11 Resource recovery

Several companies registered with the Ministry of Local Government have established an active and essential formal recycling sector; a summary of its activities is provided below.

**Plastics:** a plant recycling PET bottles based on a mechanical process is operational in Mauritius and produces flakes and granules which are then used as recycled materials to produce hard plastic objects (such as benches).

**Card boxes and paper:** collected by the formal sector for export or by the informal sector for reuse mainly.

**Glass:** collected and converted into useful decorative products by one of the recycling companies. However, the current capacity to collect all types of glass waste is limited. Projects are being developed to reuse bottles and other glass objects as support materials for filters (such as in swimming pools) or for decoration. Some glass bottles are collected and melted and sent back to the production line. The recovery of glass entails difficulties that are connected to the perceived hazardousness of broken glass.

Textile: cotton discards in particular are collected, sorted, graded and exported.

Electrical and electronic waste: There are currently no specific e-waste regulations in Mauritius, but the EPR scheme is under development. However, specific types of waste - electrolyte from batteries and accumulators; lead batteries; mercury dry cells and Ni-Cd batteries - are classified as hazardous waste under the First Schedules of the Environmental Protection (Standards for Hazardous Wastes) Regulations 2001.

Electrical and electronic waste are either stored on-site or collected for export.

A recycling firm provides a dedicated service for CF lamps: mercury is removed and shipped for treatment abroad.

Tyres: a local company reconditions used tires.

Cooking oil: it is collected from restaurants and exported.

Scrap iron: it is collected and recycled in Mauritius.

Food waste: a municipal composting plant is active which uses undifferentiated municipal solid waste and, following the biological process, separates those waste fractions with a lower organic content.

Wood pallets: wood pallets are mostly reused on-site. In some cases, the wood pallets are sold at a very low cost to the informal sector. However, a recycling company collects the pallets to produce wooden pellets that can be used in boilers; they also produce wood chips (sawdust) which can be used for horse or poultry bedding.

Waste oil: waste mineral oil consists of used hydraulic, compressor and lubricant oils. Lubricant oil is collected from mechanical workshops, garages and car dealers. Hydraulic and compressor oil is collected from industries. Once collected, it undergoes primary filtering to remove coarse material and heating and centrifugation to remove fine material and water. The product is blended with an energy booster to increase the calorific value up to 38 – 45 MJ/kg (equivalent to HFO). It is to be used in HFO boilers.

### ***3.3.12 Composting***

A compost plant with a capacity of 300 tonnes of waste daily, set up by a private promoter, is also operational at La Chaumiere. Given that no separate collection of municipal waste streams is conducted, the waste treated in this plant consists of residual waste collected by the local authorities. Thus, not only organic waste but all waste fractions undergo the composting process.

A private operator entered a Waste Supply Agreement with the government (SWMD) with no tipping fees; its feasibility was based on sales of compost to cover the operational costs. However, the operator has applied for and has been receiving a subsidy from the government since 2015 for the compost sold on the local market.

This type of processing requires periodical analyses of the compost produced; in fact, international experience has shown that composting residual waste - or even waste fractions enriched in organic components after undergoing mechanical treatments, but which were part of residual waste streams - does not produce high quality compost.

Only the separate collection of organic waste can guarantee the production of high quality compost.

### ***3.3.13 Other waste treatments***

Awareness of the relevance of recovering the value contained in different types of waste is rising in the industrial sectors participating in our study, but a strategic approach is lacking and several industries have not been able to define concrete measures to adequately address the problem.

A major difference is observed with regard to energy efficiency measures implemented. The necessary knowledge to improve energy management and reduce consumption has already been translated into actions, also through projects initiated by energy consultants and auditors. Energy reduction strategies are already in place in several firms.

The IWA project highlights that the recovery of energy from waste is already being undertaken; specifically, textile, cardboard and plastics are used to substitute fuel - coal - in industrial boilers used for the generation of heat. In line with the energy efficiency project, efforts are being made to reduce the use of fuel by using textile waste in existing coal boilers.

The agro-food industry has already activated the recovery of organic industrial discards; a process is in place to produce pet and fish food.

### ***3.3.14 Disposal***

Since recycling is carried out by private actors and there is no energy recovery from municipal waste on the island, composting and landfill disposal are the only two management phases currently being carried out by the public sector.

Since 1997, a single sanitary landfill located in the village of Mare Chicose in the Grand-Port district receives all types of waste:

- Municipal waste, including industrial
- sludge from municipal and industrial wastewater treatment plants
- some types of solid hazardous waste are macro-encapsulated and contained within concrete hazardous waste cells.

The sanitary landfill is owned by the government and managed by Sotravic Limitée (10-year contract since November 2006); previously, it was managed by Société de Traitement et d'Assainissement des Mascareignes Limitée.

The amount (tonnes) of waste disposed at the Mare Chicose landfill over the last three years was:

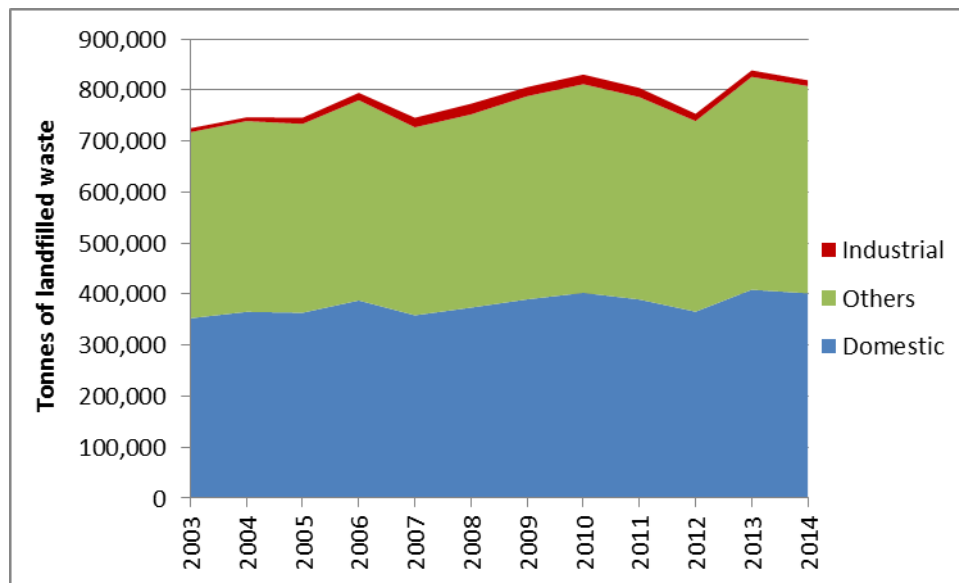
- 2015: 449,000 tonnes
- 2014: 418,000 tonnes
- 2013: 430,000 tonnes.

A general annual increase is observable since 2009.

The total amount of waste landfilled to date (end of 2015) is about 6 million tonnes.

Figure 7a: Amount of waste landfilled in Mauritius shows the continuous increase in the amount of waste disposed per year<sup>14</sup> and divided into three broad categories: Domestic, Industrial and others. Based on the data in CSO's annual Digest of Environmental Statistics, industrial waste can further be divided into textile, tuna/sludge, poultry and other industrial waste, as shown in **Error! Reference source not found**.b. It is noted that textile waste has been constantly decreasing while there has been a surge in tuna and poultry waste.

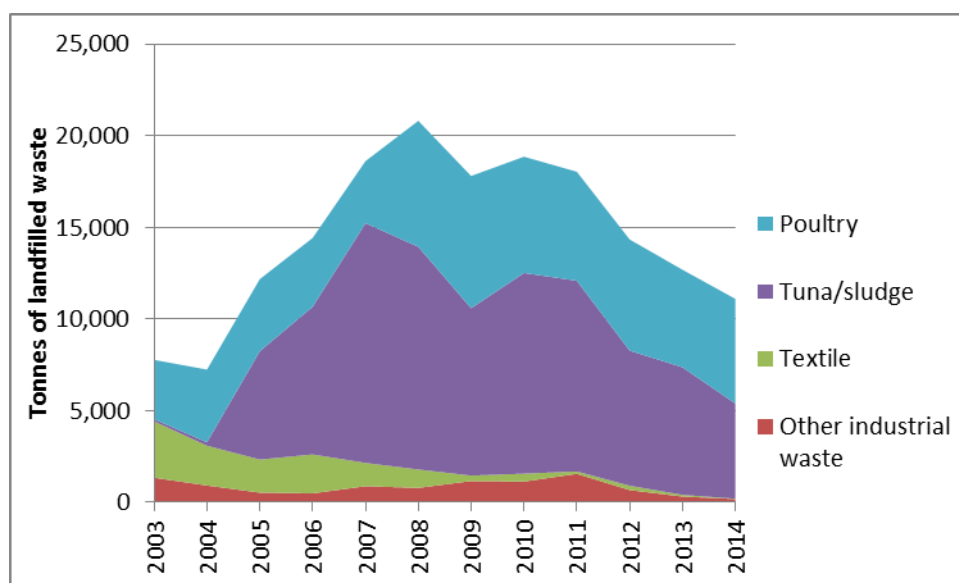
**Figure 7a: Amount of waste landfilled in Mauritius**



Source: Digest of environmental statistics 2011-2014, CSO

<sup>14</sup>Digest of environmental statistics 2011-2014, CSO.

**Figure 7b: Amount of waste landfilled in Mauritius**



Source: Digest of environmental statistics 2011-2014, CSO

As of September 2015, an approximate area of 29 ha had been landfilled. Once a new area is developed, the estimated total landfill area will be about 48 ha.

The sanitary landfill has been designed for the disposal of waste in an environmentally safe manner. The key characteristics are<sup>15</sup>:

- the impermeability of the bottom of the landfill (composite lining of soil and HDPE);
- the collection of leachate and the carting away to the Roche Bois pumping station to prevent contamination of the ground water;
- abstraction of gas from the landfill for burning in engines for power generation. Three engines operate at the Mare Chicose landfill, with a total installed capacity of 3.3 MW, together with an electrical switchgear and transmission system to the CEB grid, an upgrade of gas collection systems, filters and pumps to maximize the volume and quality of gas extracted<sup>16</sup>. The electricity produced is fed to the grid.

Environmental monitoring is ongoing.

### 3.4 Export of recyclable form Mauritius

The data collected throughout the IWA project reveal that the export of different recyclable types of waste is widespread in Mauritius. Given that Mauritius is a signatory to the Basel Convention, the shipment is only carried out by registered recyclers/exporters which document their transactions.

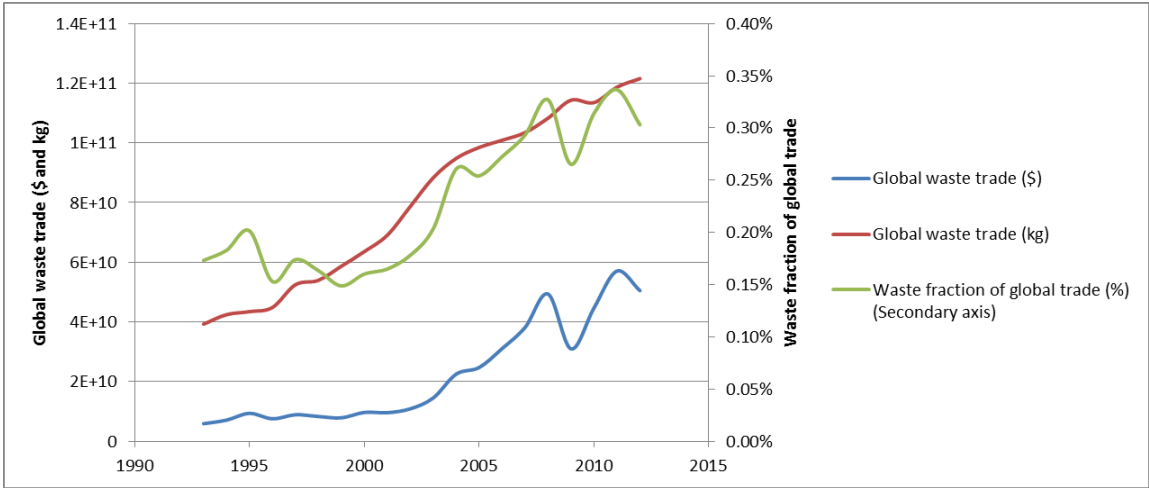
<sup>15</sup>Data from <http://environment.govmu.org/English/Pages/swmd/SWMD-Waste-Disposal-Sites.aspx>. Accessed 21 March 2016.

<sup>16</sup> From <http://www.sotravic.net/about-us/project-6-mare-chicose-landfill-gas-to-energy-project.html>



Waste trading is a common practice in the global market (as shown in Figure 8). Between 1993 and 2012, global waste trade has been growing continuously in terms of both monetary value and quantity, at a cumulative rate of 10 per cent per year, faster than the trade of all goods, which has been growing at 7 per cent annually.

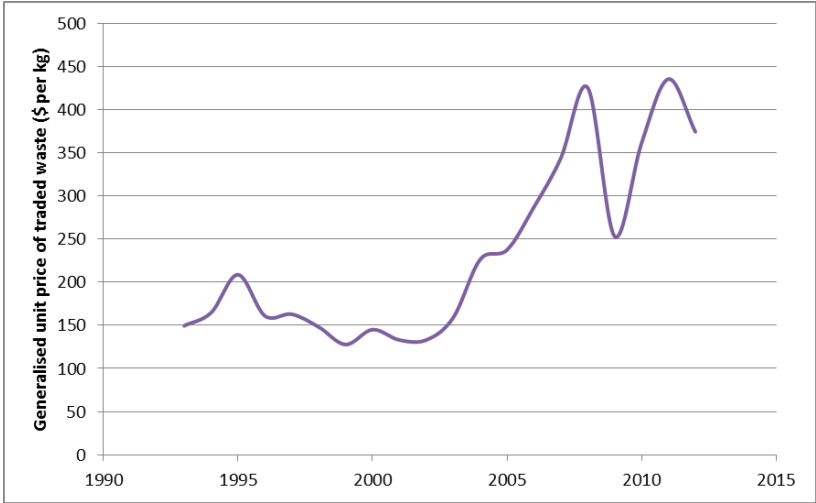
**Figure 8: Global waste trade**



Source: Own calculation based on UNCOMTRADE database

Unit prices of globally traded waste, which is considerably influenced by the price of raw materials and fuels, have also been rising on average (Figure 9).

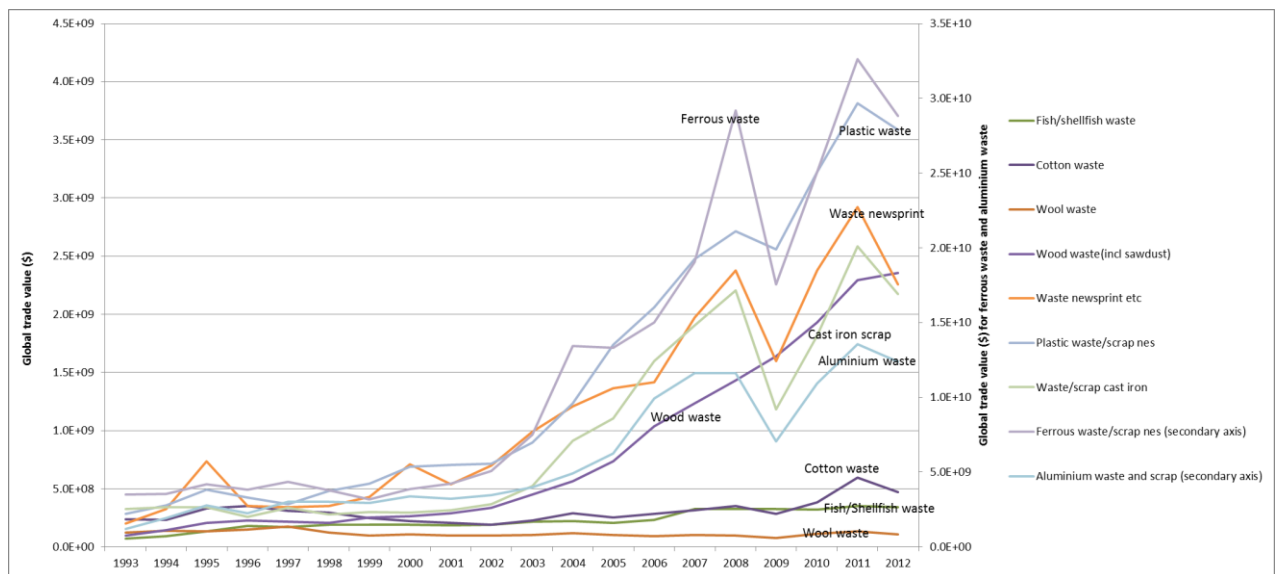
**Figure 9: Average unit price of traded waste**



Source: Own calculation based on UNCOMTRADE database

Figure 10 provides an indication of the price at which some of the types of waste relevant for the industries included in this Industrial waste assessment are being traded for globally.

**Figure 10: Average unit price of traded waste types**



Source: Own calculation based on UNCOMTRADE database

### 3.5 Waste flow description of current waste management in Mauritius

Mauritius’ national waste management strategy is currently being revised, and if the overall objective of reducing the amount of waste sent to landfills is to be achieved, the recovery of materials and energy from waste must be significantly increased. Increasing the recovery from different types of waste derived from different origins (household, industrial commercial, business, agriculture) requires, on the one hand, investment in the appropriate infrastructure (measures that are not covered by this report) and, on the other, policy changes, some of which are relevant for industrial waste and will be discussed in the Recommendations section.

In short, the waste management system in Mauritius must become more integrated . An integrated WM system can be defined as a system that:

- covers all waste hierarchy phases; it recovers materials from the appropriate waste fractions and energy from the fractions that cannot be recycled or for which energy recovery is more environmentally effective;
- includes different types of infrastructure and plants which support proper collection and recovery from waste;
- manages waste of similar characteristics in the same plants, with the aim of optimizing plants’ capacity and operation;
- recognizes the role of the different professional, social and economic actors relevant for waste management, and facilitates the exchange of opinions and resolution of conflicts.

The necessary shift is from a *linear system* in which waste is collected without separating recyclable fractions and sent to a landfill to a more *complex system*. This requires a complete overview of the problem. The **waste flow analysis**, which has been applied in other contexts as well, will be used here<sup>17</sup>.

An example of a qualitative flow diagram of waste management in Mauritius is presented in

Figure 11. The diagram only shows the flows of the industrial solid waste relevant for the IWA project as defined in Chapters 4 and 5, and overlap between these industrial wastes and municipal waste management.

The main feature of the waste flow analysis approach is that it distinguishes between fractions that are collected separately to be sent to recycling plants, and residual waste (waste that remains after separate collection). In Mauritius, no separate collection of waste takes place, therefore, the diagram can only present the municipal residual waste from collection to the transfer station and, finally, to the landfill.

The diagram shows that industrial waste could undergo separate collection, thus generating more than one waste flow.

In terms of municipal waste management techniques, this diagram can only include the landfilling of residual waste; this results in a flow diagram which is simplified with respect to WM systems developed in highly industrialized countries, which can include technologies such as anaerobic digestion and thermal treatment plants with energy recovery.

This description of the situation could provide the basic method by which the development of the Mauritian WM system can be elaborated and support planning. In fact, apart from waste prevention, which is a fundamental step in WM but is not included in the diagram, it describes all waste hierarchy phases and thus which flows may require plants that can achieve material and energy recovery from waste.

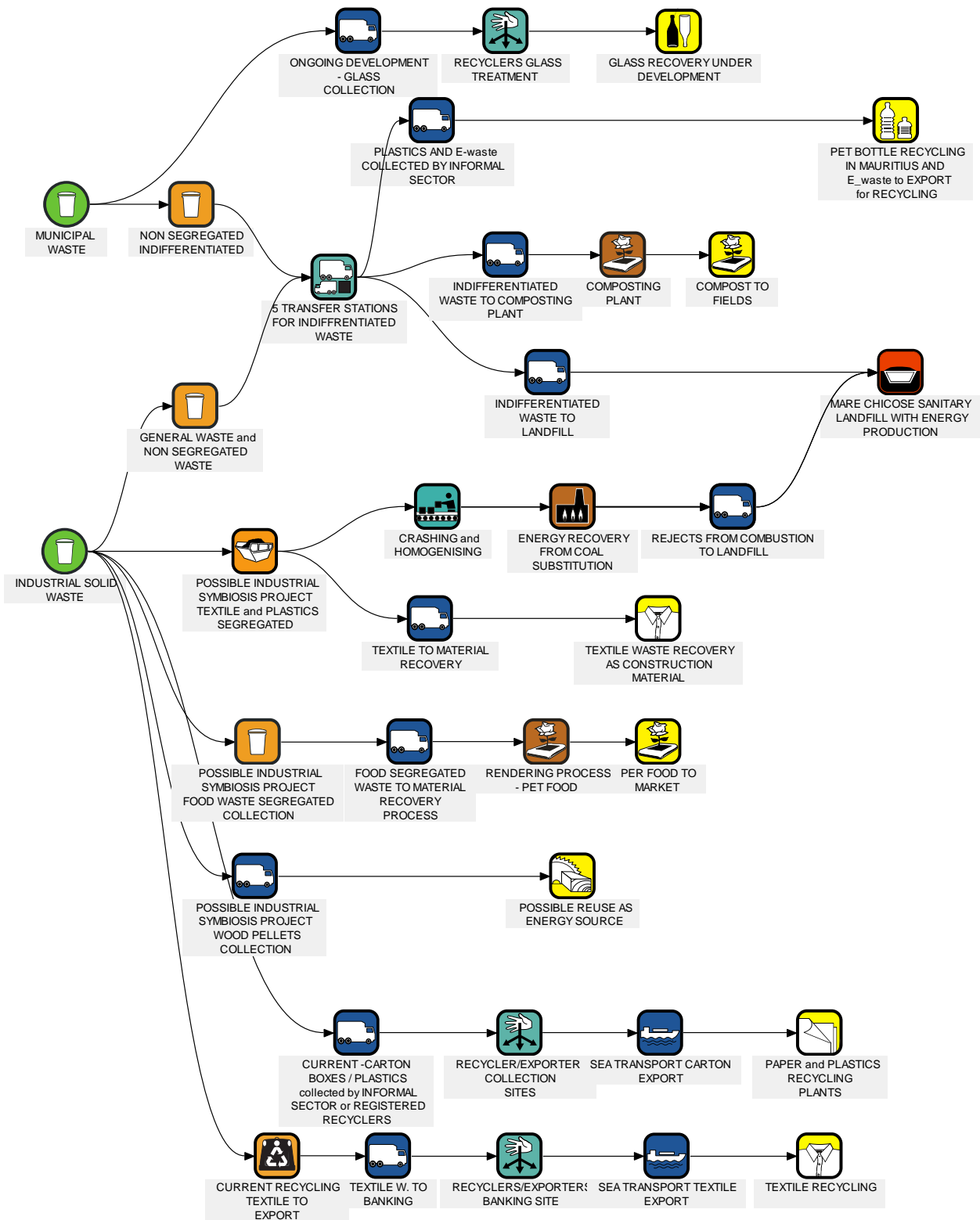
To appropriately use this diagram and to follow the waste in all its flows requires WM planners and administrators to describe the specific and real integrated WM system, including the types of containers selected for different types of waste collection; in a subsequent step, this description can be used to formulate alternative scenarios in which the recovery of materials and energy is increased by using different plants and waste organization solutions. Alternative scenarios can thus be compared in terms of environmental impacts and costs.

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<sup>17</sup>S. Tunesi, S. Baroni, S. Boarini. 2016. "Waste flow analysis and life cycle assessment of integrated waste management systems as planning tools: Application to optimise the system of the City of Bologna". *Waste Management & Research* 1–14 pg; in print.

**Figure 11: Waste flows in Mauritius**

## WASTE FLOWS in MAURITIUS - IWA project



Date 29/03/2013  
 Software Version 2.0.1.4  
 Database Version 2.0.1.4

Source: Own illustration

For the scenarios to provide useful WM alternatives, close attention must be paid to separate waste

collection, and on the basis of the organization of waste collection, three main flows can be generated. These three waste flows are distinguished because different materials or energies can be recovered from different waste fractions:

1. **Compost and energy can be recovered from the organic fractions:** when organic waste (either food or green waste) is collected separately, it can be sent to a composting plant or to an anaerobic digestion plant, where both energy/fuel and material (compost) recovery can be achieved;

2. **Materials can be recovered from the dry fractions of waste:** following separate collection of dry fractions (such as paper, plastic, glass, metals), the flows of recyclables are followed to determine which amount can be recovered nationally and how much needs to be exported.

3. **Energy can be recovered from residual waste:** in Mauritius, this is already being undertaken. In fact, electrical energy is produced by burning the methane collected from the landfill body in dedicated engines. Other technologies adopted in highly industrialized countries include the thermal treatment of residual waste in high scale plants (so-called incinerators).

The subdivision in three main waste flows supports the planner in addressing the complexity of WM because it “requires policymakers to:

- (a) understand the relevance of the collection phase and to distinguish the amounts and quality of waste flows (including composition) that originate from dependence on collection’s organization;
- (b) formulate and select effective alternative solutions – in each scenario, the type and capacity of plants can be changed for each of the flows independently of the other two;
- (c) assess each technical solution/plant by maintaining the overview of the waste managed<sup>17</sup>, without disregarding waste, plants or impacts relevant to the WM system.

### 3.6 Cost of waste management

The 12 local authorities (urban, 5 municipal councils; rural, 7 district councils) are responsible for collecting the waste collection fee, which is included in the municipal tax for the 5 municipal councils. Generators in the rural districts do not pay a collection fee or tax.

The annual average cost of WM for the government budget was MUR 1,193 million from 2013 to 2015.

Current tax collection only covers a share of total waste management costs incurred by public authorities; thus, the cost of providing municipal solid waste collection services, which is estimated at around MUR 693 million per annum, is covered entirely by allocations to the local councils from the government budget.

The costs also include MUR 200 million per annum for waste management at the transfer stations and MUR 300 million per annum for the management of the Mare Chicose landfill.

Likewise, the costs of providing and operating all publicly owned waste transfer stations and disposal facilities are financed directly from the government budget. Users are currently not being charged.

The cost of waste management is defined in the budget under the appropriate line items ‘capital’ and ‘recurrent costs’:

- capital: new investment and capital projects
- recurrent: ongoing scavenging services, consultancy services.

The WMS 2011 included in the costs of solid waste management:

- the collection of waste throughout the island;
- the transportation to transfer stations; and
- the onward transportation and disposal to the landfill.

Penalties are envisaged for the abandonment of waste in non-dedicated areas, and for cases in which the transport to the transfer station and landfill is performed by a non-authorized waste carrier.

The WMS 2011 states that as regards the coverage of costs, “it is widely acknowledged that waste producers should be made to pay (through user charges) the full costs of the services and facilities required to manage their wastes.” At the same time, it recognizes that “such a policy cannot be introduced overnight.”

What is of relevance for the IWA project is the WMS 2011’s statement that “the first ones to be targeted are the industries and commercial activities. It is thus proposed to introduce a waste disposal fee at transfer stations and landfill sites for industrial and commercial operators.” Moreover, “a key barrier to progress towards higher recycling rates is the free service being offered to industry and commercial activities in terms of no fees being charged at transfer stations and the disposal sites. We are aware that the imposition of the charging scheme may give rise to more illegal dumping. It is recommended that the penalty for illegal dumping be raised substantially”.

However, these provisions have not yet been implemented.

Several elements need to be quantified within the overall costs of managing different types of waste to determine the cost incurred by the public sector for the management of industrial waste:

- the total amount of industrial waste that enters the municipal waste management flow and the cost incurred by the public sector at transfer stations, the landfill and the composting plant that could be allocated to industrial waste;
- the total amount of tax paid to the local authority by individual firms for the disposal of waste generated within the industrial premises and which enter the municipal waste flow;
- at present, a fee only needs to be paid for waste such as asbestos or odorous waste that needs to be treated at the landfill. The WM Strategy 2011 supported the introduction of a fee to be paid by industry for all types of industrial waste deposited at transfer stations or at the landfill.

This measure has not yet been implemented, and the relevance of estimating the impact of such fees on matching the cost generated by the management of industrial waste is underlined.

### ***3.6.1 Feed-in tariffs for electricity produced at landfill***

The Central Electricity Board (CEB) is responsible for the distribution and transmission of power in the country. Independent Power Producers (IPP) sell their power to the CEB. There is no fixed feed-in tariff for the energy sold to CEB. CEB has been resorting to competitive bidding for the implementation of renewable energy projects by IPP. Thus, each tariff is negotiated with each promoter, depending on the size of the plant, the technology used and the financial viability of the project. A Utility Regulatory Authority is expected to be operational soon, which will regulate tariffs in the future.

Sotravic Ltée operates and maintains a landfill-gas-to-energy facility located at Mare Chicose, which collects landfill gas produced from waste fermentation in the landfill body. Authorization of an Independent Power Producer was concluded in 2009, and the Power Generating Plant came on stream in 2011 with the delivery of up to 3.3 MW power to the CEB. On site, the project has required the procurement and installation of three generators of 1.1 MW each, electrical switchgear and transmission systems to the CEB grid and upgrade of gas collection systems, filters and pumps to maximize the volume and quality of gas extracted <sup>18</sup>.

The CEB has been buying electricity from the landfill-gas-to-energy plant since 2011. The proposed tariff by Sotravic Ltée was higher than the average marginal cost of generation by CEB's plants. Sotravic Ltée entered an Emission Reduction Purchase Agreement on 28 June 2007 for the sale of carbon credits generated by the project. The Maurice Ile Durable Fund (MIDF) approved the financing of MUR 100 million for the project. The Mare Chicose landfill-gas-to-energy project, with an expected reduction of 95,000 tonnes of CO<sub>2</sub> equivalent per annum, was approved at the CDM executive board level and the carbon credit revenue is shared among Sotravic Limitée, the Ministry responsible for WM and the CEB.

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<sup>18</sup> From <http://www.sotravic.net/about-us/project-6-mare-chicose-landfill-gas-to-energy-project.html>



### 3.7 Waste agents

#### 3.7.1 Formal sector

Waste management is a complex system involving many public and private actors. Table 5 summarizes the role played by the selected actors in the IWA in Mauritius project:

**Table 5: Roles played by different stakeholders in waste management**

<b>ACTOR</b>	<b>ROLE in IWA in Mauritius</b>
<b>Large industries and SMEs</b>	Generating industrial waste and waste similar to municipal waste. Safely disposing of generated waste. Consignment notes: keep track of transport and management of their waste. Recover materials and energy from waste.
<b>Ministry of Environment Solid Waste Management Division Sustainable Development Division Pollution, Prevention and Control Division</b>	Responsible for the protection of the environment and public health through the proper management of solid and hazardous waste. <ul style="list-style-type: none"> <li>• formulate WM policies and strategies for the minimization and recovery from waste, storage, collection, conveyance and disposal of waste;</li> <li>• enforce control of private operators in the field of waste management.</li> </ul>
<b>Wastewater Management Authority</b>	Responsible for the management of wastewater discharges connected to the sewer network and wastewater that is disposed at the pumping station.
<b>Ministry of Industry, Commerce &amp; Consumer Protection</b>	Promote greening of large industries.
<b>Ministry of Energy and Public Utilities</b>	Setting feed-in tariffs to support the recovery of energy from waste Grid codes have been prepared that promote the production of electricity from the following renewable technologies: <ol style="list-style-type: none"> <li>1. Photovoltaic (PV)</li> <li>2. Wind turbine</li> <li>3. Hydro</li> <li>4. Biomass.</li> </ol>
<b>Ministry of Business</b>	Support for SMEs in the development of sustainable practices.
<b>Ministry of Finance</b>	Elaborate the WM budget Provide support in defining WM taxes/fees

<b>Municipal City Council</b>	Responsible for:
<b>Municipal Town Council</b>	– raising revenue to enable the Municipal City Council, Municipal Town or District Council to perform its functions;
<b>District Council</b>	– the collection and conveyance of waste, with the exception of industrial waste, to disposal sites or waste management facilities;
	– control of pollution causing a public or private nuisance.
<b>MC Landfill manager</b>	Manage landfill
<b>Transfer Stations managers</b>	Manage transfer stations and interact with the informal sector
<b>Registered Waste Transport Carriers</b>	Transport municipal and industrial waste to transfer stations and landfills.
<b>Recyclers</b>	Recycle plastics into new items; refine exhausted oil; recycle glass.
<b>Recyclers of waste by export</b>	Export recycled waste fractions.
<b>Managers of facilities that could provide energy to waste</b>	Define and implement projects for the recovery of energy from different types of waste.
<b>NGOs</b>	Support awareness and recycling information campaigns; Facilitate encounters and communication between different actors.
<b>International agencies</b>	Address capacity building; Support, also financially, the development of sustainable practices; Support, also financially, the design of WM strategies.
<b>International private funders</b>	Analyse and select industrial green economy/best practices and WM enterprises for funding.
<b>International enterprises</b>	Developing recovery from industrial waste projects and enterprises in Mauritius.
<b>Research centres</b>	Develop innovative answers to management and recovery from waste; Support incapacity building.

### 3.7.2 *Informal sector*

At present, informal waste pickers are active in nearly all visited industries.

The informal sector also plays a role at a few transfer stations.

The IWA project did not find any specific organization that monitors health and workplace conditions.

### 3.8 Preliminary observations on the overlap between the management of different waste streams

The steps of the internationally recognized ‘waste hierarchy’ are, in order of relevance:

- minimization
- re-use
- recycling (recovery of materials) and composting
- recovery of energy: anaerobic digestion<sup>19</sup> and thermal treatments
- disposal in landfill.

In international and European WM policies, landfill is always the least preferred option: this is due to the high environmental and social impacts of such plants. Landfill is the WM phase with the highest climate change impacts due to the emission of methane – a powerful greenhouse gas – from biowaste fermentation in the landfill body.

EU WM policies, in particular, address the need to reduce the amount of biodegradable waste ending up in the landfill: country-specific objectives have been set in EU legislation for a drastic reduction of organic waste being landfilled.

There is currently no overall policy in Mauritius for the separate collection of recyclable waste. The major constraints for initiating this practice is the cost of establishing a separation system.

Differently from household/commercial/business waste, the industrial firms investigated in the IWA project separate specific flows of waste they produce (see Chapter5). Recycling of industrial waste is carried out when it provides an economic advantage to firms or when recyclers, both from the formal and informal sectors, can benefit from the reuse or recovery of the secondary materials.

When industrial waste is not separated and recycled, the residual waste is disposed at the Mare Chicose landfill following transport to the transfer station.

A feasibility study could be carried out to assess the conditions under which WM costs could be leveraged to increase the advantage of recycling if taxes for the disposal at transfer stations and landfills were introduced, i.e. if the cost of landfill disposal were increased, the recovery of material or energy from industrial waste could become more cost effective.

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<sup>19</sup>Please note that anaerobic digestion, which involves organic waste, also entails the recovery of compost. Hence, for this technology, the distinction between material and energy recovery is not as relevant as for other technologies.

## 4 Methodology for conducting an industrial waste assessment in mauritius

The methodology applied in the IWA in Mauritius project is based on the following key elements:

1. adopt the appropriate **tools to quantify** industrial waste generation and identify types and amounts of solid waste at the national scale per year by each of the selected industries in which industrial symbiosis projects could be implemented.

The tools used were:

- a. a **questionnaire** was formulated with contributions from all stakeholders participating in the Steering Committee to be filled by individual firms;
  - b. **on-site visits** to 23 firms in the selected industries;
  - c. a **selection of the types of solid waste** that could form part of an **industrial symbiosis** approach was performed on the basis of waste type suitability for material or energy recovery and on the basis of the amount available per year (as reported in the questionnaires);
  - d. analyse data made available from the Central Statistics Office on each industry's gross output and from the Business Registration Department on each firm's turnover. These **gross output and turnover** data were used **to estimate** the amount of relevant waste types at national level generated per year in each industry (**scaling-up**);
2. on the basis of the quantification performed in 1., analyse the **legislative and institutional national framework** to identify the obstacles and opportunities for the development of projects for the recovery of materials and energy from industrial waste in Mauritius;
  3. identify the **relevant actors** of industrial waste management, facilitate the sharing of different points of view and support the elaboration of common industrial symbiosis strategies;
  4. address **capacity building**: strengthen the ability of public authorities to interface with industrial management and deepen the industrial management's knowledge of the legislative framework related to WM.

### 4.1 Selection of industries and individual firms

The description of the manufacturing production segment presented in section 3.1 discusses the most relevant industries contributing to manufacturing. Thus, on the basis of their relative relevance, the industries selected for this IWA study were<sup>20</sup>:

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<sup>20</sup> Statistics Mauritius - NSIC. 2016. Statistics Mauritius - NSIC. [ONLINE] Available at: <http://statsmauritius.govmu.org/English/Pages/NSIC.aspx>. [Accessed 11 June 2016].

- **Manufacture of textile and wearing apparel** (NSIC divisions 13 and 14) comprising textile and wearing apparel firms.
- **Chemicals and chemical products** (NSIC divisions 20-21) comprising firms involved in the preparation of basic pharmaceutical products.
- **Printing and reproduction of recording media** (NSIC division 18) comprising firms involved in printing and service activities related to printing.
- **Manufacture of food products** (NSIC division 10 and 11).

Given that the food industry is heterogeneous, with processes, operations, products and waste differing significantly, the firms belonging to it were divided into **three sub-industries**: poultry, seafood and beverages and bottling. To create these sub-industries, we adopted a grouping methodology at the level of NSIC sub-classes which partially deviated from the NSIC structure of the corresponding group: given the objective of the project, firms were grouped into sub-groups that generate similar types of waste.

- **Poultry** – based on NSIC division 10, group 101: the operations performed by the firms that fall within this sub-industry can be described as processing and preserving of poultry, other meat, n.e.c., e.g. production of hides, production of meat products, e.g. sausages, slaughterhouses.
- **Seafood** – based on NSIC division 10, group 102: the operations performed by the firms that fall within this sub-industry can be described as processing and preserving of fish and other seafood products.
- **Beverages and bottling** – NSIC division 11 group 110, class 1104: the operations performed by the firms that fall within this sub-industry can be described as manufacture of mineral waters and other bottled waters, soft drinks and non-alcoholic beverages, mineral and bottled water. Additional operations included in this sub-industry are manufacture of fresh liquid milk, pasteurized, sterilized, homogenized and/or ultra-heat treated, manufacture of milk-based drinks, manufacture of fruit or vegetable juices and production of concentrates from fresh fruits and vegetables.

A list of all firms that fall into one of these three sub-industries (poultry; seafood; beverages and bottling) can be found in Annex 1. The list was drawn based on data obtained from the Central Statistical Office and the Companies and Business Registration Integrated System.

The 23 firms from the relevant industries were selected by the Technical Working Group (TWG), a sub-committee of the Steering Committee. Of the 23 firms surveyed, one was not included in the results of the study as it fell outside any of the industries or sub-industries considered here.

Business Mauritius played an active role in selecting the relevant firms and was instrumental in involving the firms' management in the IWA project.

#### **4.2 Questionnaire and process flow diagram**

A questionnaire was used to collect data from each firm. It was devised in a user friendly manner to guide the firms in collecting waste data on their production process. The questionnaire was finalized by the TWG in collaboration with the UNIDO team and can be found in Annex 2.

The questionnaire required each firm to reconstruct the process flow diagram/s for their industrial activities: the process flow diagrams required firms to determine where waste – both industrial or similar to municipal waste – is produced.

This activity proved particularly significant for understanding at which industrial stage waste that could potentially be covered by industrial symbiosis is generated and which activities are carried out that generate waste that can be considered similar to municipal waste and can thus be merged in the management of the municipal solid waste stream.

Although the questionnaire collected data on wastewater generated and energy consumed on-site, the scope of the project only addresses industrial symbiosis recovery of industrial solid waste.

#### **4.3 Site visits and filling in of questionnaires**

All the firms were visited by the UNIDO team at least once to discuss the questionnaire with the firm's management, explain the data required (type and amount of waste generated) and the process flow diagram. The filling in of the questionnaire was carried out by the technical staff of the each firm.

During each visit, a walk through analysis was conducted to understand the different processes and unit operations of each firm.

The data provided were used to build the generic process flow diagrams illustrated in Section 5.4. Such general process flow diagrams highlight the processes established in units that generate waste which could be covered by an industrial symbiosis project; such tools could support further analysis of firms that belong to the selected industries but are not included in the IWA project.

As expected, in most cases, data were not easily and readily available and additional visits were necessary to complete the exercise.

#### 4.4 Selection of relevant waste types and estimates of amounts of industrial waste at the national level

For each industry, the different types of waste were classified according to:

- the main waste fraction to which they belong; and
- the current type of management (see Table 7).

Subsequently, the waste suitable—in terms of characteristics and amount—for coverage under an industrial symbiosis project was identified (see section 5.3).

Two types of quantitative analysis were performed:

1. for each industry, all different types of waste produced were determined based on their relative relevance (see pie charts in section 5.3): these charts only provide indicative values given the non-homogeneous way in which the questionnaires were filled in by the individual firms on the types of waste not relevant for industrial symbiosis;
2. an estimate of the amount of waste available at the national level was performed (scaling up) for each type of waste suitable for coverage under an industrial symbiosis project (see Table 9).

##### 4.4.1 Gross output data for each industry

To scale up the relevant waste generated per year in each sub-industry at the national level, different approaches were explored. The independent variable used for the estimates was ‘turnover’ (or gross output). This variable, for instance, proved more reliable than the number of employees. The underlying assumption is that firms belonging to a certain industry or sub-industry operate with a similar production process, thus resulting in an amount of waste generated that is directly proportional to the overall production output. The general process flow diagrams generated in the course of the IWA project (see section 5.4) illustrate this assumption in more detail.

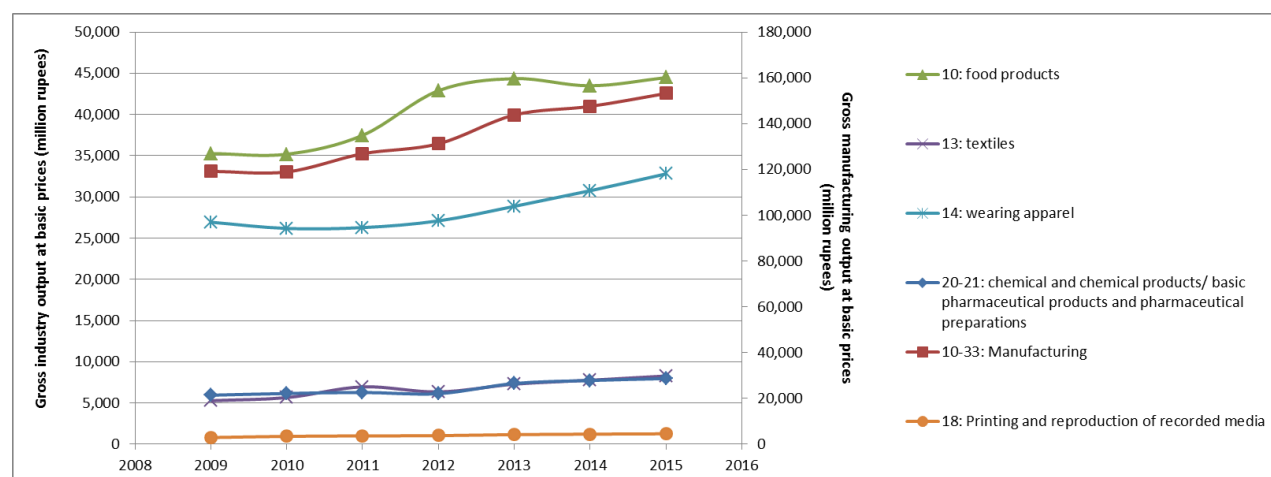
The calculation for the scaling-up at national level required some further assumptions. In particular, while the data collected from the questionnaires on the amount of waste and on individual firm *turnover* referred to the year 2015, the values of *gross output* at the national level were only available up to the year 2013. Thus, to scale-up the amount of waste referring to the year 2015, the values for gross output for 2015 were estimated.

The values of gross output for the year 2015 for the textile and wearing apparel (NSIC 13 and 14), the chemicals and chemical products (NSIC 20 and 21), the printing and reproduction of recording media (NSIC 18) and the food industry (NSIC 10 and 11) were extrapolated on the basis of the value for gross

output<sup>21</sup> for the years 2009 to 2013, taken from the Production Account of the Industrial Sector by industry group table (in the Digest of Mauritius Industrial Statistics, issued annually by the Central Statistical Office).

The resulting gross output trends and the values for 2015 are shown in Figure 12.

**Figure 12: Gross output projection up to 2015**



*Source:* UNIDO calculations based on gross domestic product/gross value added by industry group at current basic prices, 2012 – 2015 from the National Accounts Estimates, June 2015 Issue by the Central Statistical Office

The extrapolation to 2015 of gross output data are based on the following assumptions:

1. Production is growing at the same rate as value added, given that:

$$\text{Gross Output} = \text{Value Added} + \text{Intermediate Inputs}$$

2. Wearing apparel is growing at the same rate as textiles.
3. Chemicals is growing at the same rate as “others” in the table: gross domestic product/gross value added by industry group at current basic prices, 2012 – 2015.
4. Printing is growing at the same rate as “others” in the table: gross domestic product/gross value added by industry group at current basic prices, 2012 – 2015.

The values of gross output for the poultry, seafood, beverages and bottling sub-industries were estimated by adding up the 2015 turnover of all firms considered to fall into these groups. A list of these firms can be found in Annex 1.

At industry level, gross output can be approximated to the sum of the total turnover of firms in the given industry.

<sup>21</sup>Gross domestic product/gross value added by industry group at current basic prices, 2012 – 2015 were taken from the National Accounts Estimates, June 2015 issued by the Central Statistical Office.



#### 4.4.2 Turnover of individual firms

Obtaining homogeneous and comparable data for the turnover of individual firms required a specific procedure involving the collection of specific documents; this procedure was made necessary by the fact that not all firms volunteered to provide this value and those that did often provided general overall values.

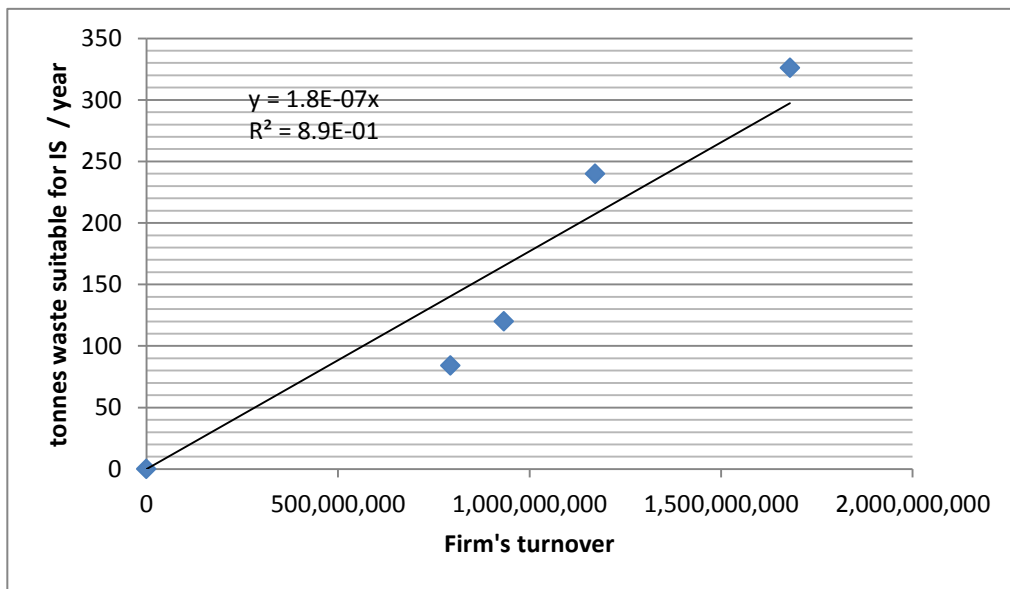
The value of each firm's turnover was obtained from profit and loss statements available from the Corporate and Business Registration Department (data for the year 2014-2015). The forms were downloaded from the Companies and Business Registration Integrated System website (accessible at <https://portal.mns.mu/MNSOnlineSearch/GetCompanies?doAction=removeOrder>).

#### 4.5 Scaling up of the relevant waste types per industry

Assuming, as described in the preceding sections, a linear relationship between the independent variables 'turnover/gross output' and 'amount of specific type of industrial waste generated per year', the turnover of each firm belonging to a specific industry was plotted against the amount of each relevant waste, and a linear relationship was assumed with an equation that intercepts the axes at (0.0) values.

A generic example of the method adopted for each industry or sub-industry is presented in .

**Figure 13: Generic example of the relationship between waste relevant for IS and firms' turnover**



Source: UNIDO calculations

The equation of the line was used to calculate the total amount of waste generated per year by the entire industry at national level, by substituting the independent variable (the x value) with the gross output value for the entire industry. All estimated values are summarized in Table 9 in section 6.1.

#### 4.6 Capacity building

The IWA project resulted in a relevant capacity building outcome, which addressed both the private and public sectors. This positive outcome is the result of the detailed application of the proposed IWA methodology and the continuous exchange of information, the shared analysis of legislation and the exchange of points of view among all relevant actors involved in industrial waste management.

A first meeting with the selected firms, the members of TWG and the UNIDO team was held at the inception of the project to share the objectives of the study and the various steps and processes included in the methodology with the firms' management. The meeting was interactive and all questions and concerns of the participating firms were considered and answered.

Once the questionnaire had been agreed on, a two-day capacity building workshop was held for all stakeholders involved, including representatives of the selected firms, members of the Steering Committee and TWG as well as representatives of recycling companies. During the workshop, different regulations and legislation on the environment and waste management were also discussed and which directly involve the Ministry of Industry, Commerce & Consumer Protection, Commerce & Consumer Protection and the Ministry of Environment.

After the workshop, the questionnaires for the industrial waste assessment were distributed and on-site visits were carried out to each participating firm. The up-scaling calculations for estimated values for industrial waste, which could be covered by an industrial symbiosis project, were carried out based on data gathered from the questionnaires during the site visits, and other secondary data sources. A draft report was prepared and shared with Mauritian institutions and the Steering Committee for comments.

A validation workshop was then held with all ministries involved, all participating firms and the majority of active recycling enterprises in Mauritius.

The positive outcomes of the capacity building exercise were strongly appreciated by all actors involved, which can first and foremost be associated with the high interest and strong involvement of the private sector as well as to the:

- detailed analysis of each firm's industrial process flow conducted during the on-site visit(s);
- follow-up by the local UNIDO team with each firm to support the filling in of the questionnaire and the design of the process flow diagram;
- presentation of the criteria that can generate an effective waste management framework;
- an in-depth and open discussion with the relevant ministries about a list of recommendations addressing, inter alia, the national legislative and institutional framework.

## **5 Types of waste generated and analysis of process flow diagrams for the industries**

### **5.1 The industries analysed**

To estimate the amount of industrial waste that could become part of an industrial symbiosis framework, the most important industries in terms of gross output (turnover) were selected for the IWA in Mauritius project:

1. Food products (NSIC 10): of which the following sub-industries were analysed:
  - Poultry
  - Seafood
  - Beverages and bottling
2. Textile (NSIC 13 and 14), which includes the textile and wearing apparel industries
3. Chemicals and chemical products / basic pharmaceutical products and pharmaceutical preparations (NSIC 20-21)
4. Printing and reproduction of recording media (NSIC 18).

Table 6 summarizes the gross output of each industry and sub-industry, the percentage of their contribution to Mauritius' overall industrial gross output and the percentage of each industry covered by the IWA questionnaire. In Mauritius, the manufacturing sector contributed 14.8 per cent of GDP in 2015 (Statistics Mauritius).

**Table 6: Characteristics of selected industries and % of industries represented by IWA**

<b>Industry</b>	<b>Gross output of industry 2015 (in MUR million)</b>	<b>% of manufacturing gross output (NSIC: 10-33) 2015</b>	<b>% of industries' or sub-industries' gross output surveyed by questionnaire</b>	<b># of companies surveyed</b>	<b># of companies in industries and sub-industries</b>	<b>% companies surveyed by questionnaire</b>
Food product	44 486 *	29		9	107 (2013)	8
Poultry	5 799 **		81	3	9 **	33
Seafood	8 174 **		3	3	12 **	25
Beverages and bottling	2 974 **		33	3	6 **	50
Textile and wearing apparel	41 091 *	27	16	6	189 (2013)	3
Chemical	7 970 *	5	21	6	31	19
Printing	4 563 *	3	4	2	36	6

\* Source: 2013 gross output from “Mauritius Industrial Statistics digest 2014, June 2015” extrapolated to 2015

\*\* Source: Values estimated by adding up the turnovers of 2015 (obtained from the Companies and Business Registration Integrated System (CBRIS)) of all exporting and non-exporting firms considered to fall into these sub-groups (see Annex 1)

## **5.2 Solid waste types generated in the selected industries and current management practices**

The firms—both export and domestic market-oriented—at which on-site visits took place showed a serious interest in improving their environmental performance. Many of them had already carried out energy audits and implemented energy efficiency improvements with the help of expert consultants and auditors. Several have ISO 9000 or 14000 certification. Wastewater treatment is also performed in the firms for which it is relevant.

A recycling industry exists in Mauritius, which is fairly diversified in its capability, is committed to improving waste collection and material recovery from waste. Many firms already recycle some of their waste, but it was observed that not all firms are aware of the wide range of options offered by registered recyclers. At the same time, several industries' waste is collected by the informal sector, primarily for reuse.

The contact with the firms' management demonstrated that at this stage, many would consider the implementation of practices that could increase the:

- recovery of materials from the waste already being separated within the firm;
- separate collection of waste that could be recycled.

Table 7 lists the different types of solid waste mentioned in the questionnaire, grouped by industry and the waste management practices currently being applied for each type of waste; the table also lists different types of waste common to all industries analysed.

**Table 7: Solid waste types recorded during IWA**

<i>Sector</i>	<i>Solid waste</i>	<i>Current management</i>
<b>Food poultry</b>	Organic waste from poultry (including offal, feathers, head, contaminated birds, feet, blood, fat)	Material recovery to produce flour for pet food Landfill
	Carton boxes / paper	Landfill: too dirty to be accepted for recycling
	Plastics	Landfill: too dirty to be accepted for recycling
	Faeces and farm waste	Composted and compost to local market
<b>Food seafood</b>	Organic waste from fish (including whole dead fish, fish bones and fish internal waste)	Landfill
	Fish food packaging (plastics)	Landfill: too dirty to be accepted for recycling
	Salt	Landfill
	Used Oil	Recycling
<b>Food bottling</b>	HDPE	Recycling
	Organic waste including plastics	Landfill
	Carton boxes	Recycling
	Milk powder packaging (composite bag made of paper and plastics)	Recycling
	Metal drums	Recycling Reuse

	Scrap metal	Recycling
	Paper	Recycling
	Glass bottles and debris	Recycling Landfill
<b>Textile and wearing apparel</b>	Yarn and cotton fabric	Recycling
	Woollen fluff	Landfill
	Obsolete chemicals	Storage Landfill
<b>Chemical</b>	Chemical waste	Storage
	Metal drums	Re-use (after cleaning in firm)
<b>Printing</b>	Aluminium plates	Recycling
	Paper to be kept confidential	Landfill
	Plastic toner container	Storage
<b>All sectors</b>	General waste (canteen, offices, sweepings)	Landfill
	Carton boxes / paper	Recycling
	Plastics	Recycling
	Wooden pallets	Reuse Recycling
	Exhausted oil	Recycling
	E-waste, Batteries, Lighting equipment	Recycling Storage (if potentially hazardous)
	Scrap metals	Recycling

On the basis of the application of the IWA methodology, the industrial waste generated at the industrial sites can be classified into the following types:

- 1) waste relevant for the IWA project because it can undergo material and/or energy recovery within the scope of an industrial symbiosis project;
- 2) waste similar to municipal waste which, following collection and transport organized by the firm, enters the municipal waste stream and is thus eventually disposed at the Mare Chicose landfill;
- 2) industrial waste (such as plastic bags containing residuals) which is not similar to municipal waste

but is mixed with general waste and, following collection, enters the municipal waste stream and is disposed at the Mare Chicose landfill;

3) waste which is already part of the recovery supply chain because it is collected by registered recyclers, such as:

- paper and cardboard
- plastic films and bags
- wooden pallets
- used oil

4) waste collected by informal recyclers and individuals primarily for reuse, such as plastic bags, drums and carton boxes;

5) potentially hazardous waste stored in dedicated areas: this will be conferred against payment to the Interim Hazardous Waste Storage Facility, once in operation, where it will be stored and prepared for shipment;

6) hazardous waste exported: on the basis of the Basel Convention, which Mauritius has signed, necessary permits/clearance must be obtained from relevant authorities before exporting such waste;

7) potentially hazardous electronic waste, currently being stored, such as neon lamps.

### 5.3 **Approximate distribution of types of waste per industry**

The waste assessment questionnaires supplied to the firms asked for quantitative information about the amount of waste generated annually for different waste types. Based on this information, the amount of waste of different types can be estimated for each specific industry investigated. The results are presented in the following sections.

The main caveat of these findings is that the amount of the different types of waste, derived from adding different waste fractions together, should only be considered approximate values for the following reasons:

- the preliminary nature of the IWA study and the small sample size; the maximum number of firms per industry was six;
- the scaled up value for each type of waste at industry level is highly biased by the gross output of the sample of participating firms and that of the industry. It assumes a homogeneous generation of waste throughout the industry;

- the addition of the amount attributed to a specific waste fraction is associated with a high uncertainty due to the fact that not all answers to the questionnaire covered the same types of waste. In fact, some firms focused on waste generated by their main industrial processes, while others also included waste generated in offices and canteens. Moreover, different types of waste have been included under the same waste heading. As a result, different types of waste could be classified under the same fraction (such as paper and plastics under packaging or organic waste under general waste and sweepings).

Table 8 provides an example of the difference in quality of data collected, which leads to uncertainties in the addition of some of the waste fractions:

**Table 8: Example of data quality on the amount of different types of waste in a specific industry (six firms)**

Type of waste	1	2	3	4	5	6
Waste relevant for IS	+	+	+	+	+	+
Paper of different types and quality	0	0	0	0	+	+
Carton boxes of different quality	+	0	+	+	+	+
Plastics of different types and quality	*	+	+	+	+	+
Wood and wooden pallets	*	0	+	P	P	P
Metal waste of different types and quality	*	0	+	+	+	0
Obsolete chemicals	0	0	+	+		
Mixed e-waste	*	*	P	P	P	P
Glass	0	0	0	0	0	+
Used oil	0	L	L	L	L	L
General waste (including kitchen)	0	+	+	+	0	+
<p><b>+</b> type and amount of waste provided in detail</p> <p><b>0</b> waste type not included in the firm's answer</p> <p><b>*</b> waste type listed but amount not provided</p> <p><b>P</b> waste type quantified by pieces but not weight</p> <p><b>L</b> waste type quantified by litre and not weight</p>						

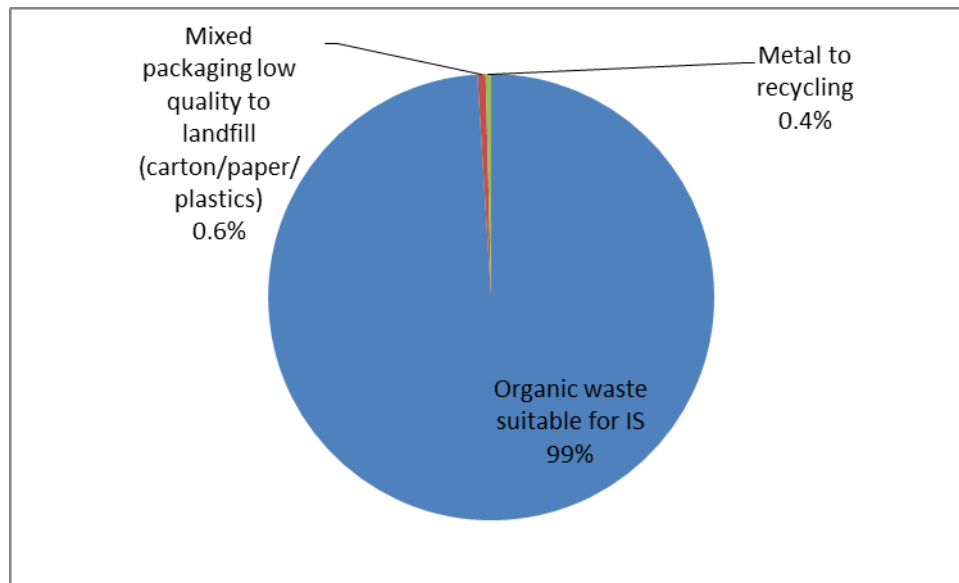


### 5.3.1 *Approximate distribution and quantity of waste types in the food - poultry sub-industry*

The total amount of waste recorded for the three firms sampled from the poultry sub-industry was over 7,100 tonnes for the year 2015.

Figure 14 illustrates the approximate percentage distribution of waste types generated in the poultry sub-industry. It shows that organic poultry waste suitable for industrial symbiosis – consisting mainly of organic waste from poultry, blood and fat – constitutes 99 per cent of total waste generated.

**Figure 14: Approximate percentage distribution of waste types generated in the poultry sub-industry**



Source: Own calculation

The other types of waste, namely packaging (dirty cartons, paper, plastics) and metals represent less than 1 per cent of the total waste generated in the sub-industry.

It was not possible to quantify the amounts of other types of waste mentioned in the firms' answers, such as used oils and e-waste.

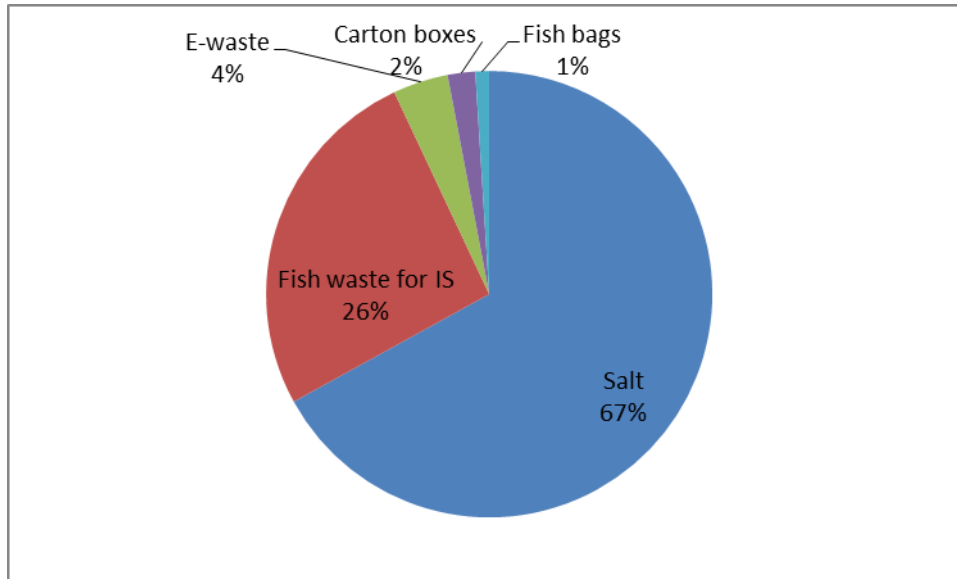
### 5.3.2 *Approximate distribution and quantity of waste types in the food - seafood sub-industry*

The seafood sub-industry consists of seafood (fish) processing industries and the manufacturing of salted fish, which are different processes and thus generate different types of waste.

The total amount of waste recorded for the firms of this sub-industry was 150 tonnes for the year 2015.

Figure 15 shows an approximate percentage distribution of waste types generated in the seafood sub-industry, where salt is the main waste of the salting fish industry followed by fish waste from the fish processing industry. Unfortunately, the largest firms of this sub-industry did not participate in the study.

**Figure 15: Approximate distribution of waste types in the seafood sub-industry**



Source: Own calculation

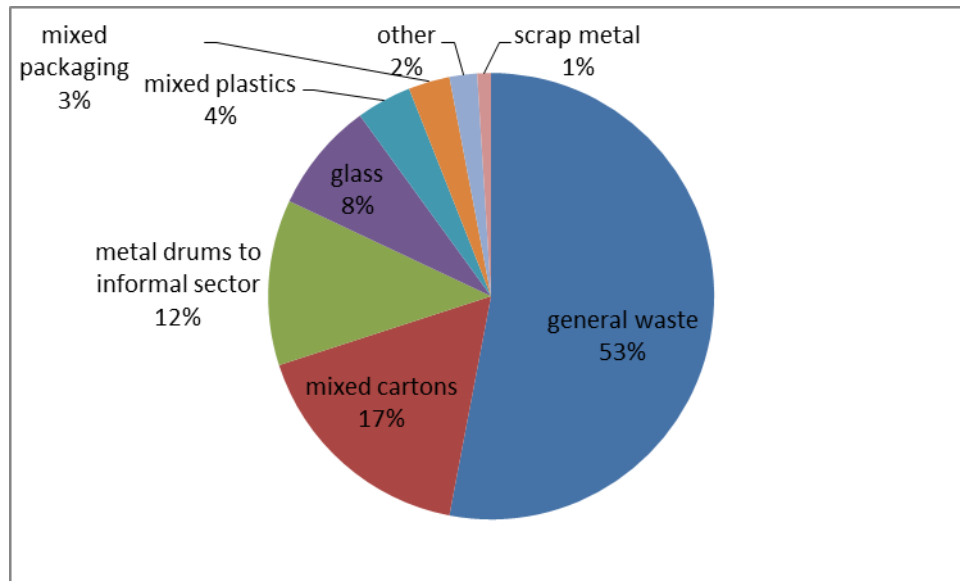
### ***5.3.3 Approximate distribution and quantity of waste types in the food - beverages and bottling sub-industry***

All beverages firms visited (both alcoholic and non-alcoholic beverage firms), edible oil and dairy industries were grouped in the beverages and bottling sub-industry.

The firms of the bottling sub-industry visited did not generate any types of waste that could be covered by an industrial symbiosis project. The total amount of waste recorded for the three firms in this sub-industry was over 700 tonnes for the year 2015.

Figure 16 shows an approximate percentage distribution of the different types of waste generated in the food – beverages and bottling sub-industry: the waste produced is highly heterogeneous. The main waste from this sub-industry is mixed general waste primarily composed of organic residues often contaminated with plastics and, to a lesser degree, with metal waste, glass and carton.

**Figure 16: Approximate distribution of waste types in the beverages and bottling sub-industry**



Source: Own calculation

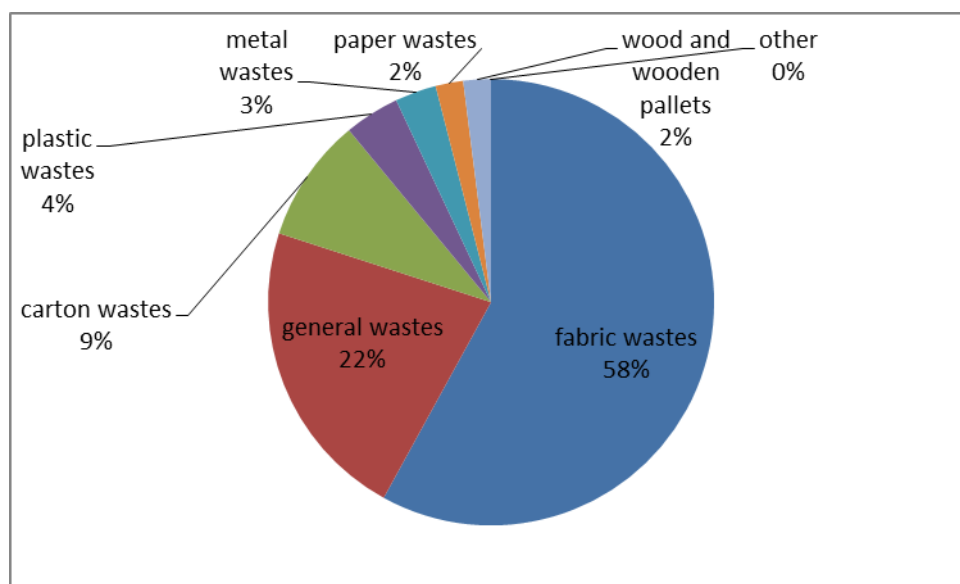
It is worth pointing out that one firm separated the different types of waste in separate containers; other firms did not separate waste and, as further discussed in the recommendations section, an expansion of this practice could result in further types of waste for recovery.

**5.3.4 Approximate distribution and quantity of waste types in the textile and wearing apparel industry**

The textile industry including wearing apparel represents 25 per cent of the manufacturing sector.

The total amount of waste recorded for the six firms in this industry was around 2,200 tonnes for the year 2015.

**Figure 17: Approximate distribution of waste types in the textile and wearing apparel industry**



Source: Own calculation

Figure 17 presents the approximate percentage distribution of the different types of waste generated in the textile and wearing apparel industry. Fabric waste represents 58 per cent of the total waste generated, followed by mixed general waste, which is mainly of an organic nature, originating from the firms' canteens.

### 5.3.5 *Approximate distribution of waste types and quantity of waste in the chemical industry*

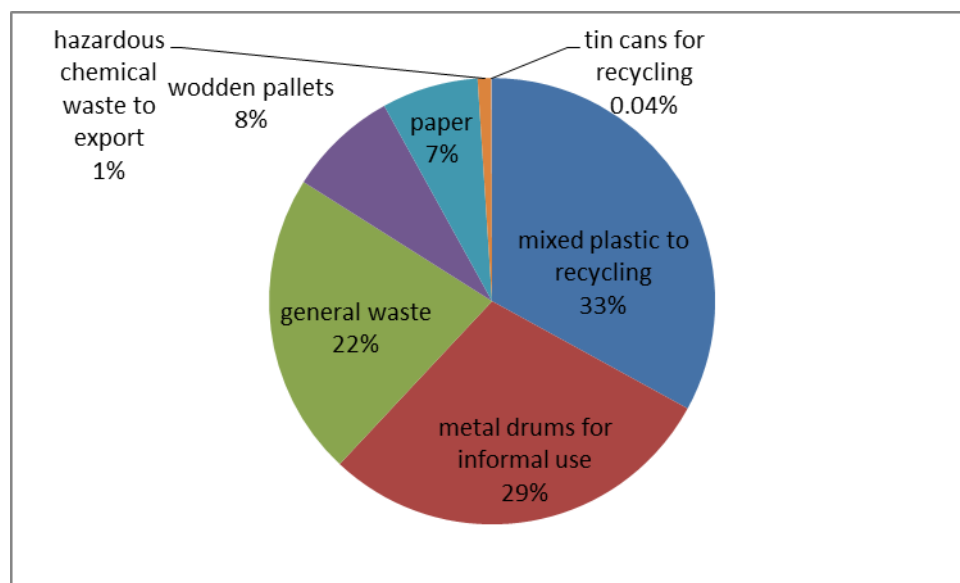
The chemical industry includes the manufacturing of paints, detergents and plastic pipes.

The firms visited in this industry did not generate any type of waste that could become part of an industrial symbiosis project.

The total amount of waste recorded for this industry was over 1,100 tonnes for the year 2015.

Figure 18 shows an approximate percentage distribution of the waste types generated in the chemical industry. The waste types generated in the chemical firms is quite heterogeneous. The main types of waste in the chemical industry include different types of plastics and metal drums which can be used to store raw materials, followed by general waste and wooden pallets.

**Figure 18: Approximate distribution of waste types in the chemical industry**



Source: Own calculation

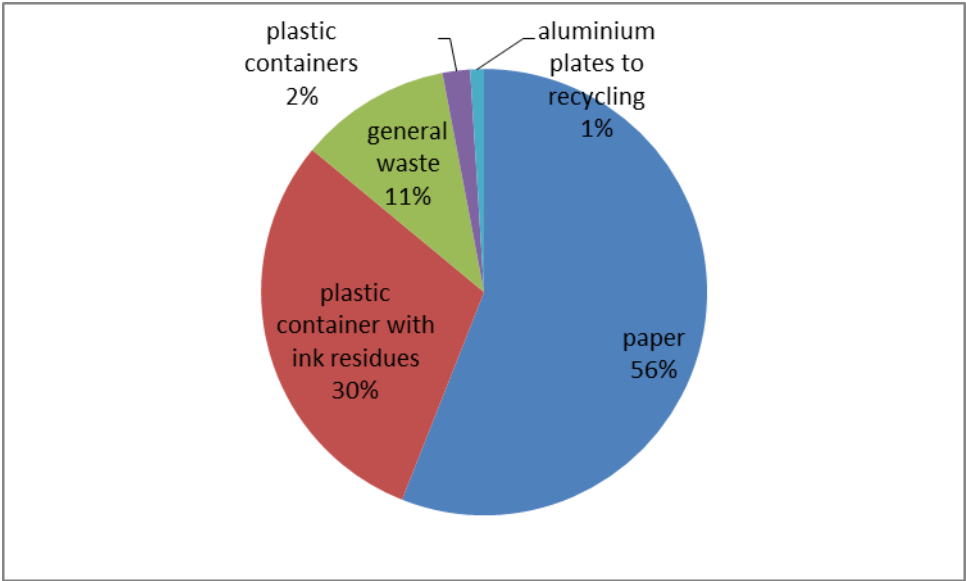
### 5.3.6 *Approximate distribution and quantity of waste types in the printing industry*

The printing industry has diversified over the years. It initially only involved the printing of paper; now it is an important industry that manufactures a variety of products ranging from utilities bills, bank cheques, etc.

The firms visited in this industry do not generate waste types that could become part of an industrial symbiosis project.

Figure 19 presents an indicative percentage distribution of the waste generated in the printing industry. The main type of waste generated is waste paper followed by industry-specific plastic containers.

**Figure 19: Approximate distribution of waste types in the printing industry**



Source: Own calculation

#### 5.4 Process flow diagrams

Each firm participating in the IWA project provided a production process flow diagram highlighting the inputs and outputs of each process unit, including solid waste and wastewater.

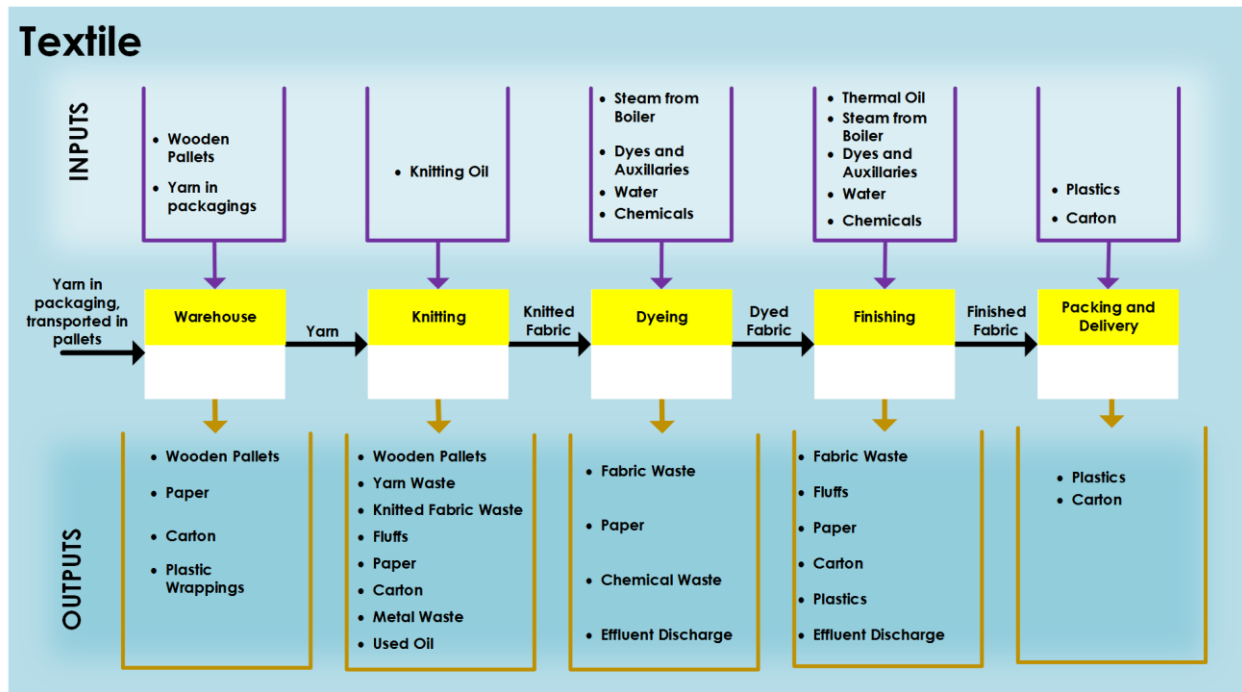
From the different and detailed flow diagrams provided by each firm, general process flow diagrams were reconstructed for those industries whose waste types are more relevant for the IWA project.

From these flow diagrams, the processing units generating the waste types listed in Table 9 can be determined. This IWA project outcome may support the identification of waste which could become part of an industrial symbiosis project in similar firms of the same industry, which are not included in this investigation.

### 5.4.1 The textile and wearing apparel industry

The following process flow diagram specifies the processing units, the input of resources and the detailed outputs of the different waste types for the textile and wearing apparel industry.

Figure 20: Process flow diagram for the textile industry



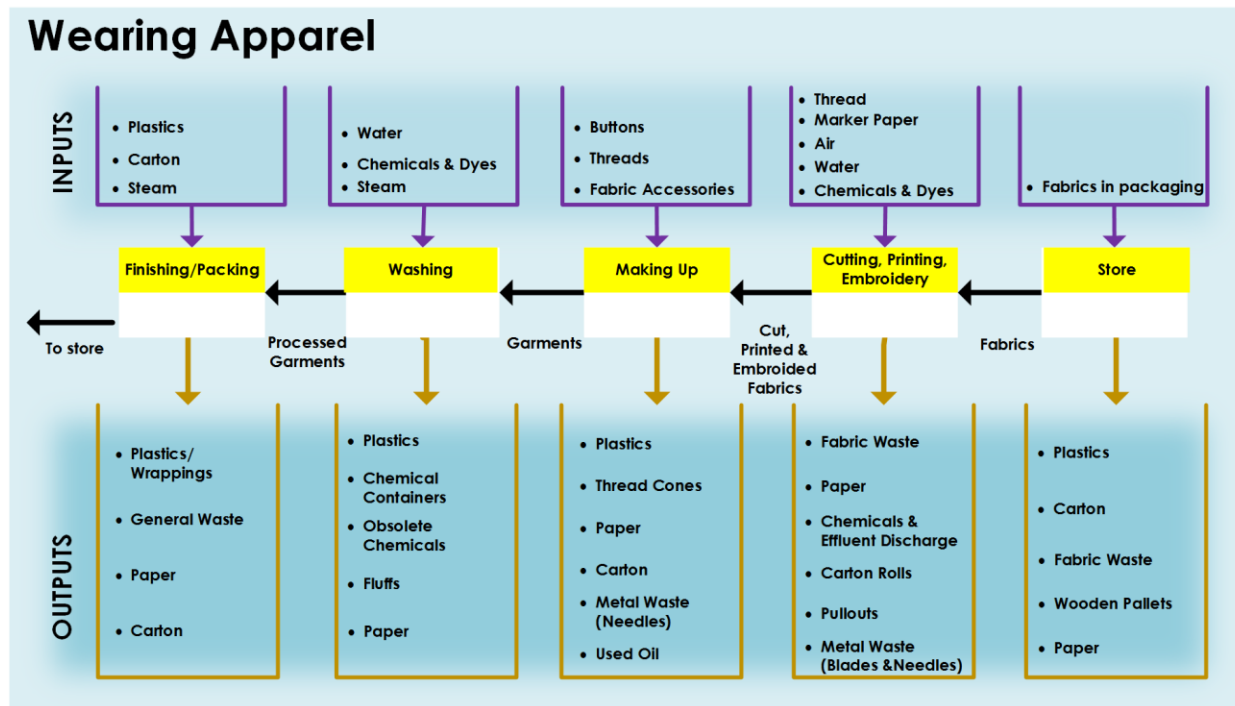
Source: Own drawing

In the textile industry, the types of textile waste relevant for industrial symbiosis projects are generated at the following unit:

- in knitting, both yarn and fabric waste is generated
- in dyeing: regardless whether dyeing takes place before or after knitting, yarn or fabric waste is generated
- finishing.

Other types of solid waste not relevant for industrial symbiosis projects are generated at every unit.

Figure 21: Process flow diagram for the wearing apparel industry



Source: Own drawing

In the textile and wearing apparel production processes, knitting and dyeing can be performed in varying order: the diagrams provide only one type of organization, which was found more relevant in the selected firms visited.

In the wearing apparel industry, the general process flow diagram shows that types of textile waste relevant for industrial symbiosis projects are mainly generated at the following unit:

- cutting.

### 5.4.2 Poultry sub-industry process flow diagram

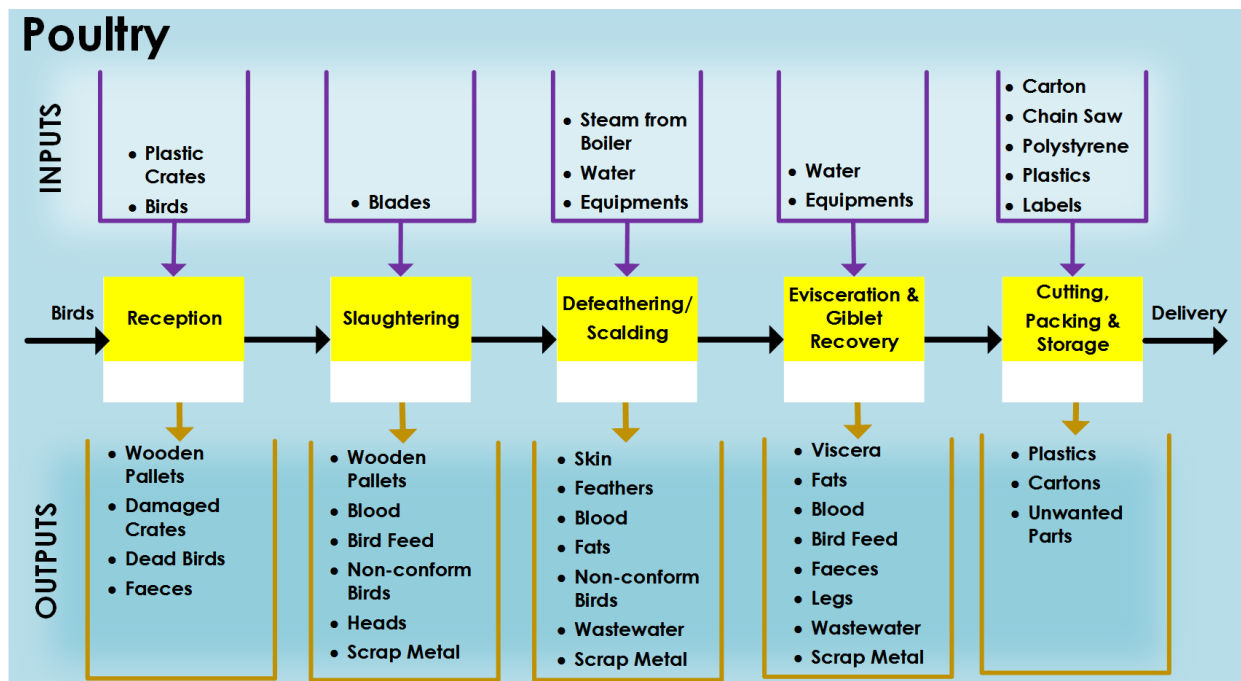
The process flow diagram for the poultry sub-industry shows the different units in which organic waste that can become part of an industrial symbiosis project is generated:

- Chicken reception
- Removal of unwanted body parts
- Processing for recovery of useful parts.

Chicken reception and the packaging units generate paper, plastic and wooden types of solid waste.

This organic waste could become part of an industrial symbiosis project, as described in section 6.1. In fact, a portion of this waste is already undergoing material recovery.

Figure 22: Process flow diagram for the poultry sub-industry



Source: Own drawing



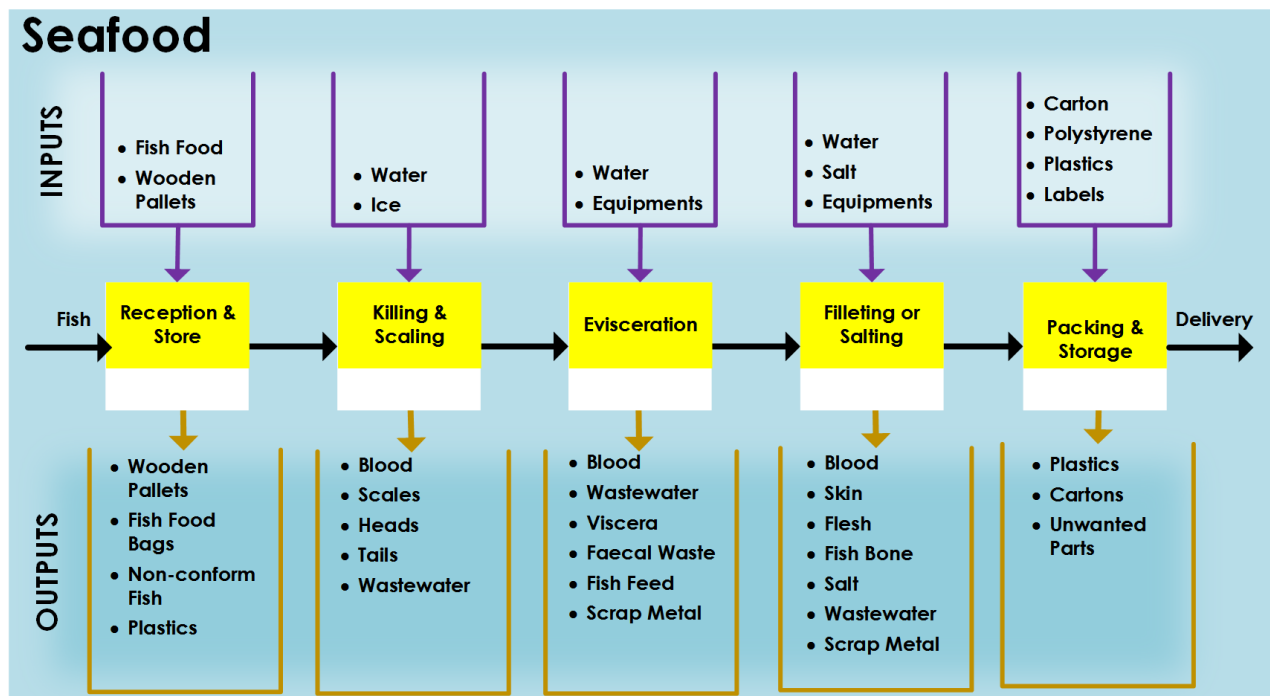
### 5.4.3 Seafood sub-industry

The process flow diagram for the seafood sub-industry presents the units in which organic waste is generated:

- at reception, non-conform fish is discarded
- at scaling, evisceration and filleting, several fish parts are severed and discarded.

This organic waste could become part of an industrial symbiosis project, as described in section 6.1.

Figure 23: Process flow diagram for the seafood sub-industry



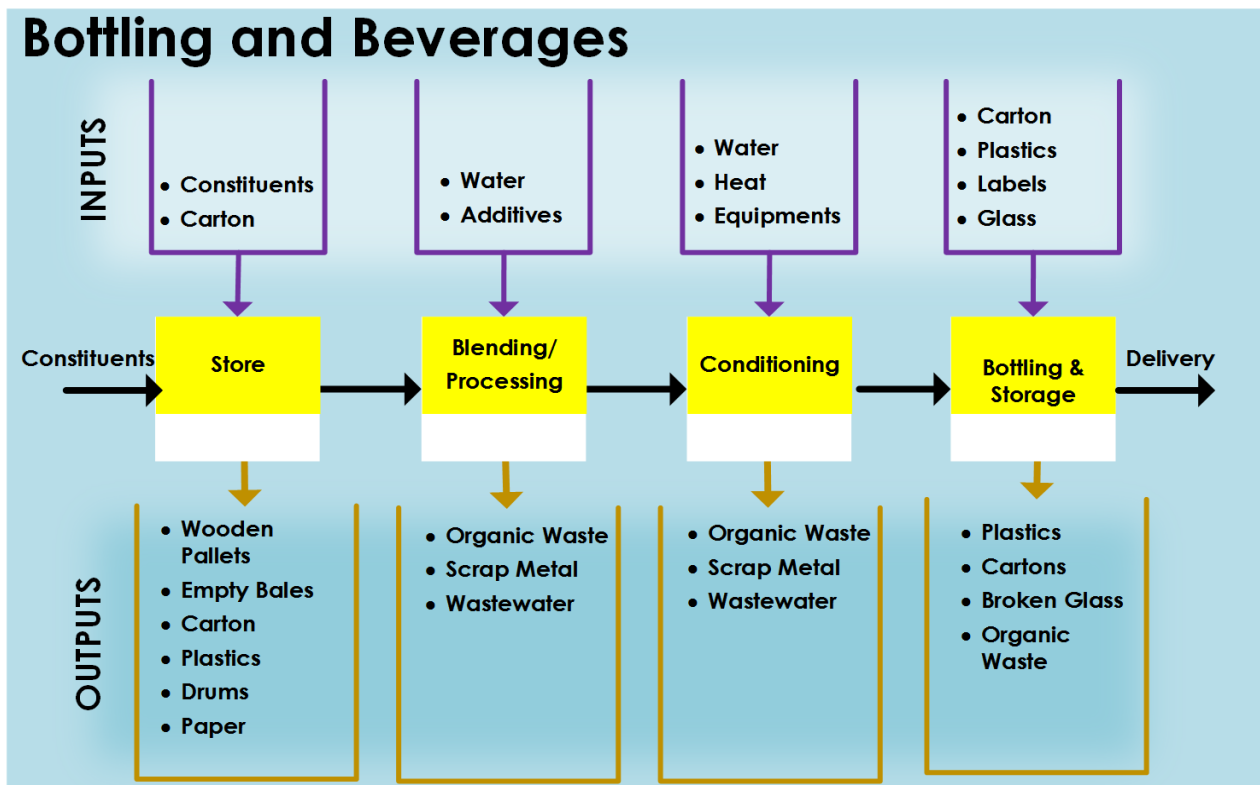
Source: Own drawing

#### 5.4.4 Bottling and beverages sub-industry

In the bottling and beverages sub-industry, no types of waste are generated which could become part of an industrial symbiosis project.

The process flow diagram shows that each unit generates various types of waste that could be considered similar to municipal waste, and are actually currently being managed in the general municipal waste system. The organic waste generated is mixed with other fractions and is currently not of adequate quality to be recycled. Separate collection of organic waste could increase the amount available for treatment such as composting.

Figure 24: Process flow diagram for the bottling and beverages

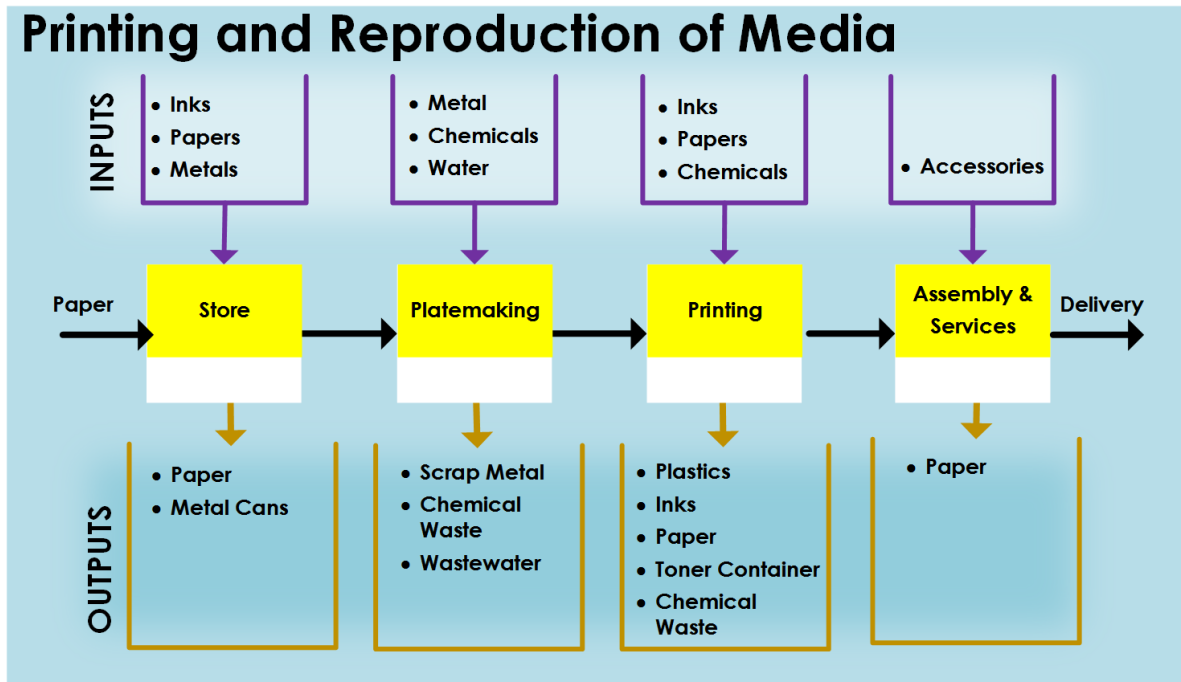


Source: Own drawing

### 5.4.5 Printing and reproduction of media industry

No waste listed in the process flow diagram for the printing and reproduction of media industry is suitable for an industrial symbiosis project. Other types of waste are already being recycled; potentially hazardous waste is stored pending the operation of the hazardous waste intermediate facility.

Figure 25: Process flow diagram for the printing and reproduction of media industry

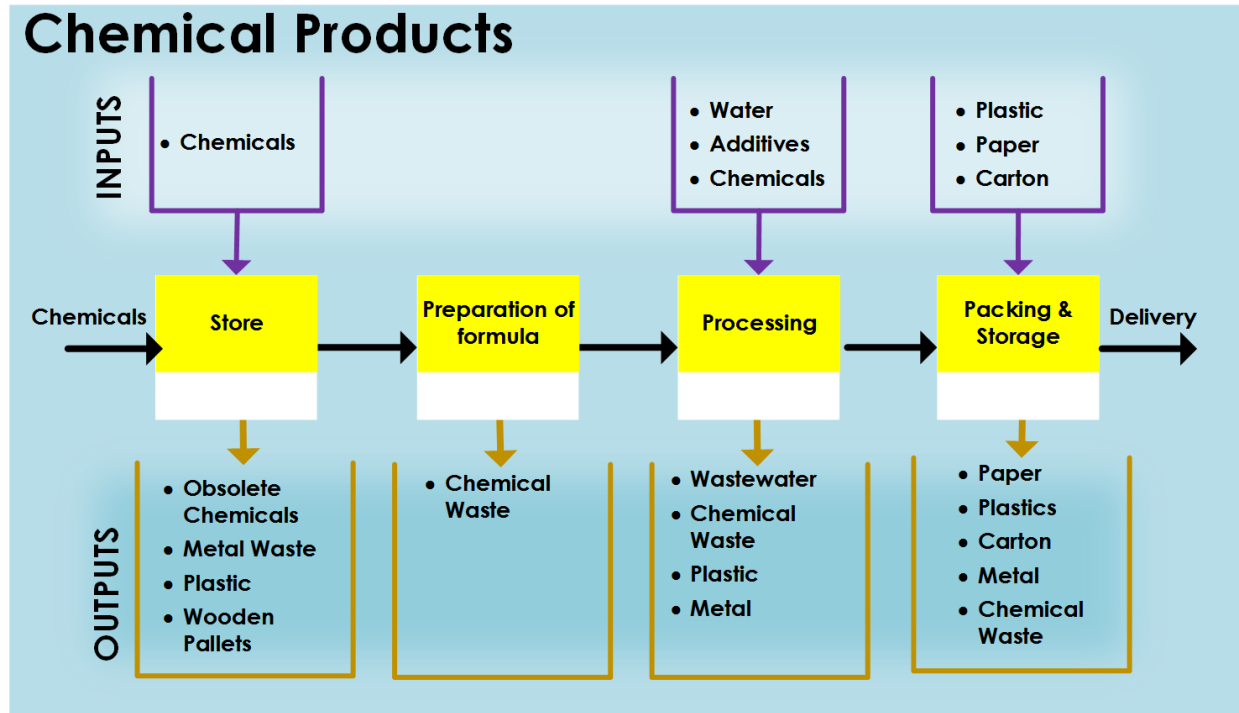


Source: Own drawing

### 5.4.6 Chemical industry

The chemical industry generates types of waste that is currently being recycled or disposed in the general municipal waste system. No waste of the chemical industry is suitable for an industrial symbiosis project.

Figure 26: Process flow diagram for the chemical products industry



Source: Own drawing

### 5.5 Current solid waste management of industrial waste not relevant for industrial symbiosis

The outcome of the on-site visits, the information collected via the questionnaires and further interviews with the firms' management showed that a high share of the solid waste generated by the industries involved already have good practices for waste management in place (as indicated in Table 7):

- different waste types are kept separate within the industrial premises
- waste fabrics are collected by recyclers for export
- suitable waste fractions, such as carton or plastics are sent to local registered recyclers
- in some cases, the carton boxes are sold to the informal sector
- potentially hazardous waste is in storage, waiting to be transported to the Interim Hazardous Waste Storage Facility (once in operation)

- wooden pallets are reused and, when necessary, sent for repair or recovery of the material by one recycling enterprise
- metal and plastics drums are reused through the involvement of the informal sector, which might include local communities for reuse
- metal drums and scrap metals are also sent to a recycling enterprise
- waste oils are collected and sent to recycling companies already operational in Mauritius.

## 5.6 **Observations on the recovery of different types of waste generated in the industries investigated**

The results of the IWA project reveal that there are three main categories of waste generated in the industries investigated:

1. waste types that could become part of an industrial symbiosis project, some of which are already being carried out;
2. waste which is already collected separately because a domestic or international market exists for the recycled materials or because possibilities for reuse exist;
3. residual waste which cannot be recycled and is currently merging with municipal waste streams and is landfilled.

Chapter 6 discusses opportunities for industrial symbiosis.

As regards the waste currently being recycled, some firms were not fully aware of existing recycling operators: the creation and consolidation of relationships between waste generators and registered recyclers is relevant for the ministerial offices that contributed to the IWA project.

For certain specific types of waste, the need to improve the interface with the relevant enforcing agencies emerged in order to accelerate recycling and export authorization procedures. The majority of the firms' management indicated that the Ministry of Industry, Commerce & Consumer Protection, Commerce & Consumer Protection could play a role in facilitating such exchange.

At the same time, the informal recycling sector needs to become the object of institutional attention:

- how many workers does it involve?
- what are the working and health conditions, in particular at the transfer stations?
- how can this sector be supported without creating conflict with registered recyclers?

As regards the management of recyclable waste, the relationships the IWA project activated with the firms' management demonstrates that at this stage, many would consider extending the implementation of practices such as:

- the recycling of waste which is already being separated, in particular e-waste and hazardous waste;
- the separate collection of waste that could be recycled.

## **6 Opportunities for industrial symbiosis of the industries investigated**

### **6.1 Waste relevant for industrial symbiosis per industry**

The analysis presented in Chapter 5 reveals that among the industries investigated, only the

- food and
- textile and wearing apparel

industries generate waste which, in terms of type and amount, could become part of an industrial symbiosis project.

These types of waste are:

1. organic waste from the poultry and seafood sub-industries;
2. cotton, wool yarn and fabric from the textile industry; and
3. wooden pallets (the amount of this type of waste is associated with higher uncertainty because not all firms reported this data with the same accuracy).

The results of the estimate of the amounts of type of waste generated at national level are presented in Table 9.

**Table 9: Estimate of waste generated nationally per type of waste**

<i>Industry</i>	<i>Solid waste type</i>	<i>Amount for the 23 individual firms(t/year)</i>  <i>Data from the questionnaires</i>	<i>Already being recovered in the 23 firms</i>  <i>Data from the questionnaires</i>	<i>Amount estimated for IS for entire industry (t/year)</i>  <i>Results of the scaling-up exercise</i>	<i>Industrial symbiosis opportunities</i>
<b>Food (poultry)</b>	Organic waste from poultry (including offals, feathers, head, contaminated birds, feet, blood, fat)	6,855	3,000 (estimated)	7,300	Production of pet food  Anaerobic digestion with energy recovery
<b>Food (seafood)</b>	Organic fish waste	35	No recovery at present	1,400	Production of pet food  Omega oil production
<b>Textile and wearing apparel</b>	Cotton, yarn and fabric and woollen fluff	1,265	Almost all yarn and fabric waste is currently recycled, a small fraction is recovered as energy	8,000	Energy recovery  Material recovery in the building industry
<b>Poultry</b> <b>Textile</b> <b>Chemical</b>	Wooden pallets	60 (this estimate is characterized by high uncertainty)	Wooden pallets are always reused, repaired and only sent recycled when necessary or occasionally used as an energy source	300	Energy recovery  Artisanal reuse and recycling

This IWA report only highlights industrial symbiosis opportunities for industries and sub-industries analysed on the basis of on-site visits to a sample of 23 firms. However, the method presented and the data obtained could be used to develop future industrial symbiosis projects.

### **6.1.1 *Organic waste from the food industries***

The organic waste generated by the food industries and associated with specific production units could be used in the recovery of waste for pet food production, a process also known as ‘rendering’. Please note that these types of waste are not included in the category of organic waste originating from the canteen or in the category of green yard waste, both of which are currently managed as waste similar to municipal waste, i.e. are deposited in the landfill.

At present, some firms in the poultry sub-industry are already undertaking organic waste recovery, while others are assessing the feasibility of this process as a new business opportunity.

As regards the scaling-up of any process related to the recovery of food materials from organic waste, it should be noted that for bio-security reasons, firms cannot accept food waste from different firms.

As a direct result of the IWA project, the seafood sub-industry is now considering to initiate a similar practice for fish waste. In the course of the IWA project, it was communicated that the seafood industry plans to expand and as a consequence, a higher amount of waste will be available which could be used to increase existing fish waste processing or to build a new processing plant.

Currently, a firm collects waste from one fish processing plant and converts it into high value added products such as omega oil and flour for pet food. In case of an increase in the amount of fish waste, this could become another opportunity for the existing plant to upgrade its capacity or a business opportunity for a new firm.

### **6.1.2 *Cotton yarn and fabric and woollen fluff from the textile industry***

Cotton and woollen waste can undergo different types of recovery:

1. Material recovery, such as in the
  - a. textile industry;
  - b. construction industry, where waste can be used for the construction of panels for thermal and noise insulation.
2. Energy recovery, when shredded fabric waste is disposed in coal boilers.

At present, the majority of firms sends textile waste to recycling through registered recyclers that export the waste collected.

A share of this material is already being recovered currently on a trial basis as an energy source in coal boilers. The firm that is active in this recovery aims to replace 500 tonnes/yr of coal annually with fabric waste. The cost of coal is around MUR 1,665 per tonne, which will result in savings of around MUR 832,000. The annual amount of coal used in the manufacturing sector has been gradually increasing over



the last five years such that in 2011, the amount of coal used was 24,200 tonnes/yr and in 2015, the amount of coal used increased to 36,436 tonnes/yr (Statistics Mauritius – ‘Digest of Energy and Water Statistics – 2014’ and ‘Energy and Water Statistics – 2015’). There may thus be scope for significant savings, especially in the manufacturing sector, thereby decreasing reliance on imported fuels. According to the estimates derived from the IWA analysis, there is sufficient fabric waste in Mauritius to achieve this target and to support other firms in replacing coal with fabric waste.

The use of textile fibres, both cotton and wool, in the construction industry has been explored for decades. This recovery method has been found to be feasible for the production of insulating panels and concrete panels in combination with other organic fibres such as palm tree fibres, coconut husk and sunflower stalk<sup>22</sup>. The production of panels for the construction industry could be a business opportunity for Mauritius, where housing/community buildings are growing and represents a good example of industrial symbiosis, because the materials would be recovered from different production sectors.

### **6.1.3 *Wooden pallets for re-use and for energy recovery***

Though wooden pallets do not belong to the main types of waste in the industries analysed in this study because they are mostly reused and recycled, this type of waste is nonetheless present in several of the industries analysed.

A recently opened recycling firm collects waste wood such as wooden pallets and wood from construction sites. The waste is being processed into wood pellets to be used in boilers and wood chips for horse and poultry bedding.

The IWA project can only reach preliminary conclusions on this type of waste, but it is recommended that an R&D and economic feasibility study be performed to investigate the possibility of increasing the recovery of energy from this type of wood waste.

## **6.2 Follow-up R&D projects and economic feasibility studies for the recovery of waste types relevant for industrial symbiosis**

The results of the IWA study highlight that in the sectors investigated, R&D projects could be undertaken for the following types of industrial waste to assess the technical and economic feasibility of recovering materials and energy from waste:

- **textile material:** an R&D project could be initiated to investigate the fuel characteristics of textile waste with respect to the impact on air emissions and on energy recovery equipment (e.g. boilers): the effectiveness of fume abatement systems must be verified when the fuel composition

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<sup>22</sup>Examples of research and applications in this area can be found in: Binici H. et al., 2014, "An environmentally friendly thermal insulation material from sunflower stalk, textile waste and stubble fibres". *Construction and Building Materials*, 51, 24–33; Aghaee K., 2013. "Mechanical Properties of Lightweight Concrete Partition with a Core of Textile Waste". *Advances in Civil Engineering*, Vol 2013, Article ID 482310; Briga-Sa A. 2013. "Textile waste as an alternative thermal insulation building material solution". *Construction and Building Materials*, 38, 155–160.

is modified; the corrosion or slagging problems caused to the boilers must also be determined to ensure lasting operation;

- **textile material:** an R&D project could investigate the possibility of using cotton and wool fabrics to domestically produce building materials for thermal and/or noise insulation. The recycling sector could also be involved in this type of project.
- **organic food waste:** the recovery of organic waste for pet food production could be increased by connecting specific firms with industries already producing pet food in Mauritius.
- **organic food waste:** the possibility of producing omega oil from seafood waste was also investigated and it appears that this is a promising area for further R&D projects.
  - The IWA project has initiated discussions between firms involved in the seafood industry where waste from industry can be used as raw material for a second one. The firms have preliminarily agreed to collaborate, however, further assessments need to be carried out, particularly to verify the future amounts of waste generated.
- **organic food waste:** the technical and commercial feasibility of using organic food waste in energy recovery projects in connection with other types of organic waste, such as municipal waste collected separately, mainly using anaerobic digestion technologies, could also be investigated by specific research projects with a medium-term reference.
- **wooden pallets:** when these tools reach their end of life, they could be used in energy recovery projects. A specific technical and commercial feasibility project is necessary to define the amount available from the entire industrial sector and the possibility of using it in energy recovery projects.

It must also be observed that the reuse of wooden pallets for the production of household objects in Mauritius has been initiated by a recycling enterprise.

### 6.3 indicators for successful practices of industrial symbiosis in Mauritius

On the basis of the outcomes of the IWA, there are different types of factors that need to be monitored to verify the possibility of applying industrial symbiosis practices in Mauritius and their effectiveness:

1. it is important to verify the ability of the IWA study to advance the analysis of the possibility of applying industrial symbiosis;
2. following the completion of technical and commercial feasibility studies, the increase in the recovery of materials and energy from industrial waste should be monitored;
3. given the relevance of creating an appropriate overall framework of reference, as highlighted in

the Recommendations section 6.4, a series of indicators to measure the increase in recovery from every type of waste should be elaborated.

In this respect, the technical and economic monitoring of policies has proven to be an essential tool in assessing the validity of specific policies, programmes or projects. Yet as a premise to the definition and application of indicators for industrial symbiosis in Mauritius, monitoring activities should be kept as simple as possible. To this end, a list of key indicators that can be easily collected is provided.

To verify the ability of the IWA study to advance the analysis of industrial symbiosis possibilities, the following indicators are proposed:

1. number of R&D projects carried out
2. percentage of R&D projects after whose completion actual measures/projects were undertaken.

To assess the effectiveness of industrial symbiosis practices, the changes in the practices of material and energy recovery from waste to be monitored are:

1. amount and percentage of industrial waste that is collected separately: this analysis shall be performed for each individual waste type;
2. amount and percentage of industrial symbiosis-relevant waste from which materials are recovered domestically: this analysis shall be performed separately for each waste type;
3. amount and percentage of industrial symbiosis-relevant waste from which energy is recovered domestically: this analysis shall be performed separately for each waste type;
4. amount and percentage reduction of industrial waste landfilled;
5. cost associated with the entire management of industrial waste paid by the industrial sector.

To assess the evolution of the legislative and institutional framework, and to set in place an appropriate overall framework that addresses all types of waste:

1. amount and percentage of waste landfilled: the denominator should include all types of waste collected by the public sector;
2. amount and percentage of waste collected separately: this should include dry and organic fractions;
3. amount and percentage of waste collected separately, which are being recycled;
4. amount and percentage of waste collected separately, which are used for energy recovery.

#### **6.4 Database on solid industrial waste to support waste tracking and the analysis of indicators**

The industrial waste assessment reveals that the implementation of industrial symbiosis projects could be feasible given the socio-economic case of Mauritius. It would require the systematic collection and analysis of relevant data. This project proposes a methodology for the collection and organization of industrial waste data based on a user-friendly questionnaire, the definition of process flow diagrams and the distinction of different waste fractions on the basis of recovery possibilities.

Moreover, data in Mauritius are also available from the Industrial Waste Audit Report and the Environmental Management Plans submitted by specific industries under the Industrial Waste Audit Regulation.

It is proposed for a database of industrial waste to be maintained on the availability of waste resources and to monitor the variation of relevant indicators for the performance of industrial symbiosis practices. A preliminary example of data organization and analysis in such a database is provided in Table 10.

**Table 10: Preliminary proposal for values to be used in an industrial waste database**

<i>Detail on firm / organization</i>	<i>Industry Sub-industry &amp; NSIC</i>	<i>Year of data</i>	<i>Type of solid waste</i>	<i>National waste code</i>	<i>Hazardous (yes or no)</i>	<i>Amount generated (tonnes/y)</i>	<i>Physical state</i>	<i>Separate collection (yes or no)</i>	<i>Current management operation</i>	<i>Storage (tonnes /y)</i>	<i>Amount of each type of WM operation (tonnes/y)</i>	<i>Carrier ID</i>	<i>Recycler ID</i>	<i>Final destination plant ID</i>	<i>Type of recovery performed in plant</i>
<b>Name</b> <b>Address,</b> <b>Contact</b> ....	Food poultry		Organic waste from poultry (offal, feathers, head, contaminated birds, feet, blood, fat)				Powder Sludge Solid ...		1. Material recovery to produce pet food  2. Landfill		1. t/y  2. t/y				
			Carton boxes / paper						Landfill: too dirty to be accepted for recycling						
			Plastics						Landfill: too dirty to be accepted for recycling						
			Faeces and farm waste						Composted and compost to local market						

As regards the industrial sector, it should at minimum be classified at the fourth level of the NSIC classification.

The experience acquired in the course of the IWA project as regards types of waste reveals that the adoption of a national classification system would facilitate a tracking system and all statistical operations. The EU Waste Catalogue is embedded in the EU Waste Framework Directive and is currently being used by waste practitioners to provide records of waste generation and management. The adoption of the European catalogue may not be appropriate for the current waste management situation in Mauritius, but the definition of a national waste catalogue would facilitate all waste management activities.

To track how the **total amount** of waste generated from each firm is managed, the amount in tonnes/y must be associated with every type of waste management activity. Such data would also allow an estimate at the national level of the waste types sent to each waste management stream and the reconstruction of waste flow at the national level.

The tracking of waste must also be ensured by identification of each subject operation in the supply chain, such as the registered carrier and registered recyclers. Similarly, the plants performing the recovery operations need to be identified nationally and possibly also internationally, in terms of:

- Current management operation
- Final destination plant
- Type of recovery operation.

A menu for the selection of specific categories should also be provided.

## **7 Recommendations for strengthening industrial symbiosis in Mauritius**

By applying the methodology described in Chapter 4, the IWA project in Mauritius has identified specific flows of industrial waste for the selected industries, which have the appropriate characteristics and are generated in a sufficient amount to become part of industrial symbiosis activities. Material and/or energy can be recovered from these types of waste within the same industrial firm that generates them or alternatively in different firms. Moreover, material and energy can also be recovered outside the industrial premises in recovery plants where these types of waste can be used together with other types of waste that have similar characteristics.

The activities carried out within the scope of the IWA project provided a methodology for estimating the amounts and types of waste suitable for industrial symbiosis and a preliminary list of waste and recovery possibilities, but it is important to underline that in order to reach the stage of implementation, further feasibility studies are necessary to determine the most appropriate technical, economic and commercial

conditions for the recovery of materials or of energy for each type of waste.

## 7.1 Opportunities

The results of the IWA study highlight that R&D projects could be carried out for the following types of waste in the industries investigated to assess the feasibility of expanding or creating production lines of new materials from waste:

- **textile material:** an R&D project could be initiated to investigate the fuel characteristics of textile waste with respect to the impact on air emissions and on energy recovery equipment (e.g. boilers); the effectiveness of fume abatement systems must be verified when fuel composition is modified; the corrosion or slagging problems caused to boilers must also be determined to ensure lasting operation;
- **textile material:** an R&D project could investigate the possibility of using cotton and wool fabrics to domestically produce building materials for thermal and/or noise insulation. The recycling industry could also be involved in this type of project.
- **organic food waste:** the recovery of organic waste for pet food production could be increased by connecting specific firms with industries already producing pet food in Mauritius.
- **organic food waste:** the possibility of producing omega oil from seafood waste was also investigated and it appears R&D projects in this industry could provide promising results.
  - The IWA project has initiated discussions between firms involved in the seafood industry where waste from one firm can be used as raw material in another. The firms have preliminarily agreed to collaborate, however, further assessments need to be carried out, particularly to verify the future amounts of waste generated.
- **organic food waste:** the technical and commercial feasibility of using organic food waste in energy recovery projects in connection with other types of organic waste, such as municipal waste collected separately, mainly using anaerobic digestion technologies, could also be investigated by specific research projects with a medium-term reference.
- **wooden pallets:** when these tools reach their end of life, they can be used in energy recovery projects. A specific technical and commercial feasibility project is necessary to define the amount available from the entire industrial sector and the possibility of using it in energy recovery projects.

It must also be observed that the reuse of wooden pallets for the production of household objects has been initiated by a recycling enterprise in Mauritius.

## 7.2 Constraints

In the course of the IWA project, no specific institutional or legislative obstacles that could potentially hamper these industrial symbiosis projects in its initial stages were identified. Technical knowhow and capacity among the workforce of the firms visited were also considerably high enough to undertake the waste assessment required for industrial symbiosis. The overall policy context could nonetheless be made more conducive to industrial symbiosis and could be summarized as follows:

1. strengthen the overall framework for the recovery of material and energy from every type of waste;
2. advance the investigation into the type, amount and characteristics of industrial waste and make the best use of information already available.

These constraints not only necessitate that the launch of industrial symbiosis projects is supported by private industrial actors, but also that the framework conditions that could improve the overall recovery from these types of industrial waste be put in place by the public sector.

Having identified these opportunities and constraints, the following recommendations for the development of industrial symbiosis in Mauritius focuses on:

- deepening of knowledge on industrial waste
- strengthening the legislative and institutional setting for industrial waste management.

## 7.3 Legislation

1) In the analysis of the current status of waste management in Mauritius presented in Chapter 2, we observed that the objectives indicated in the Waste Management Strategy 2011-2015 were only partially achieved:

- the analysis of the requirements for additional waste collection lorries, storage receptacles and labour force has been completed;
- the comparison of public and private collection costs is under revision;
- the analysis of waste composition was further extended;
- the conditions for applying the Extended Producer Responsibility to e-waste are currently being defined.

All these elements will serve as a basis for the definition of the new Waste Management Strategy, which is currently under revision.

However, it must be observed that the overall objective of increasing recycling and reducing the



landfilling of municipal waste was not achieved. It is highlighted that the lack of recycling activities in the management of municipal waste reflects negatively on the possibility of expanding the recovery of materials from industrial waste.

The capability of the institutions to define and enforce strategies and policies is a leading factor in the ability to achieve the recovery of materials and energy from all types of waste and to protect public health and the environment. Thus, the results of the IWA study suggest that the **analysis of the difficulties encountered in the application of WMS 2011** and of the **positive elements that could be implemented to move towards an effective WM system** is particularly relevant. These “lessons learnt” from the WMS2011 could support:

- defining what the legal, economic, social and institutional difficulties encountered in the development of an effective waste management system were;
- selecting the actions that could in the short- and medium-term be activated to support waste minimization, reuse and recovery from waste;
- encouraging and overseeing an industrial symbiosis programme;
- strengthening the management of hazardous waste.

The fact that the WM Strategy is under revision is a positive factor because it provides a platform where these analyses could be developed and the necessary actions assessed.

- 2) The National Environmental Policy 2007 promotes a legal framework “for establishing a recycling society, regulations be established to introduce the Extended Producer Responsibility” principle. Given the relevance of the EPR principle for engaging producers and traders in safely managing goods during their life-cycle, including waste minimization and recycling, the introduction in the legislation of the **Extended Producer Responsibility Principle** is indicated as a relevant element.

The fact that an e-waste management system based on the Extended Producer Responsibility (EPR) and the Polluter Pays Principle is being developed is promising.

The EPR principle may also be applied to a wider range of waste types generated by different producers; for instance, waste covered by the EPR in European Member States’ legislation include batteries, vehicles and tyres that no longer have any use. In Europe, the EPR principle is also widely used in support of the implementation of the Packaging and Packaging Waste Directive (94/62/EC).

The EPR principle essentially sets the costs of waste management for companies producing goods that will generate waste once their life-time is terminated. It thus requires strong involvement of producers and/or traders in ensuring high recovery rates, and a strong commitment from the public sector to support the application of an EPR scheme (any system or scheme set up by one or several

producers to implement the EPR principle). In Europe, this often resulted in the creation of sectorial PRO – Producer Responsibility Organization: a collective entity set up by producers or through legislation which becomes responsible for meeting the recovery and recycling obligations of the individual producers.

Given the high percentage of plastics present in the composition of both industrial and municipal waste that currently end up in the landfill, it is suggested that the **feasibility of extending the ERP principle to packaging** be investigated.

A recent study<sup>23</sup> highlighted that the EPR's economic and technical performance varies considerably across EU member states, and that not all EPR schemes adopted result in an effective increase in waste recovery.

Moreover, the study observed that “no single EPR model emerges as the best performing and the most cost-effective”. Mainly because “costs and performance are influenced by many factors, including factors external to the design and implementation of the EPR scheme, for example: population density and country geography; historical development of the WM infrastructure; value of secondary materials on the national market; awareness and willingness of citizens to participate; existence of complementary waste policy instruments, especially economic instruments like pay-as-you-throw schemes and landfill taxes.”

The conclusion of the European EPR comparative study suggests the necessity to perform a thorough feasibility study in Mauritius with the aim of selecting the elements that allow the development of a specific ERP approach for each waste type, which could be most effective in the national context.

- 3) The results of the IWA project also underline the relevance of providing a **unique legal definition of waste** and introducing a **classification of solid waste by their origin**: the distinction by origin—which might include household; commercial (restaurants and shops); business; industrial; construction & demolition; health and sanitation; agriculture—could be useful in subsequent pieces of legislation, in separating responsibilities and costs between households and other waste generators.

Distinguishing between industrial and household waste could be particularly relevant for keeping the costs associated with the management of each waste stream separate.

At the same time, this distinction should not affect the goal of creating a waste management framework in which different waste streams can be integrated—i.e. collected together and/or treated in the same plants—to enhance the recovery of materials and energy. It has in fact been observed<sup>24</sup>

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<sup>23</sup>“Development of Guidance on Extended Producer Responsibility (EPR) – Final Report” European Commission – DG Environment 2014.

<sup>24</sup>CIWM UK “Delivering Key Waste Management Infrastructure :Lessons Learned from Europe” Final Report November 2005.

that the integration of different waste streams increases waste management efficiency because it favours an economy of scale when planning and operating treatment plants.

Table 11 shows a partial list of definitions taken from the EU Framework Directive on Waste (2008/98/EC), which is included here to highlight some relevant terms that could be defined by future legislative actions in the Mauritian context.

**Table 11: Partial list of definitions taken from the EU Framework Directive on Waste (2008/98/EC)**

<b>WASTE</b>	Any substance or object that the holder discards or intends to or is required to discard
<b>SIMILAR WASTE</b>	Waste which in nature and composition is similar to household waste, even if from other origins
<b>HAZARDOUS WASTE</b>	Waste which displays one or more of the hazardous properties listed in an appropriate regulation: such as H1-explosive; H4-irritant; H 7-carcinogenic, H 10-toxic for reproduction
<b>WASTE MANAGEMENT</b>	The collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, including actions taken as a dealer or broker
<b>RESPONSIBILITY FOR WASTE MANAGEMENT</b>	<p>The conditions of responsibility for each producer of a different type of waste may be specified</p> <p>It may also be decided in which cases the original producer is to retain responsibility for the entire treatment chain or in which cases the responsibility of the producer and the holder can be shared or delegated among the actors of the treatment chain</p>
<b>BIO-WASTE</b>	Biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants
<b>BY-PRODUCT</b>	<p>A substance or object resulting from a production process, the primary aim of which is not the production of that item, may be regarded as not being waste but as being a by-product only if the following conditions are met:</p> <p>(a) further use of the substance or object is certain;</p> <p>(b) the substance or object can be used directly without any further</p>

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processing other than normal industrial practice;

(c) the substance or object is produced as an integral part of a production process;

(d) further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

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- 4) A clear legislative framework is essential for providing each actor of a WM system with a clear indication of his/her functions and the understanding of his/her relationship with institutions and enforcing agencies. **Clearly defining different waste management phases in legislation is of high relevance.**

A relevant example is the current definition of disposal which states that “in relation to waste, it includes the sorting, carriage, transportation, treatment, storage and tipping above or underground, and the transformation operations necessary for its recovery, re-use or recycling”. It is highlighted that for policy clarity and accuracy in the planning process and in practical operations, the term ‘disposal’ should only be associated with the last step of the waste hierarchy, i.e. landfilling.

The lack of specific definitions has an impact on the understanding of different actors of the elements that compose an integrated WM system and might thus negatively affect their WM capabilities.

In this respect, it may also be useful to insert the definition of **waste management hierarchy** in legislation: a widely used element of national and regional policy, considered the basis of effective WM practice. Below is the definition of waste hierarchy provided by UNEP<sup>25</sup>, moving from the most desirable option towards the least desirable one:

- Prevent the generation of waste or reduce the amount of waste generated.
- Reduce the toxicity or negative impact of waste being generated.
- Reuse the materials recovered from the waste stream in their current forms.
- Recycle, compost or recover materials for use as direct or indirect inputs to new products.
- Recover energy by incineration, anaerobic digestion or similar processes.
- Reduce the volume of waste prior to disposal.
- Dispose of residual solid waste in an environmentally sound manner, generally in landfills.

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<sup>25</sup>UNEP, CalRecovery. 2005. “Solid Waste Management - Volume I”.

Table 12 provides an example of definitions for the main WM operations which enter solid WM (taken from EU Directive 2008/98/EC).

**Table 12: Example of definitions for the main WM operations that enter solid WM (taken from EU Directive 2008/98/EC)**

<b>PREVENTION</b>	Measures taken before a substance, material or product has become waste which reduce: <ul style="list-style-type: none"> <li>(a) the quantity of waste, including through the reuse of products or the extension of the life span of products;</li> <li>(b) the adverse impacts of the generated waste on the environment and human health; or</li> <li>(c) the content of harmful substances in materials and products</li> </ul>
<b>COLLECTION</b>	The gathering of waste, including preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility
<b>SEPARATE COLLECTION</b>	The collection in which a waste stream is kept separate by type and nature so as to facilitate specific treatment
<b>REUSE</b>	Any operation by which products or components that are not waste are used again for the same purpose for which they were conceived
<b>TREATMENT</b>	Recovery or disposal operations, including preparation prior to recovery or disposal
<b>RECOVERY</b>	Any operation of which the principal result is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function or waste being prepared to fulfil that function in the plant or in the wider economy
<b>RECYCLING</b>	Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery
<b>DISPOSAL</b>	Any operation which is not recovery (even where the operation has the reclamation of substances or energy as a secondary consequence).

#### 7.4 Strategies at national level

The measures necessary to implement these recommendations which support the definition and implementation of a national WM strategy might require conducting R&D projects to assess the technical, economic and commercial feasibility of adopting specific organizational solutions (such as separate

collection) or selecting specific technologies and building the necessary plants.

- 5) Given the relevance industrial waste and other types of waste could have in the recovery of energy, it appears relevant to propose that the **WM strategy under revision should be coordinated with the National Energy Strategy** which is based on the relevance of increasing the use of renewable energy.

Not all types of waste can be included under the classification of renewable energy sources. In fact, only organic waste is considered a source of renewable energy as it is carbon neutral. However, non-organic waste can also be considered for energy recovery as long as it replaces fossil fuels. Nonetheless any waste to energy strategy needs to ensure that air pollution mitigation measures are put in place.

An effective **WM strategy can contribute to the reduction of greenhouses gas emissions**; this is due to the:

- recovery of secondary materials from waste, which reduces emissions associated with the production of raw materials;
  - recovery of energy from ‘renewable’ fractions of waste which substitute the generation of energy with fossil sources;
  - reduction of biogas emission from decreasing the disposal of biodegradable waste to landfill;
  - efficient recovery of energy from the biogas emitted from the landfill body.
- 6) To better enable identification of the conditions that favour the recovery of materials and energy from waste, the WM national strategy should investigate the feasibility of developing a framework supporting the **integrated management of municipal and industrial waste flows**.

The recommendation deriving from the results of the IWA project is that industrial waste should be clearly distinguished in terms of cost from household and commercial waste. However, in the management of industrial waste and municipal waste, similar waste in terms of type and characteristics, even if of different origin, should be integrated in the recovery of materials and energy.

It has been observed<sup>24</sup> that coordinated collection and treatment of waste from different origins which are similar in type and characteristics (such as plastics or biodegradable waste) is a factor increasing policies’ effectiveness: in fact, the integration of different waste streams allows for the realization of treatment plants which can reach a scale sufficient to being economically profitable.

- 7) The amount of waste that can actually be recycled is strictly dependent on the quality of the waste streams that reach recycling plants, because flows of low quality containing more than a single waste

fraction produce high percentages of rejects and operation costs. This constraint has led WM planners and legislators to support the setting in place of ‘segregated collection’ schemes, which favour the collection of cleaner fractions (reduce the percentage of extraneous fractions).

Therefore, even in Mauritius, it is relevant to investigate the technical feasibility and costs of **making the separate collection of organic waste mandatory** for both household and industrial waste, which are not separated. This step is relevant for two main reasons:

- as a consequence of the impact on the environment and the use of valuable land, the landfilling of biodegradable waste should be eliminated or strongly reduced;
- organic waste of high quality for composting can only be obtained when separate collection is being performed: if the separate collection of organic waste were performed for either household/commercial and industrial waste within the firms’ premises, these ‘clean’ flows of different origin could merge and make the recovery of organic material through composting or of energy through anaerobic digestion more cost effective. The goal of assessing anaerobic digestion feasibility was already established in WMS 2011.

## 7.5 Institutional setting

- 8) Currently, as briefly discussed in Chapter 2, the WM legislation is distributed in acts issued by the Ministry of Environment and the Ministry of Local Government; moreover, the enforcing agency for different parts of the legislation is not always the same office.

As observed in the recommendations on the definition of waste and the WM phases, the IWA project highlights the relevance of:

- **homogenizing waste legislation** among different ministries;
- **updating all acts to adapt to the most recent amendments** to facilitate understanding of duties and guidelines;
- avoiding duplication and speeding up approval processes relevant to industrial waste management by better **defining institutional responsibilities**.

Difficulties in rapidly implementing the current legislation were registered by the IWA project when several firms highlighted both difficulties in interpreting the legislative framework and the fact that approval times can be rather long.

At the same time, the enforcing agencies registered difficulties in keeping up with the monitoring of Industrial Waste Audit Reports and organizing and analysing the data related to industrial waste, as further discussed in the Recommendations section on the Industrial Waste Audit Report.

For the effective implementation of WM legislation, including the relevant controls on industrial activities, it is essential that legislation clearly defines the functions of each specific institutional entity and avoids any duplication in functions.

In the case of Mauritius, this translates into:

- the national level taking a leadership role, performing functions such as:
  - elaborating and updating the WM strategy under revision, the planning capability for the development of the necessary infrastructure for effective WM;
  - coordinating the actions of local authorities in order for different collections schemes to contribute to an increased recovery from waste;
  - providing advanced technical guidelines for the different WM phases in order for different actors to provide services that reach benchmarking standards;
- strengthening the resources and action capability of the offices relevant for WM planning and the evaluation and monitoring of the Industrial Waste Audit Report;
- provide local authorities with sufficient funding and resources to modify the collection system to reach recycling goals.

A positive element could be provided by **determining** in the legislation a **time period within which authorization request** of private actors are answered (for example, 60 days): in this respect, the possibility of reducing the times for monitoring the Environmental Management Plan seemed to be of relevance in the course of the IWA project.

With respect to institutional setting, it might also be relevant to highlight that public offices should not perform functions that could become conflicting. Effective WM requires distinguishing among the following specific functions:

- a. definition of national and local WM strategies, including waste minimization programmes;
- b. monitoring the effectiveness of policies;
- c. enforcement and monitoring activities with respect to private actors;
- d. performance of operation activities for:
  - i. collection services,
  - ii. different waste management facilities: transfer stations, landfill, composting plant, further treatment plants which will be built.



For instance, the same office should not define the policies and at the same time be the office that monitors the implementation of policies, as these are conflicting functions. On the basis of these considerations, it is proposed that the functions and activities of the institutional planners should be separated from those of the subjects that perform WM operations and from those of the enforcing agency.

In the case of Mauritius, this would mean:

- strengthening the WM policymaking ability of the Solid Waste Management Division of the Ministry of Environment;
- while separating the function of monitoring, a **specific Enforcing Unit or Agency** could be created.

9) One relevant aspect of the **monitoring of policies** is the use of specifically developed **indicators**. In section 6.4, a series of indicators is proposed to monitor the:

- a. ability of the IWA study to advance the analysis of industrial symbiosis possibilities
- b. effectiveness of industrial symbiosis projects in changing the practices of material and energy recovery from waste
- c. evolution of the legislative and institutional framework and the setting in place of an appropriate overall framework which addresses all types of waste.

## 7.6 Industrial waste audit and industrial waste database

10) During the on-site firm visits, it was registered that the firms' management perceived the Industrial Waste Audit Regulation as complex and that repetitive data collection steps were being performed resulting in the same data being derived in different formats (also for the Environmental Impact Assessment Licence). At the same time, it was also noted that the monitoring of the Environmental Monitoring Plan by the enforcing agency faces serious difficulties mainly related to the limited human resources available.

It is therefore recommended that in order to facilitate the exchange and discussion:

- a. the relevant stakeholders, including all relevant ministries, research institutions and representatives from industrial organizations review the procedures relating to the Industrial Waste Audit. This review should be carried out with the aim of simplifying, on the one hand, the fulfilment of duties by the industries and, on the other, the monitoring and enforcement activities of the public sector;
- b. in particular, it is recommended that the **Ministry of Industry, Commerce & Consumer Protection, Commerce & Consumer Protection participates in the technical Industrial Waste**

**Audit Committee.** The Ministry of Industry, Commerce & Consumer Protection, Commerce & Consumer Protection could, in fact, perform the effective function of interfacing knowledge and the exchange of needs between firms and the Ministry of Environment;

c. **capacity building** be provided to the IWA Committee members to:

- analyse the input-output data gathered by the Industrial Waste Audit forms;
- assist in resource optimization and industrial waste minimization;
- support industries in building new opportunities of recovery from waste;
- develop a waste database for industrial waste.

11) **Increase the capability to use the results of Industrial Waste Audit Reports and assess the feasibility of setting in place a database on industrial waste.**

The revision of the Industrial Waste Audit reporting process aims to expedite the filling in of the form and ensuring a quick monitoring activity.

The data contained in the Industrial Waste Audit available at the Ministry of Environment is already significant and the data collected during the IWA project could be used to define the structure of an industrial waste database.

It is thus proposed that the Technical Committee supports the action to be performed by the Ministry of Environment of analysing the feasibility of using the data already available in terms of industrial waste type, origin and amount. This measure should be aimed at initiating the implementation of a specific **database on industrial waste**.

#### 7.7 **Industrial organizations' pro-active involvement in capacity building and R&D projects**

12) A Project Steering Committee, co-chaired by the Ministry of Industry, Commerce & Consumer Protection and Business Mauritius, comprising experts from UNIDO and representatives from the Ministry of Environment, S.D, Disaster & Beach Management and other national stakeholders oversaw the implementation of the IWA project and provided views and comments on the report.

The **Steering Committee will remain in operation** because all participants felt that it plays a relevant role in supporting the implementation of industrial symbiosis activities highlighted by the IWA project. These measures will be carried out depending on funding availability.

13) The results of the study showed that the methodology adopted (see Chapter 4) was successful in defining an initial list of types and amounts of waste that could undergo industrial symbiosis.

It also showed that the majority of firms addressed and visited during the IWA project have the

capacity to carry out feasibility studies and to increase the recovery of materials and energy from the waste they generate.

However, the IWA project's results also highlight the need to **apply the proposed methodology to the analysis** of waste types and total amount generated in each industry investigated and the relevance of **launching R&D projects** and technical and commercial **feasibility studies** using an extended database.

R&D projects could also be carried out to investigate whether separate collection in specific industries could increase the amount of waste available for industrial symbiosis.

The favourable conditions registered in several of the firms visited might not yet be found in smaller firms, and it is therefore recommended to assess whether SMEs would need **support from industrial organizations in terms of capacity building and feasibility studies** and in terms of where to find a market/output for their waste. SME participation could be properly addressed through the involvement of the Ministry of Business, Enterprise and Cooperatives.

- 14) As briefly described in section 3.7, several recycling enterprises are operating in Mauritius; they face difficulties in conducting such activities on an island: this condition often makes it difficult to reach a sufficient amount of waste to make domestic recycling economically meaningful. This industry needs to therefore be supported by the creation of a policy framework that addresses the specific territorial conditions, where the search for innovative organization and technical solutions is particularly relevant.

To facilitate the relationship with institutional offices and to become an effective partner in the support of innovation programmes, the **recyclers** already active in Mauritius could **establish a Recyclers Association**. The structure and type of recyclers association is currently being discussed.

## 7.8 Cost and finance of WM

- 15) As the evidence shows and as pointed out in every WM policy document<sup>26</sup>, money matters. Thus, establishing well-functioning, transparent, full-cost accounting systems should be a priority wherever they do not yet exist<sup>27</sup>.

The economic aspects of WM are particularly relevant when, as is the case in Mauritius, WM is to move from simple collection and landfilling of waste to a more integrated WM system aimed at increasing the recovery of 'value' contained in the waste. The fact that Mauritius is an island might result in an increase in cost due to many factors, among them the lack of available land and the constraints to recovering materials domestically.

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<sup>26</sup>UNEP, ISWA, 2015, "Global Waste Management Outlook".

<sup>27</sup>UNEP, 2013, "Guidelines for national waste management strategies: moving from challenges to opportunities".

Moving towards more effective WM organization solutions (such as the separate collection of specific waste streams) and the adoption of technologies to recover materials and energy while reducing environmental impacts are very expensive goals; the implementation of a more effective WM system can only be achieved step by step. Some measures can be implemented quickly, while others will have to be delayed to the medium term.

Any shift towards more integrated and environmentally sound WM requires a **clear understanding of the costs and revenues associated with WM**. At the same time, the impacts of inactivity on the environment and on the socio-economic realities must also be considered under the costs.

Costs are associated with every step of WM, such as:

- collection
- transport
- building and operation of transfer stations
- building and operation of every plant dedicated to the recovery of materials or energy
- building and operation of landfills.

Revenues for the WM system can be associated with the selling of:

- secondary materials and the compost recovered from waste
- energy or energy vectors recovered from waste.

Revenues associated with materials are subject to the volatility of international markets and can quickly change, affecting investments' effectiveness and return periods. The cost of organizing collection and recycling activities is only partly recovered by the revenues from selling the recycled materials.

Costs and revenues associated with WM are relevant to industrial symbiosis for two reasons:

- on the one hand, the cost the public incurs for the management of industrial waste must be accounted for;
- on the other hand, if each enterprise is aware of the costs of the management of its waste, for example, through the use of fees/levies associated only with WM, the enterprise is incentivized to minimize, reuse, recycle or recover energy from the waste it generates before it disposes it in a public landfill.

What is relevant to industrial symbiosis is that in the course of the IWA project, the cost incurred by

the public for the collection and landfilling of industrial waste could not be identified.

This is attributable to the fact that with some exception, local authorities are not involved in the collection of industrial waste. Firms in general organize the transport of waste to transfer stations by requesting the service of registered carriers or by registering their own vehicles: it thus becomes difficult to determine the amount of industrial waste entering public WM.

The WMS 2011 states that with respect to the coverage of costs, “it is widely acknowledged that waste producers should be made to pay (through user charges) the full costs of the services and facilities required to manage their wastes.” At the same time, it recognizes that “such a policy cannot be introduced overnight.”

The WMS 2011 also states that “the first ones to be targeted are the industries and commercial activities. It is thus proposed to introduce waste disposal fee at transfer stations and the landfill sites for industrial and commercial operators.” Moreover, “we are aware that the imposition of the charging scheme may give rise to more illegal dumping. It is recommended that the penalty for illegal dumping be raised substantially”.

These measures have not yet been implemented.

The recommendations relating to the current cost and finance for WM in Mauritius are:

1. **carry out a detailed analysis of the structure of the costs incurred by the public to determine the contribution waste of different origins has on the different steps currently being performed:**
  - a. collection by local authorities
  - b. transport and bulking at transfer stations
  - c. transport to landfill
  - d. management of the landfill
  - e. enforcing activities;
2. **a waste tax/fee should be applied to all waste producers, which could vary according to origin of the waste.** In Mauritius, Council taxes already include a WM tax, hence this component of taxation should be removed from the general Council tax.

It is also noteworthy that in the transition from a WM system based on landfilling to a more infrastructure-focused WM system, aiming at achieving a high level of recovery from waste, the introduction of a waste fee must include an analysis of the possibility of differentiating taxes/fees on the basis of family income.

Any relevant changes take time to manifest their effects and full cost recovery might not be an objective for even the medium term. In fact, “cost recovery is possible where there is a demand for a service (e.g. primary waste collection) or a product, and is increasingly more difficult if activities are policy-driven (such as environmentally sound treatment and disposal). Full cost recovery is more affordable as income levels increase, even though the absolute costs also increase” (GWMO 2015).

- 16) The estimate of the types and amount of industrial waste generated in Mauritius that could form part of industrial symbiosis projects reveals that activities related to energy recovery from waste could also be included. This possibility highlights the need to set in place legislation that stipulates the necessary environmental standards and monitoring procedures.

At the same time, the conditions that guarantee the commercial feasibility of energy recovery projects must be clearly assessed. For this reason, the results of the IWA project highlight the need to clarify the **mechanism and conditions through which feed-in tariffs could be set in place and obtained by private investors.**

In this respect, the newly set up Mauritius Renewable Energy Agency (MARENA) within the Ministry of Energy and Public Utilities is mandated to devise incentive mechanisms, including subsidization mechanisms based on the principle of competitiveness and specific technologies, as per Section 5 sub-section (h) of the MARENA Act 2015.

Moreover, this project has been informed of the setting up of the Utility Regulatory Authority (URA) that will be responsible for regulating tariffs in the future (as per the URA Act 2005).

## 7.9 Recommendations table

Table 13 summarizes the recommendations of the project and indicates the WM actor responsible for its implementation:

**Table 13: Recommendations**

Recommendation		Responsible WM actor	Time frame	
<b>Legislation</b>	1	Analysis of the lessons learnt in implementing WMS 2011: difficulties encountered and selection of positive factors	MoE MoLG Local authorities	Short term
	2	Assess the feasibility of adopting extended producer responsibility to packaging besides weee	MoE MoFinances	Medium term
	3	Provide a unique legal definition of waste	MoE	Short term
	4	Provide a clear legal definition of each WM phase	MoE and MoLG	Short term
<b>WM strategy</b> <i>please note that this recommendation also requires the undertaking of R&amp;D projects</i>	5	Integrate the WM strategy with the energy strategy and assess the role of efficient wm in reducing greenhouse gas emissions	MoE MoE and PU	Short term
	6	Integrate industrial flows of similar characteristics with flows of municipal waste in recovery and treatment processes	MoE	Medium term
	7	Feasibility study for the introduction of separate collection of organic waste for municipal waste and in selected industries	MoE MoLG BM	Short term
<b>Institutional setting</b>	8	Homogenize waste legislation and better define institutional responsibilities Consider the possibility of creating a single enforcing agency	MoE MoLG MoH	Medium term
	9	Monitoring of policies based on specific indicators	MoE	Short term
<b>Industrial waste audit and database</b>	10	Revise industrial waste audit procedures and forms	MoE	Short term
	11	Set up a database on industrial waste	MoE	Medium term
<b>Industrial organizations proactive involvement in capacity building and R&amp;D projects</b>	12	The SC will remain operational to support R&D and implement recommendations	MoI / BM	Short and medium term
	13	Capacity building towards other firms and SMEs support further research & development projects	MoI / MoE / MoB BM Research institutions	Short and medium
	14	Establish recyclers association	Recyclers /BM MoI / MoE	Short term
<b>Cost and finance of WM</b>	15	Define the structure of WM cost and the cost of managing industrial waste incurred by the public sector Separate WM taxes from other taxes	MoE MoLG MoFinance	Short term
	16	Clarify mechanism for feed-in tariffs	MoEnergy & PU MoFinance MoE	Medium term

The indication of the period of time in which the recommendations could be realized is only meant as an indication of the priority of the components that could support the extension of industrial symbiosis practices in Mauritius' industrial sector.

The analysis of the lessons learnt in implementing the WMS of 2011 (R1) and the revision of the Industrial Audit Procedures (R10) appears highly relevant as an exercise to highlight the obstacles towards the development of a more integrated waste management system and, on the other hand, to quickly design solutions relevant to industrial waste recording.

The implementation of a waste collection organization which supports the separation of different waste fractions (R7), the consolidation of an industrial sector engaged in the recycling of materials (R14) and the extension of practices of environmentally sound energy recovery from waste (R5) are particularly relevant.



## **Annex I: List of all companies in the three sub-food industries**

The list of companies included in the calculation of the turnover for the three sub-industries was based on the list of companies provided by the Mauritius Central Statistical Office for 2013 and – following an internet survey of the main characteristics of each firms’ production – the relevant companies according to their products were identified.

The list of companies included in the calculation of the turnover of the three sub-industries is shown in the following table. The total value (in MRP) used for the scaling-up estimates is also included.

For the poultry sub-industry:

<b>Poultry Companies</b>
Chicken Master Co. LTD
Fast Foods LTD
Gourmet Foods LTD
Montida Poultry LTD
O2 Processing Co. LTD
Poulet Arc-En-Ciel LTD
Avipro Co. LTD
New Maurifoods LTD
Innodis LTD
<b>Total turnover = 5,798,562,032</b>

For the seafood sub-industry:

<b>Seafood Companies</b>
Aurifla LTD
Indico Canning LTD
Marine Biotechnology Product LTD
Mer des Mascareignes LTD
MTC Seafood LTD
Prince Tuna (Mauritius) LTD
Seskel Enterprises LTD
Ferme Marine de Mahebourg LTD
Convenience Food LTD
Ocean Products LTD
Tuna Processing Services Indian Ocean LTD
English Bay Co. LTD
<b>Total turnover = 8,174,054,643</b>

For the bottling and beverages sub-industry

<b>Bottling and Beverages Companies</b>
Faucon Products LTD
Food Canners LTD
La Laiterie de Curepipe LTD
Mauritius Oil Refineries
Oriental Foods LTD
Ramdenee Edible Oil Products LTD
Mauritlait Production LTD
SEBNA
<b>Total turnover = 2,974,175,469</b>

## Annex 2: Questionnaire

### Attachment 1: copy of the Questionnaire provided to each firm visited on-site

Please note that in order to understand the entire production and waste management process, the questionnaire also collected data on wastewater (type and amount), but only solid wastes were included in the estimates relevant for industrial symbiosis.

#### INDUSTRIAL WASTE FLOW ASSESSMENT DATA COLLECTION QUESTIONNAIRE

Organisation data	
SECTOR	
Company / Plant NAME	
Company / Plant ADDRESS	
Contact person for IWA	
Contacts (phone, email)	
Reference production year	
Date of on-site visit	

Data on productions useful to assess flows at the national scale	
Type of industry (SME, medium,...)	
Overall production	describe per EACH PRODUCTS the amount/units of product produced in the year
Number of employees	
Turnover (if available)	

Description of the products and identification of main production units
Please provide a brief textual description of activities and products

**Description of the whole production system by its main production units, including waste management transport outside the firm**

This section requires the drawing of process units and of their connections, to reconstruct the whole production system: each process has to be described in terms of input and output, of material (and energy if possible)

**MAP of the firm with identification of main production units and of points of W generation (if not sensitive data)**

Pictures of units can be usefull.      Pictures of wastes containers and their positions are also very usefull.



PLEASE NOTICE: If any laboratory analysis has been performed on the wastes or wastewater discharge(s), please provide a summary of the most recent data and the specific method by which sample(s) were taken. Attach sketches, plans, and more if usefull.

WASTE COLLECTION and TRANSPORT							
Data source							
Waste handling	SORTING (Yes/No)	Collection points (location wrt production units)	Collection containers (relevant for quality assessment)	STORAGE CONDITIONS	Transport vehicle and frequency of delivery	Facility / Plant of destination	Cost of waste transport (optional)
			e.g. monowaste				
			e.g. which wastes are mixed				

WASTE to RECYCLING (material recovery) from each production unit						
Data source						
Method used for quantification (such as documents, estimates form experience,...)						
Waste to MATERIAL recovery	Hazardous (yes/no)	from Unit	Amount	Type of recovery treatment	Destination (km)	Comments
						e.g. proportional to production

WASTE TO ENERGY RECOVERY for each production unit						
Data source						
Method used for quantification (such as documents, estimates form experience,...)						
Waste to ENERGY recovery	Hazardous (yes/no)	from Unit	Amount	Type of recovery treatment	Destination (km)	Comments (es. proportional to

Energy use in production (only if							
Data source							
Energy type	INPUT to which Unit (if known)	Consumption /year					

Air emissions
If available please provide copy of laboratory analysis of emissions at emission points as described in the process flow





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