Municipal Solid Waste Performance Indicators

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EXECUTIVE SUMMARY

This paper introduces a framework developed for the waste management sector supported by Performance Indicators. It was designed in order to be coherent and articulate and to enable full integration of its information. These indicators proved to be a useful management tool.
This framework includes 167 performance indicators (PI) divided into two types of information: 58 Context Indicators which are important for a proper identification of the System's characteristics, and 109 Operational Performance Indicators which include staff information, physical indicators, operational indicators, quality of service indicators, and financial and economical indicators. In order to test applicability of the Performance Indicators Framework (PIF) it was implemented in a Waste Management System (WMS) in the Northern Region of Portugal. It proved to be a helpful tool in providing information about the global performance of the WMS and the several waste management components. It provides efficiency assessment of the WMS, the quantification of its productivity, the identification and correction of anomalies. Another advantage of this management tool is the possibility to widen its use to other WMS in order to enable benchmarking policies.

Recently the use of PI in the urban waste sector gained an important international dimension, namely through the participation of LNEC and the Portuguese Regulator for water and urban waste services (IRAR), in the COST Action C18 – *Performance Assessment of Urban Infrastructure Services: the case of water supply, wastewater and solid waste*.

INTRODUCTION

The challenges faced today by solid waste managing entities go beyond simple quantification and characterization of the collected wastes. These challenges involve not only regulatory and law abiding but also global performance assessment by quantification of the system's efficiency. Efficiency is measured in terms of achievement of management targets and resource optimization.
The definition of a Performance Indicators Frameworks (PIF) can help verify the adequacy of management procedures, whether targets have been met or how far they are from being accomplished. PIF monitor services compliance with the scheduled activities and strategic goals by supporting decision makers with the analysis of updated information.

PIF for WMS are useful tools for decision makers, managers and technicians dealing with complex situations which involve deciding, planning or acting (Ljunggren, 2000). PIF aims to evaluate different alternatives that prove to be intelligible and consistent and also to evaluate the environmental, economic and social consequences of its implementation.

Building PAF is followed by its implementation (Ljunggren, 2000). This stage involves several actors responsible for the various components of WMS: deposition, collection, transport, transfer, treatment and elimination. A strong participation is required to each of these actors in the development of the PIF. This active participation comprises data collection and treatment and the analysis of the performance indicators included in the PIF. The implementation of PIF's, whether for internal or external use requires adequate measuring procedures that ensure an uniform data collection and also a performance assessment process based on clear definitions and common language. These procedures can take the form of indicators (Coelho and Alegre, 1999).

The European Environment Agency (EEA, 1999) (EEA, 2003) defines an indicator as an elementary datum or a simple combination of data capable of measuring an observed phenomenon. Performance indicators monitor the effect of policy measures. They indicate whether or not targets will be met, and communicate the need for additional measures. According to Beja Neves & Antão da Silva (2000a) (2000b), Performance Indicators can quantify and qualify the level of quality of a service rendered by a WMS. A PI can evaluate simultaneously how efficiently the resources are put into use and how far the System is from achieving predefined management goals. Each indicator reflects the performance of the System, according to each management component and in a well defined period of time and area.
This paper presents a set of Performance Indicators (PI) for Waste Management Systems. It was built in order to be coherent and articulate and allowing a full integrated analysis. For the current paper it was considered best to divide the PI into two major groups: context information and operational performance information.

The adopted set of PI includes 167 indicators that evaluate environmental, social and economical aspects of WMS. It provides information about deposition, collection, transport, transfer and elimination technologies. It also includes information about human and material resources and valorisation and elimination strategies. The framework assesses the consequences of political and technical decisions, reflecting collection, waste recovery and market rates, and demonstrating potential fields of intervention. The framework is also capable of evaluating the need to introduce waste reduction mechanisms. Several potential recipients can be identified at the national and international level. Municipalities, Associations of Municipalities, Waste Management Systems, Waste Regulator Institutes and the Ministry of the Environment constitute the first group. Organizations such as Eurostat, OECD and the European Commission constitute the latter.

METHODOLOGY

The Performance Assessment Framework was based on the "Performance Indicators for Water Supply Services" book, developed by the International Water Association (IWA) (Coelho and Alegre, 1999) (Alegre, 2000), taken to a broader perspective to the solid waste scope.

These indicators include two kinds of information:

a) Context (58 indicators) - important for a proper identification of the System's characteristics, its Managing Entity and the geographical region where it is inserted. It allows an objective analysis of the PI's and enables an independent comparison with other System's;

b) Operational Performance (109 indicators) – staff information, physical indicators, operation indicators, indicators of the quality of service and financial and economical indicators.

The scope of the proposed PIF is the Solid Waste Management System. These systems are considered open since they exchange energy, resources and financial flows through its frontier. Figure 1 shows a typical Waste Management System. After its deposition, waste is collected, transported, transferred and eliminated inside the system's limits. In order to perform these operations there is a consumption of financial and energetic resources. The system produces raw materials (recycled products) liquid and gaseous emissions into the environment. Five factors were taken into account when creating this PIF: quantity, composition and sorting degree of the solid waste; demand and market prices of the recycled materials; energetic consumption (electricity and fuel); technology and resources available; and legal and environmental constraints. The definition of the PIF took place in 6 stages (Teixeira and Beja Neves, 2004): institutional and legal framing of the management system; functional characterization of the managing entity; identification of the management components; first draft of the PIF; initial PI screening; and final PIF proposal.

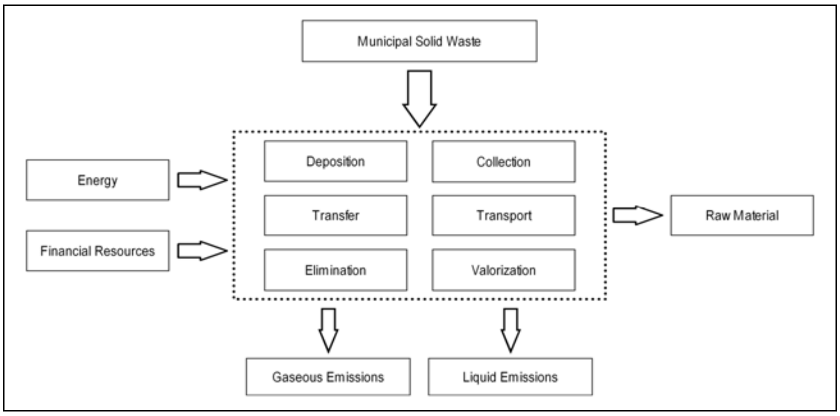

Figure 1 – Waste system boundaries and flows

Organic recycling, waste incineration and international transport of waste were left out of this PIF, as well as hazardous waste, industrial waste, hospital waste and special waste flows (oils, tyres, WEEE, batteries and wastewater sludge).

The Performance Indicators Framework was defined as shown in Table 1. Each of the major groups is divided into several subsets of indicators. The first subset *Profile of the Managing Entity* describes the managing entity in terms of stakeholders, geographic area, number of employees, tariffs, investments made, among other relevant information. The subset *Profile of the Management System* provides information about the WMS regarding the number of integrating components, coverage percentage of the service provided, area of coverage, waste quantities and composition and the installed processing capacity of each infrastructure. The subset *Profile the Region* describes the region's population, demographic and climatic characteristics.

The subset *Personnel Indicator's* assesses the efficiency of numerous tasks performed by the staff. Administrative, operational and maintenance tasks are accounted for in this subset. *Physical Indicators* contain information that describes the conditions of the infrastructures and equipments allocated to each management component. The *Operational Indicators* subset describes the operational performance of the system. Fuel, water and electricity consumption, equipment breakdowns, liquid and gaseous emissions, collection rates and recycling rates are an example of the information considered. The subset *Quality of Service* describes the quality patterns of the deposition, collection, transfer and elimination services. It also assesses the environmental quality of these services. The subset *Financial Indicators* reflects the service's efficiency from a financial and economical point of view. It can be very useful in financial planning and the control of costs and profits of the managing entities. This subset is divided into two other groups: *Balance and Financial-Economical Results* which provides information on the WMS incomes, costs, expenses and assets; the subset *Operation Indicators* includes information on the costs of human resources, equipments, maintenance and infrastructures.

The general requirements are as follows: PIF must contain a representative number of PI that retains the essential characteristics of the WMS; PIF must be applicable to waste management entities with different characteristics and in different stages of development; PIF must be referenced in time; and PIF must be referenced in space.

The selection criteria for the Performance Indicators are shown below:
1. PIs should be associated with a clear concept and must be unambiguous;

2. PIs should be independent among themselves;
3. PIs calculation must require simple processes that most of the management entities can adopt;
4. PIs should be verifiable;
5. PIs should be calculated through simple mathematical processes (mostly by dividing one variable by another or by performing a sum between two variables).

Table 1 - Performance indicators framework

Information	***Code***	***Group of Indicators***	***Indicators***		
A.Context Information	PEG_{xx}	*Profile of the Managing entity*	-	-	20
	PR_{xx}	*Profile of the Region*	Population	-	10
			Climate	-	
	PSG_{xx}	*Profile of the Waste Management System*	1. Global Characterization	-	28
			2. Production and Deposition	-	
			3. Collection, Transfer and Transport	-	
			4. Sorting, Processing, Valorisation e Elimination	-	
	Context Indicators				**58**
B. WMS Performance	Pe_{xx}	*Personnel Indicators*	1. Global Characterization	-	9
			2. Production and Deposition		
			3. Collection, Transfer and Transport	-	
			4. Sorting, Processing, Valorisation e Elimination	-	
	Fis_{xx}	*Physical Indicators*	2. Production and Deposition	-	6
			3. Collection, Transfer and Transport	-	
			4. Sorting, Processing, Valorisation and Elimination	-	
	Op_{xx}	*Operational Indicators*	1. Global Characterization	-	32
			2. Production and Deposition	-	
			3. Collection, Transfer and Transport	No. Breakdowns	
				Consumption	
				Yield	
			4. Sorting, Processing, Valorisation and Elimination	No. Breakdowns	
				Consumption	
				Emissions	
				Yield	
	QS_{xx}	*Quality of Service Indicators*	1. Global Characterization	-	17
			2. Production and Deposition	-	
			3. Collection, Transfer and Transport	Yield	
				Monitoring	
	Fin_{xx}	*Financial Indicators*	1. Efficiency Indicators	-	45
			2. Stakeholders	-	
			3. Leverage Ratio	-	
			4. Liquidity Indicators	-	
			5. Profitability Indicators	-	
			6. Unitary costs	-	
			7. Balance and Financial Results	-	
			8. Operational Indicators	WMS management	
				Production	
				Deposition	
				Collection	

				Transfer and Transport	
				Valorisation and Treatment	
				Elimination	
				Processing	
	Total Performance Indicators				**109**
Total Indicatores of the Framework					**167**

RESULTS

In order to demonstrate and validate the PIF, it was implemented in a WMS in the Northern Region of Portugal in the year 2002. The system is managed by a company named RESAT and is responsible for treating the waste of 6 municipalities. The system serves 104 768 inhabitants and presents a population density of 35.7 inhabitants / km^2. In the reference year the system treated a total of 29 364.34 tons of municipal solid waste translated in 0.68 kg/inhabitant (Table 2).

Table 2 - Context information for the WMS

Municipality	**Population (no.)**	**Population Density (inh. / km^2)**	**Waste Production (tons / year)**	**Waste generation rates (kg / inh./day)**
Boticas	6 417	20,1	1 417,48	0,60
Chaves	43 667	71,1	15 076,76	0,94
Montalegre	12 762	15,9	2 775,00	0,59
Ribeira de Pena	7 412	32,9	1 591,10	0,58
Valpaços	19 512	35,5	4 625,86	0,64
Vila Pouca de Aguiar	14 998	34,7	3 878,14	0,70
WMS	**104 768**	**35,7**	**29 364,34**	**0,68**

Waste characterization campaigns (Figure 2) show that 29% of waste is composed of fermentable material followed by paper (24%). Non-ferrous metals take only 1% of the generated waste.

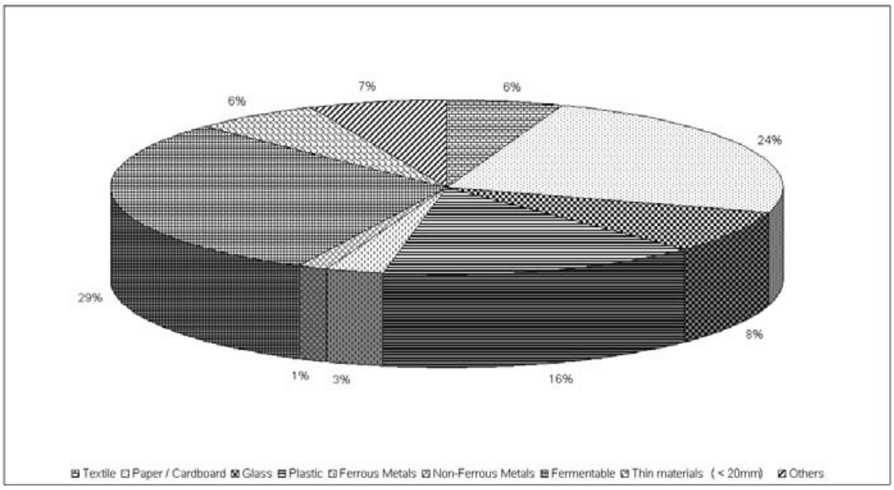

Figure 2 - Waste characterization

Collection routes of residual waste are mostly rural (55%) whilst 44% are urban and 1% are collects commercial areas (markets, malls). The large number of rural routes is an indicator of the weight of agriculture in the region. Most of the contracts for waste collection services (Figure 3) refer to household waste (96%). Other contracts refer to companies (3%) and other commercial activities or small construction companies (1%). The deposition capacity *per capita* (Figure 5) is 30.67 l/inhabit. Containers with 110 l capacity represent 48.05%, followed by 1100 l containers (28.90%). The large percentage of 110 l containers can be explained by the number of single-family residences

(1.1 dwelling per building) or small commercial stores that are located away from the city centres of the region.

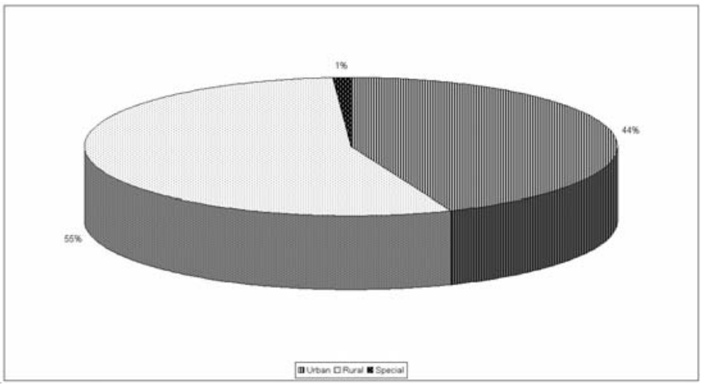

Figure 3 - Collection routes

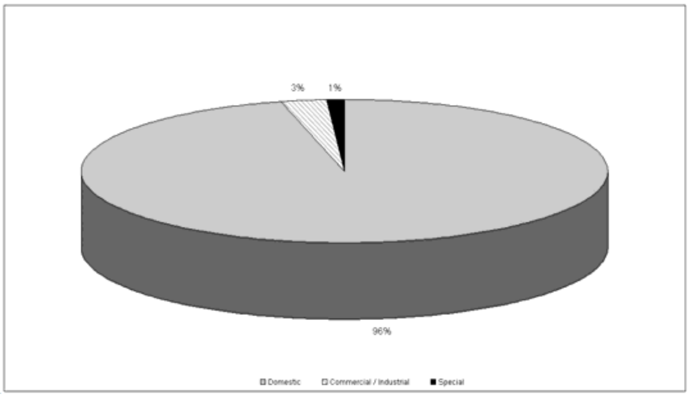

Figure 4 – Waste collection contracts

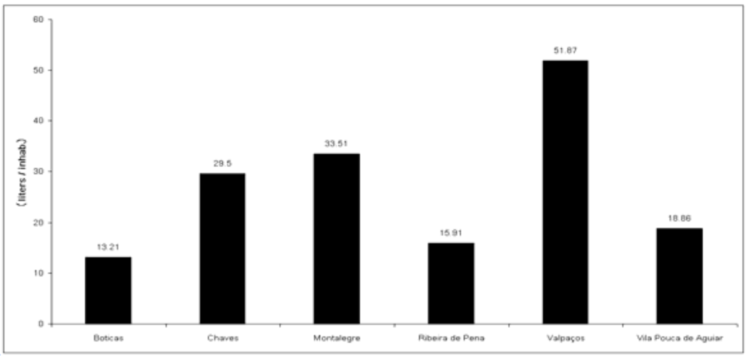

Figure 5 – Waste deposition capacity per capita

Recyclable materials can be disposed of in two ways. The first one consists in normal deposition in waste containers that receive 3 different sorts of materials (paper, plastic and glass). The second one is done by waste deposition in drop-off sites. These sites accept additional materials such as tyres, WEEE and bulk waste. The average coverage rate of the WMS for the recyclable waste containers is about 361 inhabitants per collection point. In each of the municipalities the coverage rate is inferior to 500 inhabitants per collection point. However there is a possible distortion in the distribution of these collection points. Considering the available data in Table 2 it is clear those municipalities with the highest population density aren't the ones with the highest coverage rate. In order to make the energetic consumption easier to quantify, *Electricity Consumption* and *Diesel Consumption* were reduced to *ton of oil equivalent* (toe). Toe is a unit for measuring energy that is internationally accepted in which other energy units are converted to. In Portugal, conversion coefficients for toe are published in Table 3.

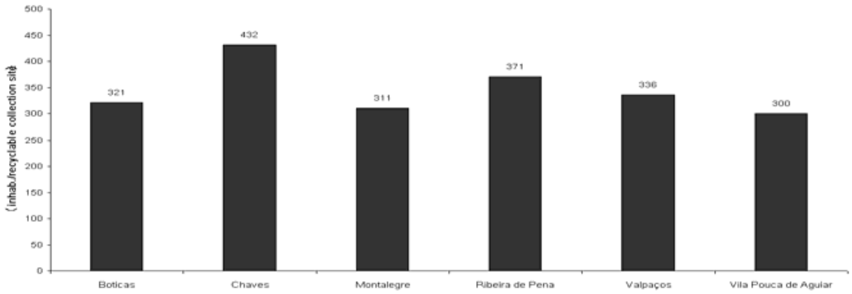

Figure 6 – Coverage rate for recyclable waste deposition

Table 3 - Energy conversion coefficients for toe (Ferrão, 1998)

Energy Form	Unit	Energy equivalent (toe / unit)
Diesel	m^3	0,873
Electricity	MWh	0,290

The energy consumption for the WMS was 4.33×10^{-3} toe per ton of processed municipal solid waste (residual and recyclable waste). Residual waste required 3.95×10^{-3} toe/ton whilst recyclable waste required 33.35×10^{-3} toe/ton. Collection and transfer was responsible for the consumption of 3.24×10^{-3} toe/ton of residual waste and 1.2×10^{-3} toe/ton for recyclable waste. Vehicles need to travel greater distances to collect recyclable waste hence collecting residual waste is more cost-effective.
Sorting and processing recyclable waste at sorting plants consumes 7.20×10^{-3} toe/ton while landfill deposition takes 0.69×10^{-3} toe/ton, showing that in terms of energy landfill deposition is 10.43 times more advantageous than processing waste for later recycling.

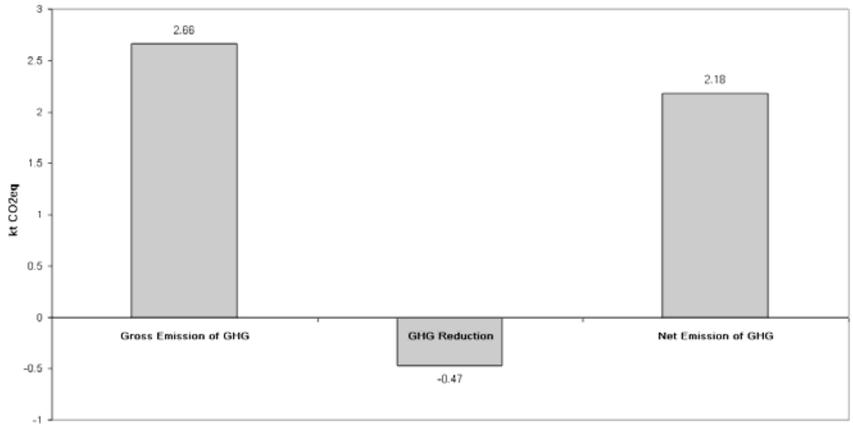

Figure 7 – Energy consumption for waste management components

Collection data per ton of waste was also collected. Average collection time was 0.85 hour/ton of residual waste and its collection distance was 15.7 km/ton.
Recyclable waste collection took 35.4 hour/ton of paper, 87.2 hour/ton of plastic and 6.2 hour/ton of glass. Average collection distance was 230 km/ton of paper, 540 km/ton of plastic and 407.6 km/ton of glass. In 2002, 98.7% of MSW were eliminated by landfill confinement. The recyclable waste system ensured a deviation rate of 2.5%. However the calculated potential deviation rate was 79.95%. As a result of the contamination of the recyclable waste (3.8%) the valorisation rate was 2.5% which is inferior to the recyclable waste collection rate – 2.98%.
Valorisation rates were 1.8% for paper, 1.2% for plastic, 0.3% for ferrous metals, 0.3% for non-ferrous metals and 8.1% for glass.

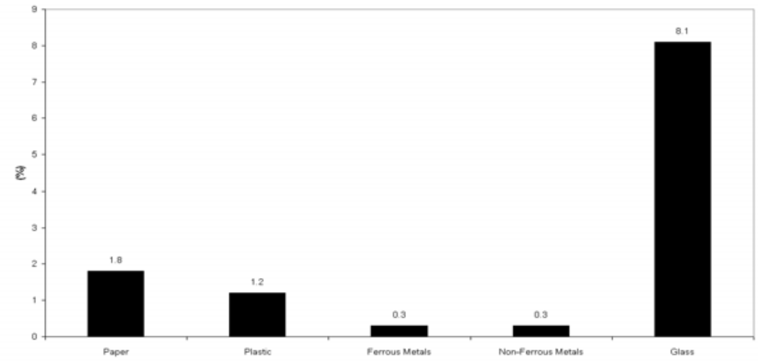

Figure 8 – Valorisation rates for recyclable waste

The valorisation rate for recyclable waste (2.5%) was inferior to the target stated in Decreto-Lei no. 366-A/97, which transposes the Council Directive 94/62/EC of 15 December 1994 on packaging and packaging waste. According to the directive, no later than 30 June 2001 between 25 and 45 % by weight of the totality of packaging materials contained in packaging waste will be recycled (with a minimum of 15 % by weight for each packaging material). In spite of its low productivity, the recyclable waste system presents high quality levels, stated by the 100% acceptance rate of the sorted materials. This means that recyclable waste complies with the quality standards of the Green Dot Society after being processed in the sorting plant. The quality of the service of the waste company was assessed by the clients of the waste system. The company received a total of 60 complaints divided by citizens (30%), public entities and municipalities (70%). Private companies didn't make any complaint. The reasons for complaints were environmental issues (16.7%) and deposition and collection problems (83.3%). 75% of the total complaints received a satisfactory answer. The quantification of emission of Greenhouse Gases (GHG) – methane and carbon dioxide – of the landfill was based on the United Stated Environmental Protection Agency (USEPA) models "Emission Factor Documentation for AP-42 Section 2.4 - Municipal Solid Waste Landfills" (1997) and "Solid Waste Management Assessment of Emissions and Sinks" (2002).

Landfill deposition was responsible for the gross emission of 2.66 kTon of CO_{2eq} of GHG. This number doesn't include mobile source's emissions such as collection vehicles or heavy machinery of the landfill. Recyclable waste valorisation avoided the emission of 0.47 kTon of CO_{2eq} of GHG. The overall emission balance was 2.18 kTon of CO_{2eq} of GHG (Figure 9). In spite of the low valorisation rate of the recyclable waste (2.50%) it was possible to reduce the GHG emissions of the WMS (17.6%).

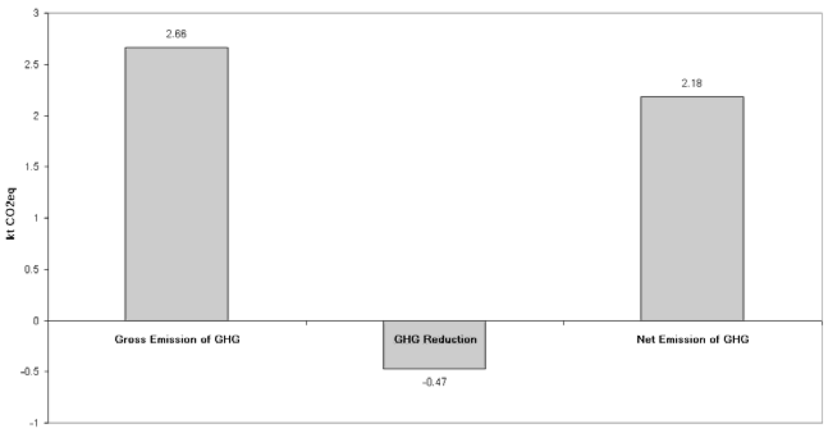

Figure 9 – Greenhouse Gas Emissions

The unitary costs of the WMS show that mixed and recyclable waste collection, transfer and transport take up to 60% of the total costs. Waste deposition cost 15% due to the acquisition of new containers. 10% of the total costs were allocated to administrative expenditures. Sorting recyclable materials at the sorting plant cost 5% whilst landfill deposition cost 10% (Figure 10). The Green

Dot Society financed 48% of the collection costs of the recyclable waste. The remaining 52 % were financed by the Municipalities.

Conclusions and recommendations

It was demonstrated that PIF are a reliable and feasible tool, capable of quantifying the quality of service rendered by a managing entity and assessing its global performance in all its management components.

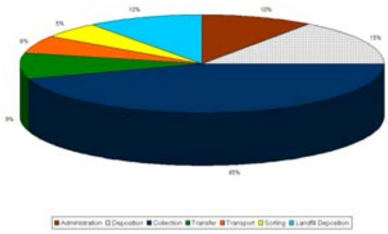

Figure 10 – Distribution of the Waste Management Costs

The performance indicator's value shouldn't be understood as the final stage in the performance assessment process but rather as a management tool. It is also essential to the decision-making process and to support strategic planning of future programmes or projects. The adopted PIF is well referenced in space and time and can be implemented by other managing entities in distinct regions and in other development stages. In this case different entities can compare results, correct irregularities and evaluate the efficiency of decisions made previously. Another characteristic of this PIF that is of great relevance is the possibility to carry out benchmarking with several entities in order to compare performance mutually. Future developments that can arise from this work may include the selection of PI that are more relevant according to each managing entity's needs and characteristics or even a benchmarking procedure that reduces the number of PI. Other works may include the development of analysis mechanisms that integrate the context information and the performance indicators and that can further integrate this information in decision-support tools. Additionally it is expected to extend this PIF to other waste management components, such as anaerobic digestion or incineration.

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