Evaluation and Proposed Development of the Municipal Solid Waste Management System in Mexico City

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Abstract

The work reported involves the evaluation of technologies and management systems applied to Municipal Solid Waste (MSW). The study focuses on Mexico City, which with a population of approximately 9 million inhabitants and an estimated daily generation of 13,000 tonnes of waste, is encountering extreme waste management issues. The structures and public policies designed to provide waste management services have proved inadequate in relation to high rates of population growth and intensive business activities. The significant increase in demand has led the government of Mexico City to base public services on rudimentary techniques using obsolete equipment.

The research approaches the problem through the analysis of several different aspects: (1) a comprehensive literature review of waste management including technologies and legal frameworks; (2) a general overview of the main demographic, geographic and economic aspects of Mexico City; (3) an extensive analysis of historic and future waste generation profiles and composition of waste in Mexico City; (4) an evaluation of the current status of the waste management system, including programmes, plans, facilities and infrastructure; and (5) a comparative study of the waste management system of Mexico City and the systems of selected international cities.

The evaluation resulted in the identification of the following significant issues: (1) limitations in legislation related to waste management and environmental laws; (2) high population growth and increasing business activity, which contribute escalating generation of MSW; (3) ineffective public policies focused on waste management; (4) significant gaps in low levels of recycling activities; (5) obsolescence of equipment, infrastructure and facilities; (6) lack of diversification in treatment methods for MSW; and (7) failure to exploit market opportunities in the waste management sector.

In addition to the evaluation of the system in Mexico City, the analysis of waste management systems in selected international cities allowed the author to identify key factors in order to develop integrated proposals. The analysis highlighted significant aspects including: legal frameworks, the participation of the private sector, waste hierarchy, and guiding principles for plans and programmes. The information enabled the design of a proposed development plan of a comprehensive waste management system in Mexico City through two main proposals.

Firstly, an integrated programme for waste management in Mexico City was developed to provide feasible long-term strategies in the field of waste management. The specific objectives, goals, actions, responsibilities and time scales were defined in order to provide concrete activities under specific fields of operation.

Secondly, a project to obtain funding for technology transfer structured according to technical, market and economic studies, was elaborated. The guide is aimed to exemplify an investment project through the analysis of a feasibility study related to generation of energy from biogas in a controlled landfill in Mexico City. The process may be adapted to the acquisition of technology in different sectors of the waste management process.

Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning

Copyright Statement

List of Acronyms and Abbreviations

BANOBRAS	National Bank of Works and Public Services of Mexico
BANXICO	Central Bank of Mexico
BSR	Berliner Stadtreinigungsbetriebe
CEMEFI	Mexican Centre for Philanthropy
CCAS	Clean City Awards Scheme
CIPS	Chartered Institute of Purchasing and Supply
CONAGUA	National Water Commission of Mexico
CUEI	Columbia University's Earth Institute
DEFRA	Department for Environment, Food and Rural Affairs of the UK
EDF	Environmental Defence Fund
ECLAC	Economic Commission for Latin America and the Caribbean of the United Nations
EPA	Environmental Protection Agency of the U.S.A.
ESR	Corporate Social Responsibility
FICEDA	Trust for the Construction and Operation of “Central de Abasto”
FIRCO	Venture Capital Trusts
FME	Federal Ministry for Environment of Germany
GFD	Government of the Federal District
GLA	Greater London Authority
HMRC	Her Majesty's Revenue and Customs
INE	National Institute of Ecology of Mexico
INEGI	National Institute of Statistic and Geography of Mexico
IEEP	Institute for European Environmental Policy
LAFD	Legislative Assembly of the Federal District
LMSWFD	Law of Municipal Solid Waste of the Federal District
LSWMP	Local Solid Waste Management Planning
MEJ	Ministry of the Environment of Japan
NYC-EJA	New York City Environmental Justice Alliance
NYSDEC	New York State Department of Environmental Conservation
ODPM	Office of the Deputy Prime Minister of the UK
OECD	Organisation for Economic Co-operation and Development
PB	Political Boroughs of the Federal District
RRC	Reuse and Recycling Centres
SAGARPA	Mexican Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food
SDUDE	Senate Department for Urban Development and the Environment of Berlin
SEMARNAT	Mexican Secretariat of Environment and Natural Resources
SE-FD	Secretariat of Environment of the Federal District
SENER	Secretariat of Energy of Mexico
SIEM	Mexican Enterprise Information System
SSTFD	Secretariat of Science and Technology of the Federal District
SWS-FD	Secretariat of Works and Services of the Federal District
SWOT	Matrix of Strengths, Weaknesses, Opportunities and Threats
TMG	Tokyo Metropolitan Government
UNDP	United Nations Development Programme
WRAP	Waste & Resources Action Programme

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Chapter 1

Introduction

1.1 Description of the place

The Federal District, (commonly referred as Mexico City) is the capital city of Mexico founded in 1325. Mexico City has served as the capital of the country since the establishment of the Viceroyalty of New Spain by the Spanish Crown in 1521 (Hamnett, 1999). Mexico City is one of the 32 federal entities of the United States of Mexico, and it is the base of the Legislative, Executive, and Judicial power. Mexico City is not strictly considered to be a state. However, since 1997 residents directly elect the “head of the government of the Federal District” an equivalent position to Governor or Mayor. Mexico City is divided into sixteen political boroughs (officially named delegations) and it is bordered almost totally by the State of Mexico except on the south where it is bordered by the State of Morelos. The highest elevation in Mexico City reaches 2,420 meters above sea level. Mexico City has an estimated extension area of 1,485 m^2; the climate can be considered as subtropical and the average annual temperature varies from 12 to 16 °C (Molina, *et al.*, 2009).

1.2 Problem definition

Waste is a significant issue in urban settlements. High population densities coupled with inefficient waste management systems, can generate significant environmental impacts. Main impacts and damage that result from inadequate handling of waste include: (1) contamination of surface and groundwater bodies, (2) emission of greenhouse gasses, (3) alteration of soil properties, (4) blocking of sewers and drains, (5) proliferation of insects and harmful fauna, (6) alteration of the urban environment, (7) deterioration of public spaces.

The case of Mexico City exhibits both, the population growth has led to an increase in waste generation; and a waste management system, the capacity of which has been exceeded. The consumption patterns have led to an unconscious generation of waste and the waste management system lacks policies and programmes for prevention, separation and recycling. Projects to diversity the treatment methods have not been supported and the utilization of uncontrolled sites for waste disposal has been widely used for many years. The technical and financial capacities of the government seem to be depleted.

The waste problem in Mexico City can be approached from several perspectives; nevertheless, there is a clear need to: (1) develop a comprehensive study of the current status of the waste management facilities; (2) evaluate the public policies, programmes, plans and current strategies in the waste management field. This thesis highlights the main waste management issues in Mexico City, discusses the significant findings, and presents recommendations on strategic planning.

1.3 Evolution of the aims of the research

The research required a diversity of approaches due to the wide scope of the field of study. At the begging of the research (in the context of the situation in Mexico City at that time) it was anticipated that the main challenge for the waste management problem could be the improvement and modernization of facilities, mainly technology and machinery aimed at waste treatment. Therefore, this research began with an early aim of the research as "to design a technology transfer model for machinery aimed at waste management". In order to fulfil the general aim, several activities and tasks were carried out. In the original proposal, there was a need for a thorough analysis of the current status of technology transfer in Mexico in order to identify factors whereby transfer of technology is limited in Mexico. The initial literature review mainly focused on aspects related to technology, knowledge and their transfer. Subsequently, the perspective of the technological development in Mexico was studied. The main findings included that lower level of investment by private companies in technological development and the purchase of foreign technology, have led to creating a significant barrier to the achievement of technological independence.

The second stage of the research required interviews conducted with staff of the Secretariat of Environment of the Federal District. The main findings indicated a complete lack of proper plans and programmes for waste management. The government of the Federal District has failed to develop the design of public policies aimed at waste prevention.

The main aim of the research was expanded and refocused on the development of an integrated programme which would include: principles of operation, strategies, activities and timescales in order to generate a coordinated project to restructure the waste management system in Mexico City. The topic related to technology transfer was not completely discarded; however, it was identified that the priority would be focused on the development of a waste management programme. Transfer of technology became a second aspect within the research; nevertheless, its study was approached from a different perspective. The theoretical framework of the technology transfer was studied. However, it was given priority to the development of a practical project to generate a guide that can be used to transfer or purchase technology for waste management processes.

Thus the main aims and subsidiary objectives of the research include those listed below.

1.4 General aims

1. To design an Integrated Waste Management Programme for Mexico City..

2. To design a guide to obtain funding for technology transfer focusing on waste management activities and projects, using an applied case in Mexico City.

1.5 Specific objectives

1. To conduct literature reviews related to waste management in order to provide a theoretical basis for the research.
2. To analyse the economic and demographic context of Mexico City in order to generate estimations and to project future trends.
3. To conduct a comprehensive analysis of the generation, type of wastes, status of facilities and any other aspects related to the current Municipal Solid Waste Management system of Mexico City.
4. To analyse waste management models of selected international cities in order to identify key aspects that can be applied in Mexico City.
5. To identify the fundamental elements required in the development of a feasibility study of the generation of energy from landfill gas, including commercialization conditions, economic and financial aspects, and suitable funding sources.

1.6 Methodology

The research was conducted through a methodology divided into different stages in order to fulfil the aims. The stages included: (1) Planning, (2) Construction of the literature review, (3) Information collection, (4) Discussion, (5) Applied proposals, (6) Results. The methodology helped to identify a general structure of the research after the different changes described in section 1.3. Figure 1 presents the main stages of the applied methodology. The subsequent sections describe the general activities of each stage.

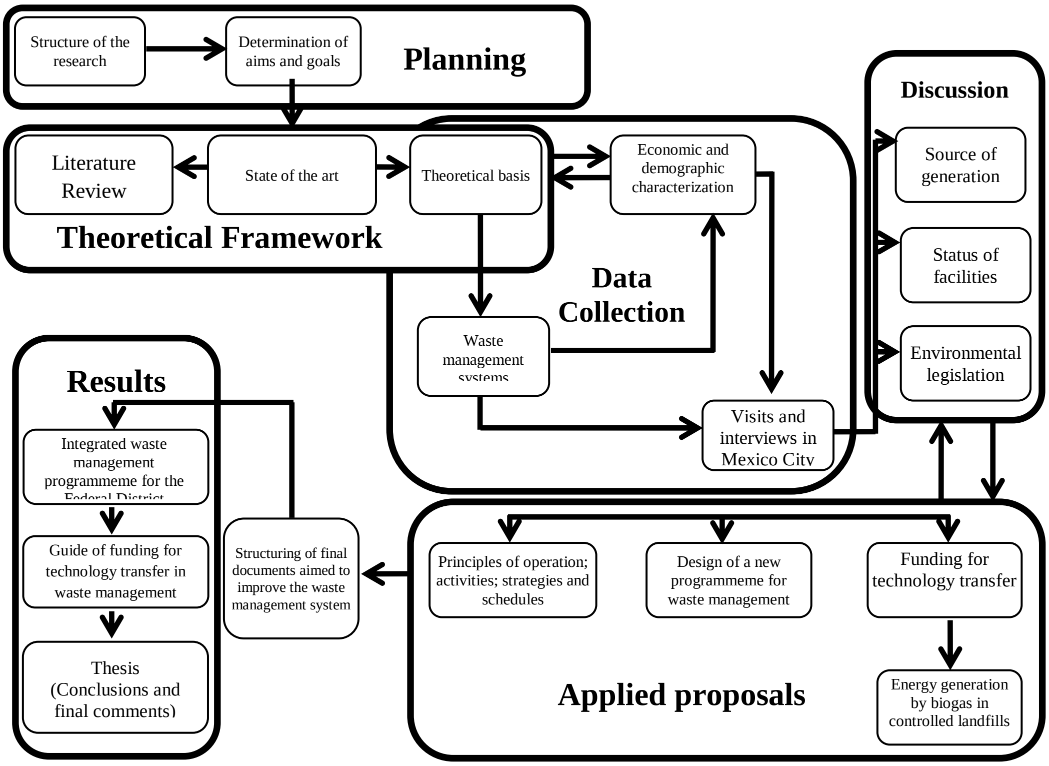


Figure 1 Methodology of the research

1.6.1 Literature review related to waste

This stage aimed to review, categorize and analyse multidisciplinary literature related to Municipal Solid Waste. In order to obtain a manageable proportion of information, books, scientific journals, technical handbooks and reports were reviewed in different categories. Figure 2 shows the categories in a clockwise structure of the main aspects analysed in the literature review. The analysis of theoretical aspects involved the revision of different concepts in an individual approach in order to generate a proper understanding of the terminology related to waste management. The literature review is indented to present a single analysis of several concepts, and to observe how such concepts integrate as whole to provide the theoretical framework for subsequent analysis presented in the thesis.

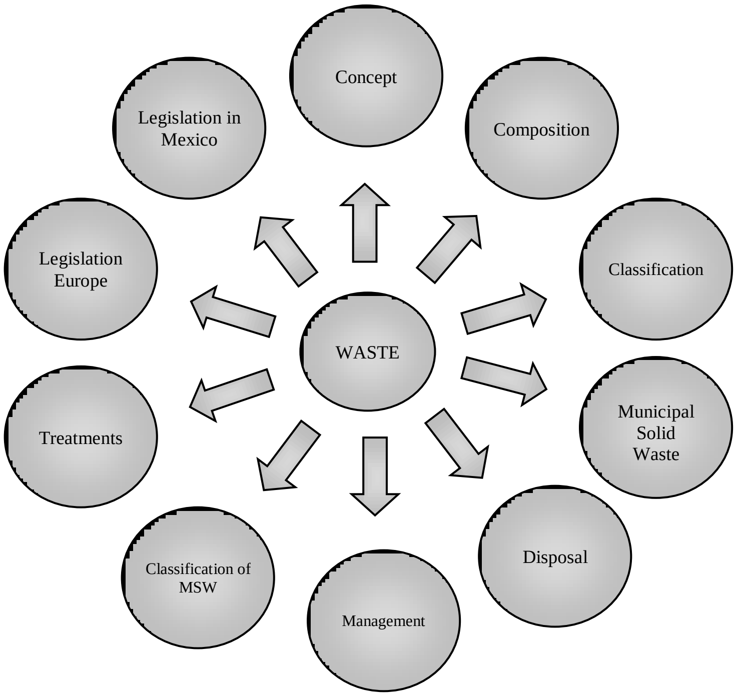


Figure 2 Main aspects related to waste management in the literature review

1.6.2 Data collection of different waste management indicators

The second stage of the research involved the collection and analysis of information. The analysis of historical data from official reports from governmental agencies in Mexico (National Institute of Ecology, Secretariat of Environment, Secretariat of Government of Mexico City, Secretariat of Economy, Secretariat of Works and Services among others) and reports related to the performance in the field of environment conservation developed by international agencies (European Environment Agency, Organisation for Economic Co-operation and Development, Environmental Protection Agency of the USA, among others), was carried out.

1.6.3 Examination, validation and comparison of information

The analysis was carried out in two stages. Firstly, the examination of data related to MSW allowed the author to identify trends in the generation. The results could be compared against data from selected international cities. Secondly, interviews with authorities in Mexico City were conducted. The interviews enabled the determination of the current strategies, programmes, activities and public policies. Visits to facilities for waste management were carried out. The visits to facilities allowed the author to analyse current treatment methods, the obtained yields and the environmental problems which are caused by the existing processes. The study of the effectiveness of individual facilities for selection, treatment and disposal enabled a compilation of a comprehensive assessment of the waste management system in Mexico City.

1.6.4 Discussion of the main outcomes

The evaluation evidenced the current status of the waste management system in Mexico City. The comparison of results with systems in selected international cities, allowed the author to define proposals to improve the overall MSW system, taking into consideration the main findings obtained in previous stages of the research.

1.6.5 Results, conclusions and final considerations

The final stage is related to the expected results. The research resulted in two main sections within the thesis: a proposal for an integrated programme for waste management in Mexico City, and a guide to obtain funding for technology transfer in waste management activities. Such proposals are presented in Chapter 6 and 7. The results also involved the main conclusions and final comments which are presented in Chapter 8.

Chapter 2

Literature review

2.1 Introduction

Prior the description of the waste management process, it is necessary to clarify some concepts: waste and specially Municipal Solid Waste (MSW). The term “waste” might can be subject to different interpretations. There is a general understanding which notes that waste includes all mixed rubbish which is generated by human action in, either domestic, industrial or commercial activities. Directive 2008/98/EC from the Commission of Environment of the European Union defines waste as “*any substance or object which the holder discards or intends or is required to discard*” (European Parliament, 2008). In the same way, all those objects which are no longer valuable and are useless for the owner can be considered waste. Human settlements and societies have always generated rubbish and throughout time, such generated amounts have become a problem. Natural reserves of raw materials and energy sources, decrease whereas extraction costs increase. This action generates serious environmental problems and social imbalances. Societies are immersed in the culture of disposability. Waste which is generated at home may include small proportions of hazardous waste (paints, cleaning products, solvents, insecticides, etc.). The mishandling of such materials can represent a significant health risk and important environmental impacts (DEFRA, 2012). This research specifically focuses on the household waste and any other waste which is not considered by applicable laws as hazardous waste. Such a kind of waste can be categorized as Municipal Solid Waste. Therefore, for further references to “waste” this thesis will focus on Municipal Solid Waste only, the definition is presented in the following points.

2.2 Municipal Solid Waste (MSW)

The U.S. Environmental Protection Agency defines MSW according to three different categories (EPA, 2012)**:**

1. Domestic sources - The solid component of the waste stream arising from domestic premises that is received directly from the public.
2. Hard Waste - The solid component of the waste stream arising from domestic premises which is not suitable for collection using a bin system, but does not contain Commercial and Industrial Waste, Listed Waste, Hazardous Waste, Radioactive Waste or waste that is not deemed suitable for collection by local councils.
3. Bin Collection - The solid component of the waste stream arising from mainly domestic but also commercial, industrial, government and public premises, including waste from council operations, services and facilities that is collected by or on behalf of the council via bin collection, but does not contain Commercial and Industrial Waste, Listed Waste, Hazardous Waste or Radioactive Waste.

The Law of Municipal Solid Waste of the Federal District in Mexico provides another definition; the text is originally in Spanish, and is translated by the author as follows (LAFD, 2003):

"*…all waste that is generated at home resulting from elimination of materials that are used in domestic activities and consumed products (packaging, wrapping), and that from any other activity which generates waste with household characteristics and the resulting from cleaning public spaces, roads, common areas provided that they are not considered by the law as waste requiring special handling…"*

Therefore, the author suggests a working definition as follows: Municipal Solid Waste can be understood as household waste and any other wastes which are collected by the cleaning authority. This includes waste from homes, parks, public areas, gardens, beaches, and commercial or industrial waste, provided that any applicable legislation does not characterize them as hazardous that may include medical waste, dangerous substances, gaseous effluents, radioactive waste, waste resulting from mineral resources, or any type of waste which present properties of hazardous waste according to applicable legislations (The properties of hazardous wastes according to Directive 2008/98/CE of the European Union is presented in Appendix 1).

2.2.1 MSW classification

Waste cannot be simply divided into safe and hazardous. Therefore, the selected method for MSW handling must be in accordance with the type of waste. According to the Law of Municipal Solid Waste of the Federal District, MSW are divided into organic and inorganic waste. The law stipulates that (Original text in Spanish translated by the author):

- Organic Waste: are biodegradable solid materials.
- Inorganic Waste: are all those not characterised as organic; they may have economic value if reused or recycled. These may include: glass, paper, cardboard, plastic, recyclable laminate, aluminium, not-hazardous metals and others not requiring special handling.

The waste classification admits several approaches and the consideration of different parameters. In order to establish an accurate classification it is necessary to consider some aspects such as: origin or mode of generation, and physical, chemical and biological characteristics including toxicity and hazard.

It must be pointed out that classifications normally tend to simplify the real situation, given a categorization, which in reality, is not always as simple to apply. Classifications do not normally encompass either the whole possible cases arising from the heterogeneity in aspects such as the chemical composition; and they do not always consider the direct or indirect interrelationships between the processes of generation. Sztern & Pravia (2001) have suggested more specific definitions of inorganic and organic wastes.

- Inorganic waste: Includes all materials of origin and substances or compounds which are synthesized by man. This category normally includes metals, plastics, glass, etc. Waste from pesticides, chemicals, or those coming from agro-veterinary activity even when special treatment is required. Inorganic waste can be considered as an important source of raw material from some productive sectors.

- Organic waste: It refers to all those which have their origin in living beings, animals or vegetables. They include a wide variety of wastes originated in a natural way during a "life cycle" as a consequence of physiological functions of maintenance and perpetuation.

2.2.2 MSW composition

MSW is broadly classified into organic and inorganic. Organic waste normally includes food scraps, yard (leaves, grass, brush) waste, wood, process residues. Inorganic waste, within the MSW stream, can include: paper (cardboard, shredded paper, magazines, bags, boxes, newspapers, wrapping paper, telephone books, etc.), plastic (bottles, bags, packaging, containers, etc.), glass (bottles, broken glassware, light bulbs, etc.), metal (cans, foil, tins, non-hazardous aerosol cans, appliances/ white goods, railings, bicycles, etc.), other materials such as: textiles, leather, rubber, multi-laminates, e-waste, etc. (OECD, 2000).

MSW composition varies by region. The composition is influenced by several factors including: economic activities, climate, culture, energy sources, etc. The identification of the MSW composition enables the proper development of collection and disposal strategies (OECD, 2013). Low-income countries tend to generate a significant proportion of organic waste, whilst high-income countries present highest proportions of paper, plastics, and other inorganic materials (EPA, 2011).

Income Level	Organic (%)	Paper (%)	Plastic (%)	Glass (%)	Metal (%)	Other (%)
Low Income	64	5	8	3	3	17
Lower Middle Income	59	9	12	3	2	15
Upper Middle Income	54	14	11	5	3	13
High Income	28	31	11	7	6	17

Table 1 Waste composition by income level (Constructed with data from World Bank, 2012).

Table 1 illustrates the different values of the MSW composition by income level. The table was constructed with information from the World Bank, which includes data from 105 countries classified by income and with generation rates from 2006 to 2012. The generation rate included urban areas only and in some countries the composition values were from one city only. Table 1 shows that low-income countries have an organic fraction of 64% compared to 28% in high-income countries. This shows that, as a country become wealthier, the organic fraction decreases while consumption of inorganic materials increases; however, in low and middle-income countries, there is a high percentage of organic matter ranging from 40 to 85% of the total (World Bank, 2012).

2.2.3 MSW treatment

Directive 2008/98/EC states that "*treatment means recovery or disposal operations, including preparation prior to recovery or disposal*". In addition, it states that "*recovery means any operation the principal result of which 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*" and that "*disposal means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy*" (European Parliament, 2008).

Therefore, according to the Directive 2008/98/EC of the European Union, MSW treatment can include the following operations:

- Disposal operations:
    - ➢ Specially engineered landfill (placement into lined discrete cells, which are capped and isolated from one another and the environment)
    - ➢ Land treatment (biodegradation of liquid or sludgy discards in soils, etc.)
    - ➢ Deep injection (injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)
    - ➢ Release into a water body except seas/oceans
    - ➢ Biological treatment which results in final compounds or mixtures which are discarded by means of other operations numbered in the Directive 2008/98/EC
    - ➢ Physico-chemical treatment (evaporation, drying, calcination, etc.)
    - ➢ Incineration on land
    - ➢ Permanent storage (emplacement of containers in a mine, etc.)
    - ➢ Blending or mixing prior to submission to another operation
    - ➢ Repackaging prior to submission to another operation
    - ➢ Storage pending other operation

- Recovery operations
  - Use waste principally as a fuel or other means to generate energy (This includes incineration facilities dedicated to the processing of municipal solid waste)
  - Solvent reclamation/regeneration
  - Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes, this includes gasification and pyrolysis using the components as chemicals).
  - Recycling/reclamation of metals and metal compounds
  - Recycling/reclamation of other inorganic materials (This includes soil cleaning resulting in the recovery of the soil and recycling of inorganic construction materials)
  - Land treatment resulting in benefit to agriculture or ecological improvement

The treatment operations most widely used are presented below. The descriptions of those specific techniques are based on the need to identify sustainable alternatives to treat MSW. Each technique involves particular characteristics in the process which focuses on a specific type of MSW. Therefore, the description of sustainable alternatives is divided into biological treatment and thermal treatment.

2.2.3.1 Biological treatment of MSW

Biological treatment of MSW aims to control and enhance natural biological processes, and as such can only act on biodegradable organic materials, this means that it focuses only on organic waste. This treatment involves mainly two operations, composting and anaerobic digestion (DEFRA, 2013).

- **Composting**

Compost is humus obtained in a natural process of the biochemical decomposition. The decomposition favours the aerobic fermentation (with oxygen) of organic waste. The process involves the mass reproduction of thermopiles aerobic bacteria (Gomez *et al.*, 2006). The infrastructure, technology and methods of composting plants may vary according to the type of compost intended to be produced.

Windrow composting is identified as a method where the compost is produced by piling organic material in long rows (windrows) of approximately 1.25 metres high and four to six metres across the base (Figure 3). Throughout the composting process, the turning of the waste is needed in order to provide oxygen and facilitate the aerobic decomposition and control the temperature (Silva *et al*., 2008). The most common machinery includes windrow turners.

Figure 3 Composting method in windrows (Adapted from EPA, 2002)

In-vessel composting is a method which differs from windrow composting in that the aerobic digestion is carried out in an enclosed container (Figure 4). In the in-vessel composting process, the activities such as the control of moisture, temperature and irrigation are carried out by an automated system. The compost can be produced quicker than in windrow composting (Kopcic *et al*., 2014).

Figure 4 In-vessel composting method (Adapted from EPA, 2002)

- **Anaerobic digestion**

Anaerobic digestion can be used as a technique to provide a proper and controlled treatment of segregated biodegradable municipal wastes and commercial food waste. In anaerobic digestion the biodegradable material decomposes in the absence of oxygen. Such a process is carried out within an enclosed vessel under controlled conditions. The main output of this process is biogas, which is produced by bacterial anaerobic fermentation of organic materials (Rajeeb, 2009). Biogas is a flammable gaseous fuel comprising CH_4 primarily used as a fuel. Biogas is a result of methane fermentation of different materials such as agricultural raw materials, agricultural products and liquid or solid animal feces (Iglinski *et al.*, 2012). Combustion of the biogas enables energy recovery and has been widely used in heat and power plants, among other industrial applications (Tampio *et al.*, 2014).

Biogas can be used as an energy source, and can be used in combined heat and power engines. It can be used also as a natural gas substitute by removing CO_2 from CH_4. The biogas is a versatile fuel that can be used for both energy generation and as feedstock for the chemical industry (Scholz *et al*., 2012).

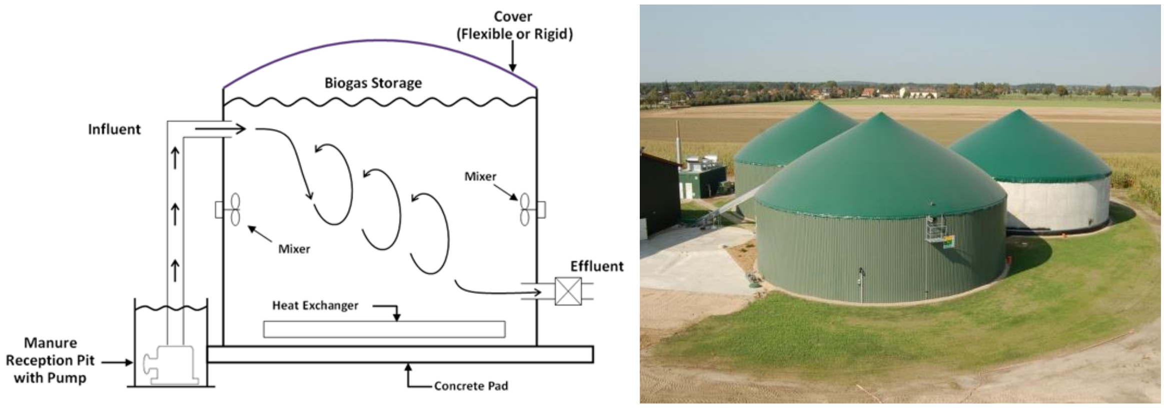


Figure 5 Diagram of anaerobic digester (Adapted from EPA, 2002).

2.2.3.2 Thermal treatment of MSW

The thermal treatment of MSW involves operations based on a change in the chemical structure of the waste. According to Letcher & Vallero (2011), thermal treatments can represent significant benefits including 1) the potential for energy recovery; 2) volume reduction of the contaminant; 3) detoxification as selected molecules are reformulated; 4) the land-area requirements are small relative to other hazardous-waste management facilities such as landfills.

Incineration is the most common thermal treatment; however, some clarification should be made. Incineration is highly used to process MSW and involves the combustion of waste in the presence of oxygen (Letcher & Vallero, 2011). Nevertheless, it must be noted that incineration is not a synonym of Energy-from-Waste (EFW, also referred as Waste-to Energy), as incineration involves the thermal destruction of waste for the primary purpose of disposal, with or without recovery of energy (EPA, 2012), whilst EFW focuses on processing of waste in designed boilers to ensure complete combustion with the aim of generate energy (electricity and steam). Within the incineration operations, the Energy-from-Waste processes are identified as a sustainable thermal system (Knox, 2005).

In addition, two advanced thermal options to treat MSW can be identified: Pyrolysis and Gasification:

- **Pyrolysis**

Although pyrolysis has been widely used to produce charcoal and coke, in recent years the process has been applied for treatment of MSW (Meisen & Hipps-Morgan, 2010). Pyrolysis is a thermal process in which organic waste is heated in the absence of air in order to generate a mixture of gaseous and liquid fuels. Solid inert residues, mainly carbon, are also generated (Liu *et al*., 2014). Pyrolysis generally requires a consistent waste stream to produce a usable fuel product (ODPM, 2004). Among the different thermal methods, pyrolysis presents favourable processes to convert waste into valuable liquid hydrocarbons. The liquid product known as bio-oil or pyrolytic-oil is a complex mixture of oxygenated hydrocarbons and water. The oil can be used directly as a liquid fuel or as a source of synthetic chemical feedstock (Hassen-Trabelsi *et al*., 2014). The use of pyrolysis can provide different sub-products from the biomass, as shown in figure 6:

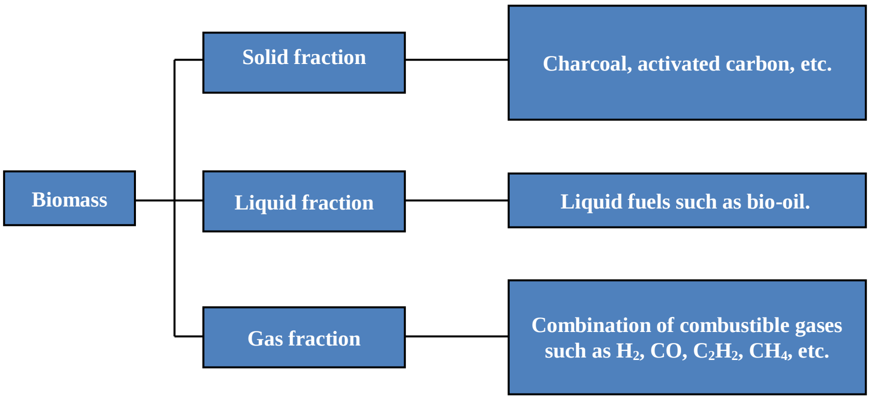


Figure 6 Pyrolysis products (Motasemi & Afzal, 2013).

- **Gasification**

Gasification involves the partial oxidation of a substance. The process involves the addition of limited oxygen to enable a partial oxidation of the fuel limiting a full combustion. The temperatures reach more than 650°and two main products can be identified: syngas, which contains carbon monoxide, hydrogen and methane and solid residue of non-combustible materials (ash) which contains a relatively low level of carbon (DEFRA, 2007).

The calorific value of this syngas will depend on the composition of the input waste to the gasifier, however, syngas is normally used as a fuel to generate electricity or steam. It can also be used as a basic chemical feedstock in selected industries including petrochemical and refining (FCE, 2004).

- **Difference between Pyrolysis, Gasification and Incineration**

There are elements to differentiate Pyrolysis and Gasification (Advanced Thermal Treatments) from traditional Incineration. One important element is the scale, Pyrolysis and Gasification present facilities on a smaller scale than in typical incineration. The difference in scale and size allow advanced thermal treatments to decentralise operations and to have a greater degree of flexibility in terms of location. In terms of operational processes, incineration usually involves the combustion of unprepared MSW (raw or residual) with sufficient quantity of oxygen to fully oxidise the fuel. In contrast, in Pyrolysis there is an absence of oxygen and the process requires an external heat source to maintain the temperature required. Therefore, Gasification can be seen as between pyrolysis and combustion in that oxygen is added but the amounts are not sufficient to allow the fuel to be completely oxidised and full combustion to occur (DEFRA, 2007).

2.3 Waste hierarchy

Through an archaic waste management scheme, wastes are collected and directly disposed of in landfills; however the absence of collection consequently may cause the waste accumulation in public areas and the contamination of the environment (EEF, 2011). In locations with high population density a general assumption can be formulated: the amount of waste that the environment can assimilated may be exceeded, given the change in the economic activities and the increase in the demand for services. An integrated management system is divided into three main activities (identified as 3Rs) before the use of landfills or incinerators: Reduction, Re-use, and Recycling. (1) Reduction in the generation that, through a change in the patterns of production and consumption of human satisfiers, reduces the amount of waste generation; (2) Re-use that consists of a re-use of waste in the same original use or for another use; (3) Recycling, defined as the transformation of waste into newer satisfiers.

The fourth article of Directive 2008/98/EC stipulates that waste hierarchy shall be applied in waste management programmes and plans. Figure 7 shows the main aspects which make up the waste hierarchy:

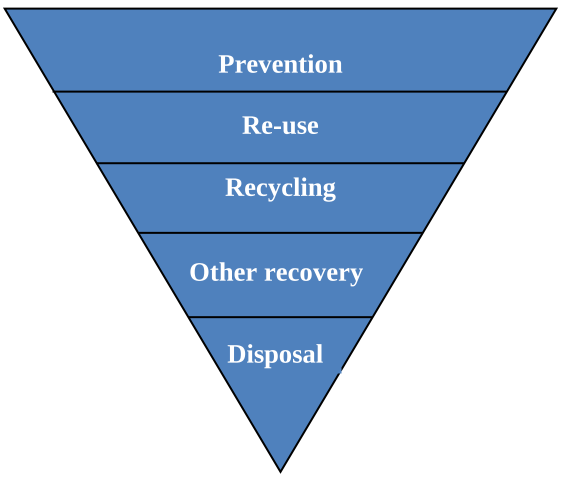


Figure 7 Waste hierarchy of MSW (DEFRA, 2011a).

Each element of the waste hierarchy is defined in the Directive 2008/98/EC as follows:

- Prevention refers to measures taken before a material has become waste, such measures include reductions of: (1) quantity of waste, including through the re-use of products or the extension of the life span of products; (2) adverse impacts of the generated waste on the environment and human health; (3) content of harmful substances in materials and products.
- Re-use refers to operations to use again products or components that are not waste, for the same purpose for which they were originally conceived.
- Recycling refers to operations aimed to reprocess waste materials into products, materials or substances, whether for the original or other purposes (it does not include energy recovery or the reprocessing into materials that are to be used as fuels).
- Recovery refers to operations aimed to generate usefulness to waste in activities or processes by the substitution of other materials.
- Disposal refers to the final stage in the management of waste; it includes treatment of waste prior to disposal, and involves the deposit of waste to land or water in a permanent, indefinite or long term storage scheme.

As the environmental recycling cost is higher than the cost of re-use, and the cost of re-use is higher than the cost of reduction; it is technically and economically advantageous to optimize the reduction before moving towards re-use and then sequentially to recycling. As the final step and only in the cases in which waste was not re-used or recycled, it should be confined and isolated from the environment in order to prevent pollution (Bartl, 2014). In addition to the waste hierarchy a proper waste management strategy should take into consideration the prudent use of natural resources, therefore, a key aspect to achieve a sustainable waste management should be the reduction of waste at source by the adoption of waste minimisation methodologies (Phillips *et al*., 2006).

2.3.1 Waste minimisation

Waste minimisation is intented to apply the waste hierarchy in practical techniques. A significant strategy to reduce waste may be preventing its generation. Therefore, in addition to the waste hierarchy, it is important to develop strategies to improve waste minimisation techniques.

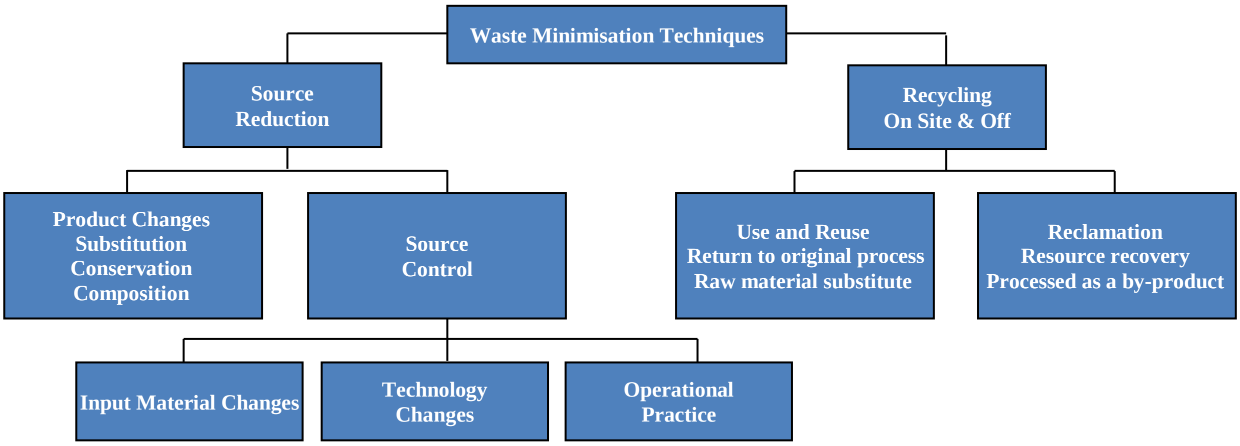


Figure 8 Waste minimisation techniques (CIPS, 2007).

Figure 8 summarizes the main waste minimisation techniques used within waste management systems. The minimisation focuses on reduction and recycling. The reduction of the different sources of waste can be mainly achieved through changes in the product composition and in the substitution and conservation of elements in any product. Joint work and integration of small organisation and companies can also lead to significant savings, waste reduction and improvement of competitiveness in local areas (Cheeseman & Phillips, 2001).

A significant change, in the technology and the operational methods to manufacture products, can reduce the amount of waste generated. In addition, recycling (including re-use) can decrease the amount of waste. The search for alternatives to re-use products or use them as a raw material for other processes can also reduce waste (Shaw & Blundell, 2010). Waste minimisation can be also achieved with interventionist approaches based on comprehensive training in environmental practices and proper waste management. Interventionist approaches may lead small companies in selected sectors to significant financial and environmental savings given waste minimisations plans supervised by trained personnel (Jones *et al*., 2012).

2.4 Waste management

Once the main elements associated with the MSW (Concept, classification, composition, treatment, waste hierarchy and minimisation techniques) have been described; it is important to understand how all those aspects are integrated in a waste management process. The proper description of an integrated waste management process enables the identification of significant stages and elements. Therefore, the definition of waste management should be clarified.

Directive 2008/98/EC from the Commission of Environment of the European Union states that "*waste management means the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker*" (European Parliament, 2008).

Bontoux & Leone (1997) argue that waste management consists of waste prevention, re-use, material recycling, composting, energy recovery and final disposal. These authors also mention that most of the time waste management is characterized by the lack of involvement and feeling of responsibility of the generator within any of the management activities. In a waste management system, all management aspects require input from legal, economic, governmental, political, administrative, and environmental players (Letcher & Vallero, 2011).

Therefore, the author suggests a working definition as follows: waste management can be understood as the activities which are linked with waste generation, such activities involve separation, collection, transport, selection, processing, treatment or disposal. All the activities form part of a process to prevent and decrease environmental damages and thus reduce negative effects on human health. Although in most cases, waste management activities are carried out by the local authority or by concessionaires, waste management must be understood as a system that involves the participation with the same commitment of all stakeholders, from the generator to the final receiver.

2.4.1 Importance of an integrated waste management system

When MSW accumulates in the environment without being properly collected or treated, pollution is generated impacting not only on the soil, the flora, fauna, and different bodies of water but also on urban settlements. Public health problems may be generated as the result of mismanagement of waste.

MSW management involves the substantive activities related to the direct handling of MSW: generation, separation collection, transfer, transport, treatment (re-use, recycling, recovey) and final disposal. Wehenpohl & Kolb (2007) have suggested a model that shows the MSW management process (Figure 9). It can be observed the interrelation among each stage. The waste management process begins with the generation of waste. MSW can be collected in public areas and in households. After collection, wastes can be sent to transfer station and sorting plans, or can be sent directly to final disposal sites. Treatment is identified as the main stage in the process. The resulting materials in the treatment process can be applied in economic, industrial and agricultural activities. If materials that are obtained after treatment cannot be used in other activities, they should be disposed of in controlled landfills.

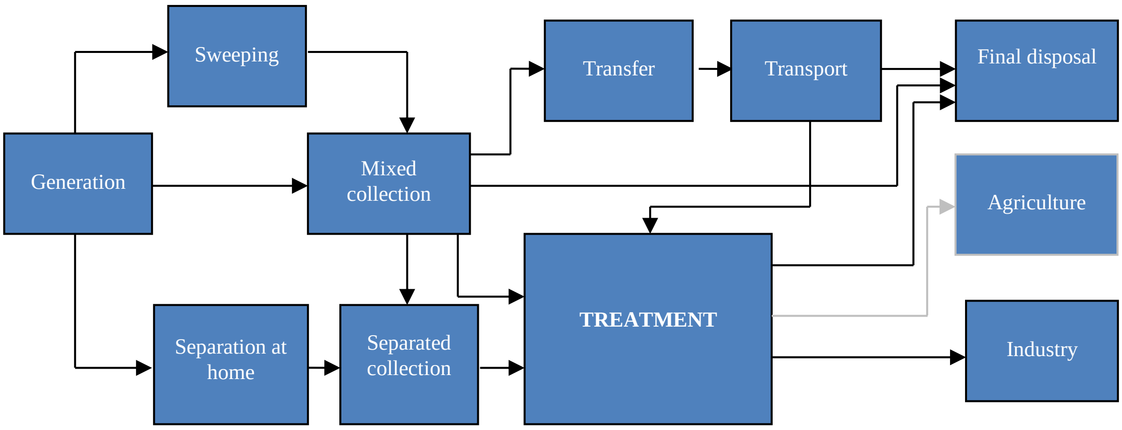


Figure 9 Flow chart of integrated Municipal Solid Waste management (Wehenpohl & Kolb, 2007).

It must be noted that an integrated system should go further into the waste management actions. In addition to the substantive activities, a proper system should consider the waste hierarchy as the fundamental component of the system. The waste hierarchy enables the design and implementation of waste minimisation techniques in order to generate a wider scope of individual, institutions, agencies and organisations associated with the MSW management (Rodríguez & Córdoba, 2006).

The waste management process requires the availability of proper infrastructure and technology, which enables the efficient handling of waste. Therefore, the description of the most common type of facilities used in MSW management is presented in the following sections.

2.5 Facilities for Management of MSW

Waste management facilities are all those physical spaces intended to carry out waste management activities. These facilities must be equipped with proper infrastructure, technology and procedures in order to provide treatment to all incoming waste. Combined facilities can involve the minimisation in transportation cost and the saving in terrains to build different waste management facilities. Although facilities which combine different waste treatments on one site have been constructed in developed countries, developing countries present significant difficulties to design and build such facilities (ODPM, 2004).

2.5.1 Transfer stations

A transfer station for MSW is defined as the set of equipment and facilities that performs the transfer of the waste from collection vehicles to larger capacity vehicles in order to transport waste to other facilities (INE, 1996). The transfer station is widely used to receive and transport waste directly from the collection points to recycling centres, final disposal sites or treatment centres, which are usually situated far away from the generation point (El-Haggar, 2007). The underlying objective is to optimise profitability and efficiency (EPA, 2001). The fundamental objective of a transfer station is to increase the overall efficiency of the management services of MSW that is achieved by decreasing: the overall cost of management, the reduction in transport times, and the intensive use of equipment and human resources (Bovea *et al*., 2007).

- **Types of transfer stations**

Based on the method used to transfer MSW into the vehicles, transfer stations can be categorised as: (1) Direct discharge stations; (2) Indirect discharge stations (INE, 1996).

- Direct discharge stations:

The direct discharge transfer system operates by emptying, by gravity, the MSW into an open trailer. In this process the waste can be unloaded directly into the "open top" of the vehicle. However, in these transfer stations the recovery of materials and waste inspections is not possible due to the direct transfer of waste into trailers. The capacity of the trailers may vary, however, in most cases the capacity is 100 cubic yards. Space is also another disadvantage given that the waste is not compacted; it requires more space in the trailer, which generates more trips to the final disposal site. The technology needed in direct discharge stations does not need sophisticated equipment. Its operation is recommended to manage low-volume of waste (EPA, 2002).

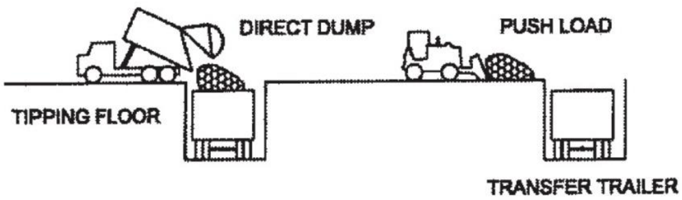


Figure 10 Open top transfer trailers (Adapted from EPA, 2002).

- Indirect discharge stations:

In these transfer stations the discharge of waste from collection vehicles is made into either a storage pit or onto a platform. Subsequently waste is loaded into transfer vehicles using auxiliary equipment. The technology in these stations may vary according to the method. However, in most cases a compactor or pre-compactor system is used in order to reduce the volume of the waste before transferring into trailers. Both systems use a hydraulic ram to compact waste into vehicles. As the trailer must resist the compacting force; such vehicles are made of reinforced steel. In stations with pre-compactor systems a walking floor technology is used to unload the waste by gravity. The U.S. Environmental Protection Agency, in 2002, estimated that an investment for the installation cost of more than US$250,000 per unit may be required for this type of technology. The amount of investment may be higher in recent years due to inflation levels.

Another type of indirect discharge station utilises balers, where the waste is compressed into self-contained bales. The bales are moved by forklifts and transported on flatbed trailers. This kind of technology can be also used for recycling paper or plastic. As this is an advance technology, the process is recommended in high-volume plants. However, special equipment or infrastructure may be required at landfills. Also the installation cost may exceed

US$500,000 per unit (EPA, 2002). The following figures show the different alternative processes in indirect discharge stations.

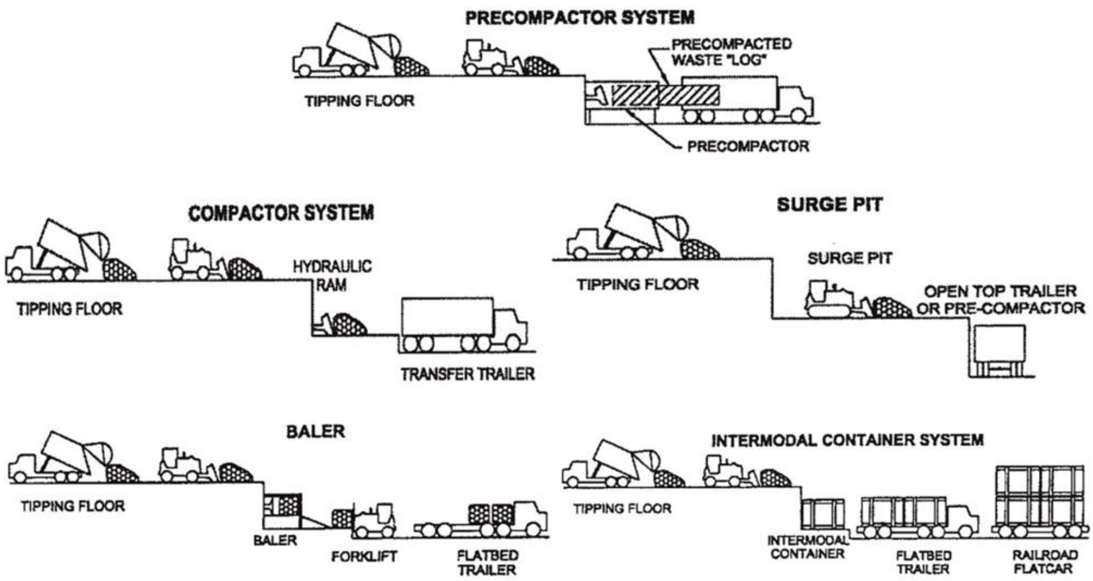


Figure 11 Different methods in indirect discharge stations (Adapted from EPA, 2002).

2.5.2 Sorting plants

Sorting plants are used to receive waste from transfer stations or directly from the waste collection system. They aim to separate valuable material. The objects which are recovered in sorting plants can be sent to markets of re-use waste or can be sent to recycling facilities. In some cases, sorting plants are equipped with recycling technology. The sorting of material can be carried out by different techniques which typically include (ODPM, 2004):

- Hand picking:

Hand picking is the most widely method used. It involves the advantage of picking materials from a conveyor belt (Figure 12). The usefulness is related to the direct interaction of individuals with the waste. This involves the direct identification of the waste intended to be separated.

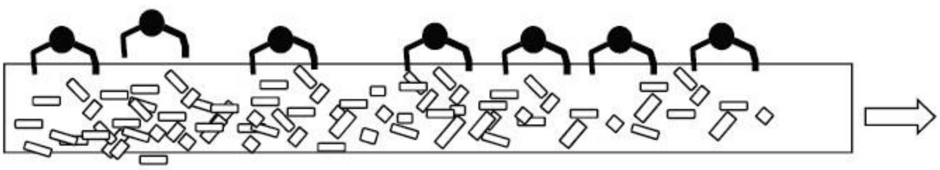


Figure 12 Sorting with single conveyor belt (Adapted from Chandrappa & Das, 2012).

In hand picking, two types of belts can be identified; the trough and the flat belt. The trough type belt conveyor uses idler rolls which cause the belt to form a concave contour. This type of belt, facilities the retention of materials such as aluminium cans, bottles, crushed glass, etc. With the flat belt the conveyor belt slides on a steel supporting surface, which facilitates the access to the material on the belt (Swartzbaugh *et al*., 1993).

- Air separators for paper:

This activity involves air classifiers which are used to separate the less-dense materials by air. In the process, objects will be trapped in an upward current of air. Therefore the less-dense materials which are trapped in the air stream can be separated and recovered (Chandrappa & Das, 2012).

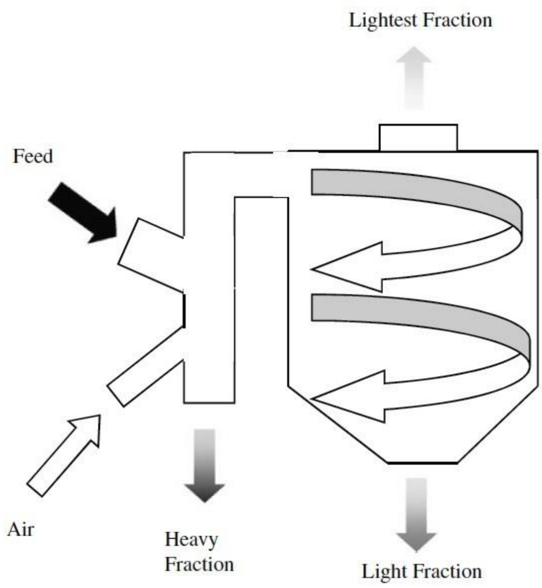


Figure 13 Cyclone waste classifier (Adapted from Chandrappa & Das, 2012).

- Mechanical sorting/screening/sieving:

Screening is a process in which a series of uniform-sized openings enable separation of material smaller than the openings (Chandrappa & Das, 2012). Screen for processing vary according to the characteristics of the waste.

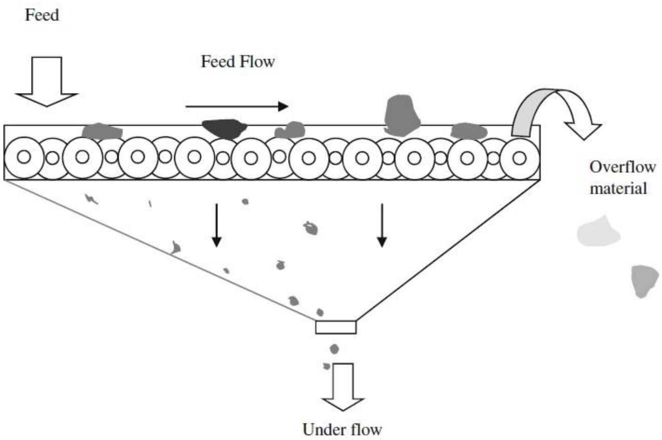


Figure 14 Selection through screening process (Adapted from Chandrappa & Das, 2012).

- Magnetic separation:

In the magnetic separation process, magnets are used to sort magnetic materials and separate them from other elements. A magnet must be placed in a strategic location near a conveyor belt (Chandrappa & Das, 2012).

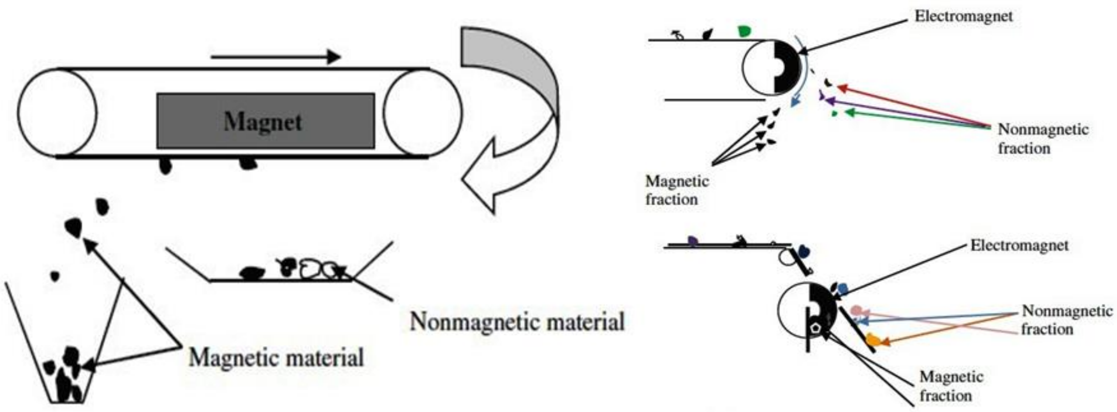


Figure 15 Magnetic separators (Adapted from Chandrappa & Das, 2012).

- Other methods

Depending on the infrastructure and characteristic of the plant, different technology can be used to carry out different sorting and recovery operations. Other technology and methods to separate waste can include (Chandrappa & Das, 2012): (1) Sink/Float separators, (2) Inclined tables, (3) Shaking tables, (4) Optical sorting, (5) Sorting by differential melting temperature, (6) Sorting by selective dissolution, (7) Eddy current separators, (8) Electrostatic separators, (9) Shredding, (10) Pulping, (11) Crushing, (12) Baling, (13) Ballistic separators.

The sorting plants are generally located in large warehouse which are usually constructed with a standard steel frame. Recovered material varies from place to place, however the most commonly sorted items include: metals, glass, plastic and paper. The amounts of recovered waste in sorting plants vary according to the implemented waste management strategy. Some strategies involve the use of special containers in public areas and buildings to encourage the recovery; this activity is known as segregation of solid waste (Chandrappa & Das, 2012).

2.5.3. Landfills

The term landfill refers to waste disposal mainly below ground level. "Landfill" is also used to refer to waste disposal sites above pre-existing ground levels, although this should be more correctly known as "land-raise". Landfill sites are normally sited where an existing void is available, including existing mineral workings like quarries, or in areas from which material has been excavated. The excavation process can be for commercial purposes or can be also carried out to provide engineering materials needed in the landfills. The location of land-raise sites is less limited. Land-raises may include derelict land, extensions to existing landfills and even green-field sites. Some of the largest landfills include land-raise sites (ODPM, 2004). Although in developed countries the use of landfills has been discouraged in recent years, in developing countries landfill is still widely used for final disposal of waste (Letcher & Vallero, 2011).

In the case of Europe the use of landfill implies a high cost of operation due to fees and taxes fixed by federal governments. The imposition of higher fees for landfill operations is designed to minimise the use of landfills by local authorities, thereby, limiting the amount of waste sent to landfills each year (ODPM, 2004).

In any case, landfills must be the final depository of a waste only when all other waste management treatment and options have been carried out. Landfills can be categorized according to the characteristics of the site in (Chandrappa & Das, 2012): (1) Open dumps (uncontrolled landfills), (3) Sanitary landfills (engineered landfills).

In an engineered landfill or sanitary landfill, treatments or processes are required to prepare MSW for disposal. Treatments and processes include: minimizing, stabilizing the waste, eliminating hazardous properties, reducing the volume. A typical landfill will carry out the following activities during the shelf life (Figure 15) (Chandrappa & Das, 2012): (1) Planning, (2) Site selection, (3) Site preparation, (4) Landfill bed construction, (5) Leachate and gas collection system incorporation, (6), Land filling, (7) Monitoring, (8) Closure of landfill, (9) Post closure monitoring.

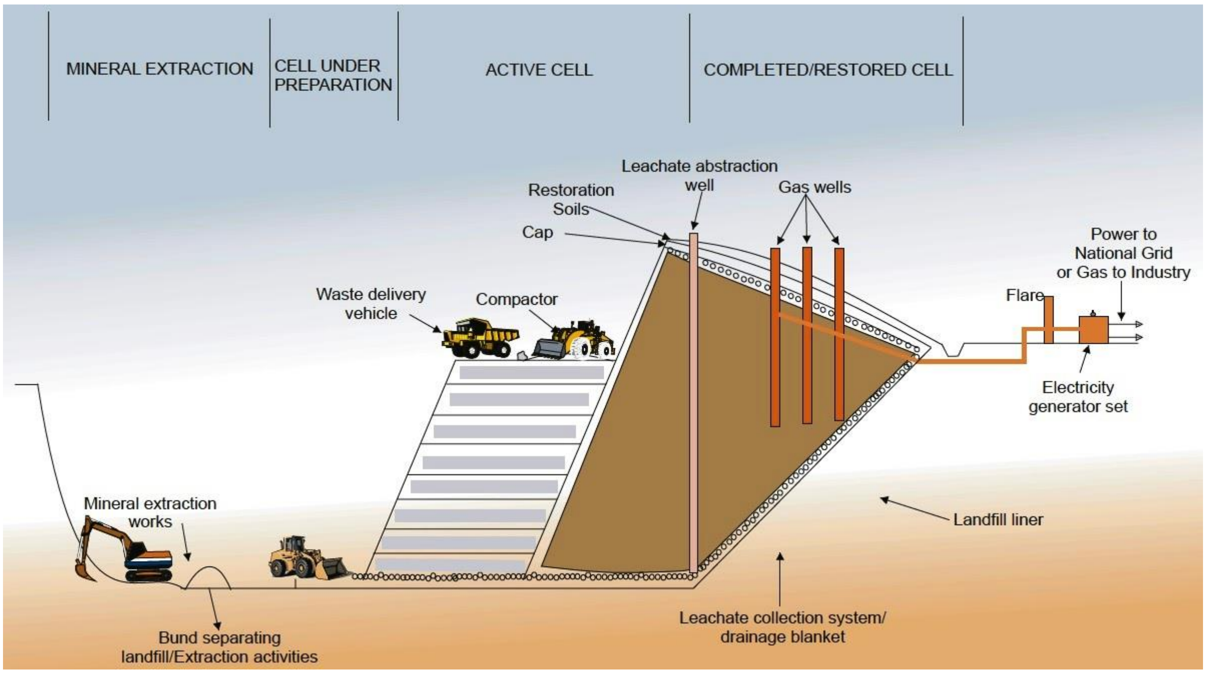


Figure 16 Schematic representation of a typical landfill engineering design (Adapted from ODPM, 2004)

Engienerred landfill methods can be broadly classified into: trench method, area method, and depression method as follows (Chandrappa & Das, 2012):

- Excavated Cell/Trench Method: In this method solid wastes are placed in cells/trenches in the soil. This method only can be carried out in areas where there is an adequate depth of cover material and the water table is not near the surface. The characteristics of the cells vary according to the capacity of the landfill and the specifications of the operation.
- Area Method: In this method the waste is disposed of in the ground, which has previously received a liner system to manage leachate. The waste is covered with different materials to prevent negative impacts. This method is highly used due to the difficult to find areas with natural caves or areas not suitable for the excavation of cells or trenches.
- Canyon/Depression Method: This method uses multiple lifts to fill the canyon/depression. The waste is disposed of at the head end of the canyon and

concludes at the mouth. The landfill airspace determines the permitted length, height and breadth of the landfill.

Regardless the method used for the operation; the design and construction must be carefully supervised in order to avoid environmental damages and impacts. The development of newer infrastructure including not only enginerred landfills but any waste management facility should consider the following proximities prior construction (Bates *et al*., 2008): (1) Road network, (2) Rail network and navigable waterways, (3) Existing waste facilities, (4) Compatible land uses, (5) Sensitive receptors, (6) Ecological and heritage sites.

Local authorities must enact legal dispositions to regulate operations. In the European Union the Directive 1999/31/EC establishes the regulations for landfill operations. In any case, landfills must reduce the environmental impacts (European Parliament, 1999). The main risks of uncontrolled landfills include (ODPM, 2004):

- Traffic: Heavy Goods Vehicles (HGVs) are needed to transport the waste from transfer stations or treatment plants to the landfills. The created traffic in the surrounding areas of the facility will increase due to all vehicles entering the landfill. In addition, traffic problems are associated with air pollution by burning of petrol.
- Air Emissions: The disposal of waste in landfills contributes to the generation of greenhouse gases, such as methane, which typically comprises 60% of landfill gases.
- Dust/Odour: Odour from waste facility has the potential to cause a nuisance. This problem is linked to the air emission due to odor normally occurs when the landfill gas is allowed to escape.
- Flies, Vermin and Birds: Due to the characteristics of the waste, landfill sites can generate: vermin, flies and birds. Health risks are related to organic material in the wastes. Seasons with climatic variations and high temperature may result in fly and insect infestations.
- Noise: The activities carried out in landfills may tend to generate noise. Manoeuvres of vehicles, engines and generators, and site preparation/engineering works, are identified as significant source of the noises.
- Water contamination: Wastes in landfills generate leachate. The leachate is generated when water passes through decomposing waste. Leachate can cause significant

pollution if reaches water bodies (lakes, ponds or rivers) or groundwater. The toxicity of the leachate depends on the characterization of the wastes.

- Land Stability/Geology: The construction of landfills must be carried out in order to protect geological outcrops/faces. Unstable local geology may potentially compromise containment and environmental management systems.
- Visual Intrusion: Landfills sites affect the landscape. The construction of landfills must be carried out avoiding constructions on sites near urban settlements, tourist sites and nature reserves.
- Explosion/Asphyxiation Risks: As mentioned, landfills generate methane, which is highly flammable. The migration of this gas to confined spaces can highly increase the risk of explosions

2.6 Waste legislation

2.6.1 Legislation in Mexico City

The legislation related to waste management goes back to 2003, when the Law of Municipal Solid Waste of the Federal District was enacted. Such a law aims to regulate the management of any solid waste not considered as hazardous waste, and the provision of the cleaning service. Additional legislations include the General Law of Ecological Equilibrium and Environmental Protection and the Environmental Law of the Federal District. The Law of Municipal Solid Waste of the Federal District establishes the main responsibilities and obligations of both: government and citizens. The law is composed of 77 articles and it is divided into seven main titles: (1) general issues, (2) competence, (3) prevention and minimisation of waste generation, (4) cleaning public service, (5) commercialisation and composting of waste, (6) prevention and control of soil contamination, (7) security measures, penalties and civil complaints.

Each title contains specific chapters related to the main topics. In a general overview the law provides general guidelines to implement a handling plan for MSW. The main aspects of the law include: (1) Separation, reduction and avoidance of MSW generation, (2) Sweeping of public areas, (3) Promotion of the reuse and recycle of MSW, (4) Fulfilment of specific guidelines of the law, (5) Storage of MSW, (6) Report of infractions.

The law involves the main aspects related to waste management in a general perspective. Nevertheless, the legal framework related to waste management lacks supporting documents and additional regulations focused on specific stages of the waste management process. The main legal framework in Mexico City seems weak in comparison with legal frameworks of other cities.

In order to generate a comparative point of view, the legislation related to waste management in the European Union can be taken as comparative model.

2.6.2 Legislation in the European Union

In common with most industrialized economies, there has been a general increase in the generation of waste within the European Union (Figure 17). This has led the European Parliament to develop a legal framework according to the increase in generation. The European Union has designed waste management legislation focused on environmental protection and sustainable development. Each one of the Member States should follow and apply the European directives in their local programmes and regulation of waste management.

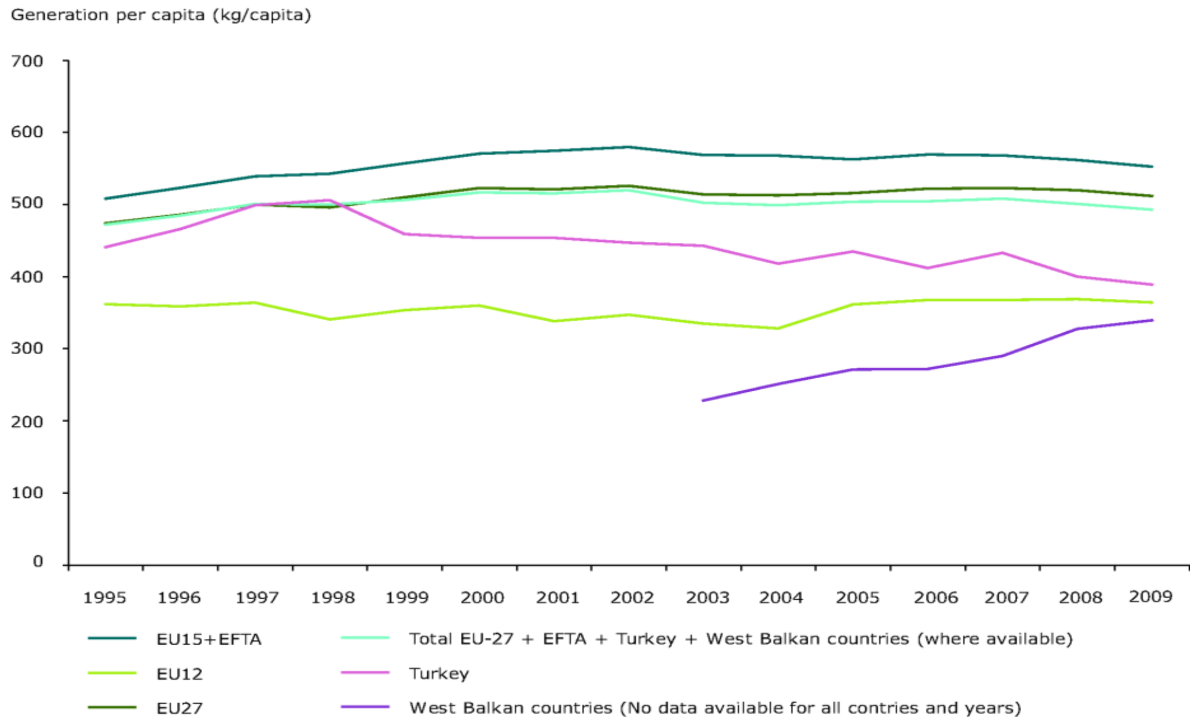


Figure 17 Municipal waste generation per capita in Western Europe
(Adapted from the European Environment Agency, 2015).

Waste legislation goes back to the Directive 75/442/EEC enacted in July of 1975 focused on waste management. Such a directive has been amended on several occasions in order to be updated to current problems and situations. Directive 2008/98/EC published on November 22, 2008 is the main current legislation related to waste management. Such a Directive defines key concepts and establishes essential requirements for waste management.

Based on the principles of the European Directives, any waste management policy should be focused on the waste a hierarchy mentioned in section 2.3. In a general overview the directives aims to avoid waste generation and to use waste as a resource. MSW should be collected separately if technically, environmentally and economically practicable, before undergoing recovery operations that deliver the best overall environmental outcomes. The directives allow Member States to design their own local laws, provided that such regulations are aligned with the guidelines of the European Commission for Environment.

The main directives of the European Commission for Environment related to waste management in force include:

- Waste Framework Directive (Directive 2008/98/EC): Establishes measures intended to protect the environment and human health through the prevention and reduction of negative impacts of waste generation. It also provides definitions related to waste management and indicates particular activities, responsible, and guidelines to undertake procedures and waste management actions.
- Environmental Liability Directive (Directive 2004/35/EC): Establishes guidelines to design a programme of fines based on the principle “polluter-pays” in order to prevent and sanction whosoever causes environmental damages.
- Landfill Directive (Directive 1999/31/EC): Establishes rigorous technical and operational requirements, measures and procedures intended to reduce the contamination caused by disposal of waste in landfills. Describes the characteristics of operation needed to operate a landfill. It is supported by the Council Decision 2003/33/ that establishes criteria and procedures related to acceptance of waste in landfills.

- Waste Incineration Directive (Directive 2000/76/EC): Establishes the guidelines to be followed to reduce the negative impacts of emissions to the atmosphere caused by incineration procedures of waste.
- Shipments of Waste (Regulation (EC) No 1013/2006): Establishes control procedures for shipment and transport of waste according to the origin, destination and route including the type of waste and the type of treatment to be received.
- Information of Generation (Regulation (EU) No. 849/2010): Establishes the requirement of a statistical information system for waste; specifies the characteristics of all information related to waste management activities reported to the European Commission of Environment.

2.6.3 General comparison of legal frameworks of Mexico City and the European Union

In a general overview, the Law of Municipal Solid Waste of the Federal District, enacted in 2003 is the only legislation focused on MSW; however, the law lacks a proper specification related to separation, collection, transportation, recycling, treatment and disposal of waste. Such a lack of specifications involves an inefficient handling and the existence of unregulated stakeholders within the system. The analysis of the legal framework applied in the European Union showed the existence of specific directives for different activities of the waste management system. In a comparative perspective, the legal framework of Mexico City lacks guidelines for treatments and facilities, also there is not a proper supervision for waste management activities; therefore several unregulated actions are carried out by different stakeholders. In addition, there is an absence of linkage among different legislations. The legal framework requires important attention from the government in order to be significantly improved.

Chapter 3

Overview of Mexico City

3.1 Introduction

The main aspects related to Mexico City provide supporting information in order to frame the waste management system according to the situational context. The waste management system of Mexico City is discussed in Chapter 4; the analysis refers and mentions local characteristics of the city, therefore the determination of certain parameters can help to obtain an accurate understanding of future detailed data and subsequent analysis in following points. The description of the main characteristics of the place can also provide robust basis to formulate assumptions and proposal related to the main findings.

3.2 Demography of Mexico City

The Federal District is the largest urban agglomeration in Mexico. Based on a census conducted by the National Institute of Statistic and Geography (in Spanish INEGI), in 2010 there were 8,851,080 inhabitants. There were 4,617,297 women and 4,233,783 men. The population per borough can be observed in Table 2. The majority of the population is concentrated in Iztapalapa with 1,815,786 inhabitants, followed by Gustavo A. Madero with 1,185,722. Lower concentrations can be found in Milpa Alta and Cuajimalpa de Morelos with 130,391 and 186,391 habitants respectively. Milpa Alta is a rural and agricultural region focused on nopal (Prickly pear cactus) production and Cuajimalpa de Morelos is the centre of important business activities.

Borough	Population
Álvaro Obregón	727,034
Azcapotzalco	414,711
Benito Juárez	385,439
Coyoacán	620,416
Cuajimalpa de Morelos	186,391
Cuauhtémoc	531,831
Gustavo A. Madero	1,185,772
Iztacalco	384,326
Iztapalapa	1,815,786
La Magdalena Contreras	239,086
Miguel Hidalgo	372,889
Milpa Alta	130,582
Tláhuac	360,265
Tlalpan	650,567
Venustiano Carranza	430,978
Xochimilco	415,007
Total	**8,851,080**

Table 2 Population of Mexico City per borough according the 2010 census
(Constructed with data from INEGI, 2012)

Population growth in Mexico City has been significant since 1910. The population increased by more than 35% each year between 1910 and 1980 (Figure 18). The economic crisis of 1982 implied emigration of a significant number of people to the United States of America (Garcia & Manuela, 1991), which resulted in a decrease in the population levels between 1980 and 1990. Since 1990 until 2010 there has been further a growth; however, although the growth has been gradual, population density is evidenced as a significant problem. According to information from INEGI, whereas in 1910 there were 486 inhabitants per square meter, in 1980 density reached 5,971/km^2 and in 2010 the level was 5,920/km^2.

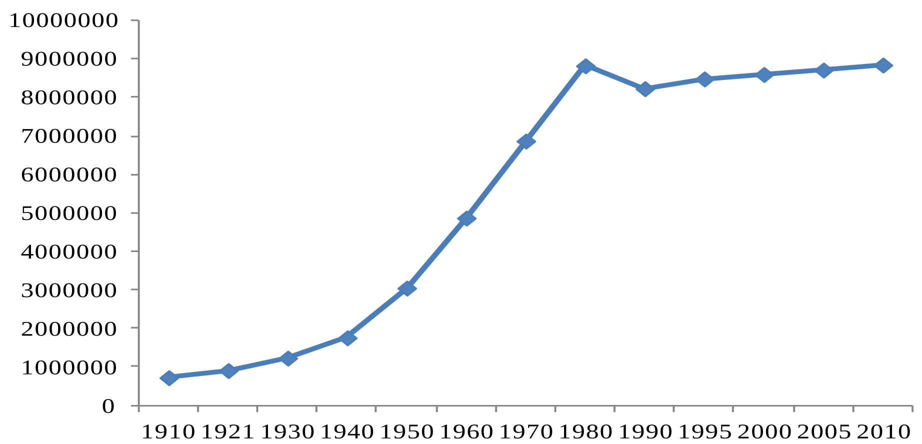


Figure 18 Population of Mexico City 1910-2010 according to 2010 census
(Constructed with data from INEGI, 2012)

Figure 19 shows the average growth rates (AGRs) of the population of Mexico City taking 1970 as the base year. The subsequent decade (up to 1980) evidenced one of the highest rates. As can be observed, since 1990 the AGRs have increased each year. The trend is upward, resulting in a low but constant population growth.

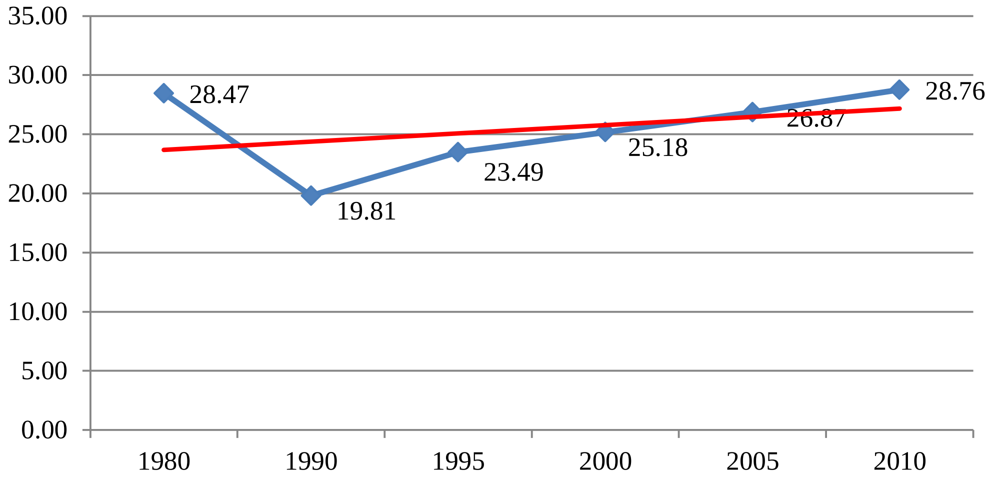


Figure 19 Average growth rates of the population from Mexico City (year base: 1970)
(Constructed with data from INEGI, 2012)

According to the Department of Economic and Social Affairs of the United Nations (DESA-UN, 2012) Mexico City is ranked as the fifteenth most populated city in the world. The whole Mexico City Metropolitan Area (MCMA) includes a population of 20,116,842 inhabitants. The MCMA is the third most populated metropolitan area worldwide. The Mexico City Metropolitan Area (MCMA) is composed of 16 boroughs of the Federal District plus 54 municipalities of the State of Mexico and 1 municipality of the State of Hidalgo.

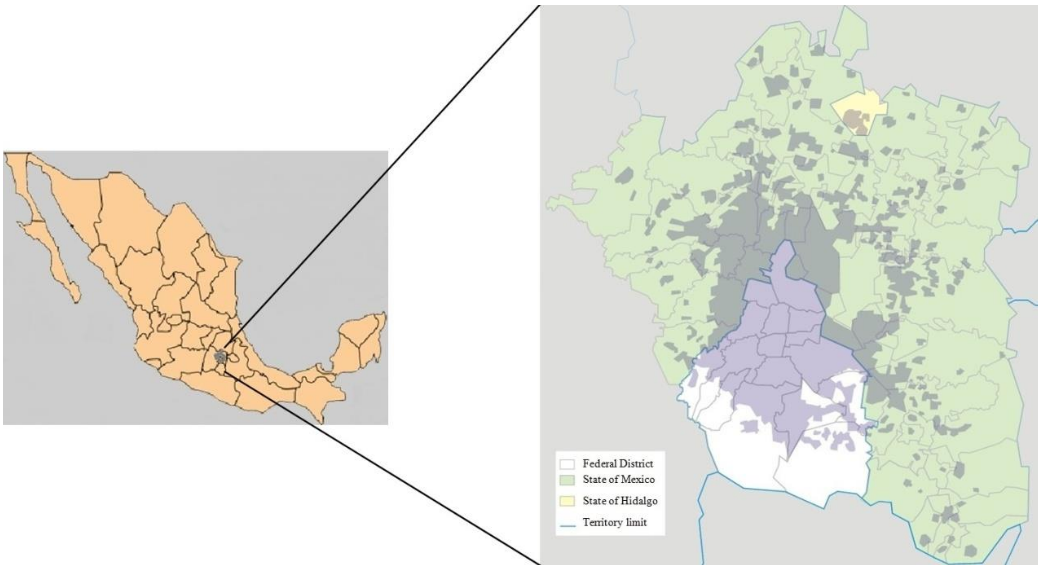


Figure 20 Mexico City Metropolitan Area with urban concentration

The MCMA is predominantly composed of the Federal District and the Northern State of Mexico (Figure 20). The State of Mexico has been governed by the Institutional Revolutionary Party and the Federal District by the Party of the Democratic Revolution. Therefore, although possible issues may appear, joint collaborations have been undertaken in recent years, seeing the MCMA as a single territory (Garcia, 2010).

3.3 Economy of Mexico City

Economic factors and business activity can represent a significant aspect to encourage the government to develop public policies focused on the participation on the private sector on the waste management system. Therefore, the economy of Mexico City is analysed in order to identify market conditions in which waste management projects may operate.

Mexico City represents a significant contribution to the economy of Mexico. According to information from INEGI, The Federal District contributes 22% to the GDP of Mexico. The business activity is mainly represented by Micro, Small and Medium Enterprises (MSMEs). The large enterprise only represents 0.66% of participation in contrast to 92.19% of micro-sized businesses (Figure 20).

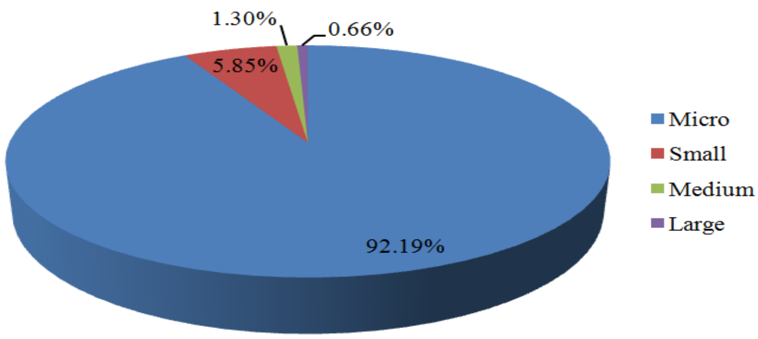


Figure 21 Enterprises per size in Mexico City
(Constructed with data from the Mexican Enterprise Information System, 2012)

The business activity in Mexico City is mainly concentrated in selected boroughs. From 83,602 registered enterprises in 2012, approximately 56% are located in four boroughs only: (1) Cuauhtemoc, (2) Iztapalapa, (3) Gustavo A. Madero, (4) Miguel Hidalgo (Table 3).

Borough	Enterprises
Azcapotzalco	3,416
Coyoacan	4,553
Cuajimalpa de Morelos	2,887
Gustavo A. Madero	9,220
Iztacalco	2,313
Iztapalapa	10,482
La Magdalena Contreras	1,425
Milpa Alta	195
Álvaro Obregon	4,360
Tlahuac	905
Tlalpan	3,292
Xochimilco	1,320
Benito Juarez	7,592
Cuauhtemoc	19,289
Miguel Hidalgo	8,502
Venustiano Carranza	3,851
Total	**83,602**

Table 3 Enterprises per political borough in Mexico City
(Constructed with data from the SIEM - Mexican Enterprise Information System, 2012)

The business activity is mainly located in selected sectors of the economy. Figure 22 shows the percentage participation of enterprises according to the economic activity. The 94.64% is concentrated in the trade and general services sector, whereas participation in sectors including agricultural, mining, water and electricity is significantly lower. Although Mexico City is the principal producer of ornamental plants, amaranth, and nopal; agricultural activities represent a low contribution in the GDP of Mexico City. The industrial sector was affected by the decentralization of industrial activities in the early 90's. The decentralization was caused in part by the high pollution levels in the region, but mainly because of the North

American Free Trade Agreement (NAFTA). With the NAFTA many industries moved to different states in Northern Mexico. Since then, the industrial activity in Mexico City has decreased. The remaining industrial parks in Mexico City focus on the manufacture of mass-market consumer goods (Scott *et al.*, 2006).

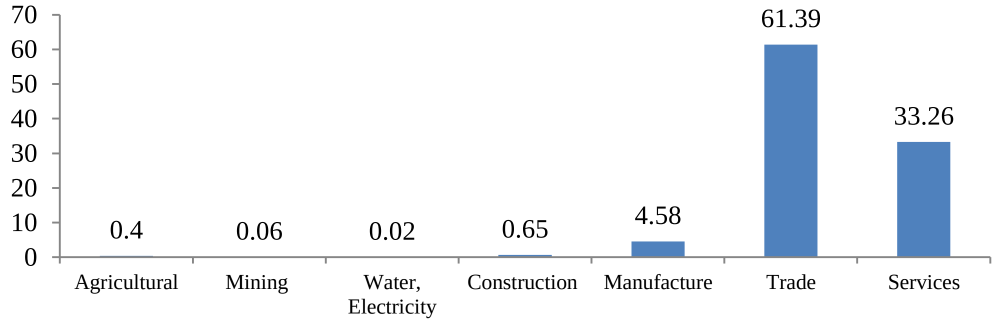


Figure 22 Enterprises in Mexico City per economic sector
(Constructed with data from the Mexican Enterprise Information System, 2012)

Although the business activity is mainly concentrated in the trade sector, the service sector represents a higher contribution to the GDP of Mexico with approximately 81%. This involves that the main economic activities which are carried out in Mexico City are represented by the service sector, which may be a key aspect to consider the feasibility of creating a new sector in the economy: the waste management sector.

The development of a new private sector focused on waste management, would take advantage of the significant business activity mainly due to the following reasons: 1) the large amount of business located in the service sector can enable the diversification of waste companies. This is given by the dynamic of the sector; current service companies may be motivated to open a complementary business activity related to waste management given the acknowledgement of the market dynamism and the profitability of the service activities; 2) the significant number of enterprises located in all types of economic activities, is an attractive and potentially market to focused private waste management services for business and organisations.

3.4 Mexico City in the world

Mexico is considered among the most important economies from developing countries (OECD, 1998). The economy of Mexico presented an average annual growth in the economy by approximately 3% in 2011 with a significant contribution from Mexico City (OECD, 2011). According to a study conducted by Hawksworth *et al.* (2009), the economy of Mexico City was ranked 8th among the largest economies of cities in nominal terms with an estimated GDP of ($US) 390 billon. Table 4 shows a list compiled by Hawksworth *et al.* (2009).

Rank	City	GDP ($BN)	Population (millions at 2008)	GDP per capita
1	Tokyo	1,479	35.83	41.3
2	New York	1,406	19.18	73.3
3	Los Angeles	792	12.95	62.9
4	Chicago	574	9.07	63.3
5	London	565	8.59	65.8
6	Paris	564	9.92	56.9
7	Osaka/Kobe	417	11.31	36.9
8	Mexico City	390	19.18	20.4
9	Philadelphia	388	5.54	70.1
10	Sao Paulo	388	19.09	20.4

Table 4 Top 10 urban agglomerations by GDP (Hawksworth *et al.*, 2009).

Mexico City is presented as the richest city in Latin America. The principal economic activities including service and trade have led Mexico City to be an attractive market for foreign investment. Mexico is part of the G8+5 which is group integrated by the eight major economies of the world (Canada, France, Germany, Italy, Japan, Russia, the United Kingdom and the United States) and by five of the most important emerging economies (Brazil, China, India, Mexico and South Africa).

Mexico City may have a significant future growth in its GDP and might contribute to Mexico becoming an increasingly important world economy (Hawksworth *et al*., 2009). Figure 23 shows the future projection in which Mexico may be ranked as the fifth economy among the nations with the most important GDP per capita growth. According to the OECD (2013), Mexico City has opportunities to improve its economy, based on enterprise activity and the foreign investments in strategic areas.

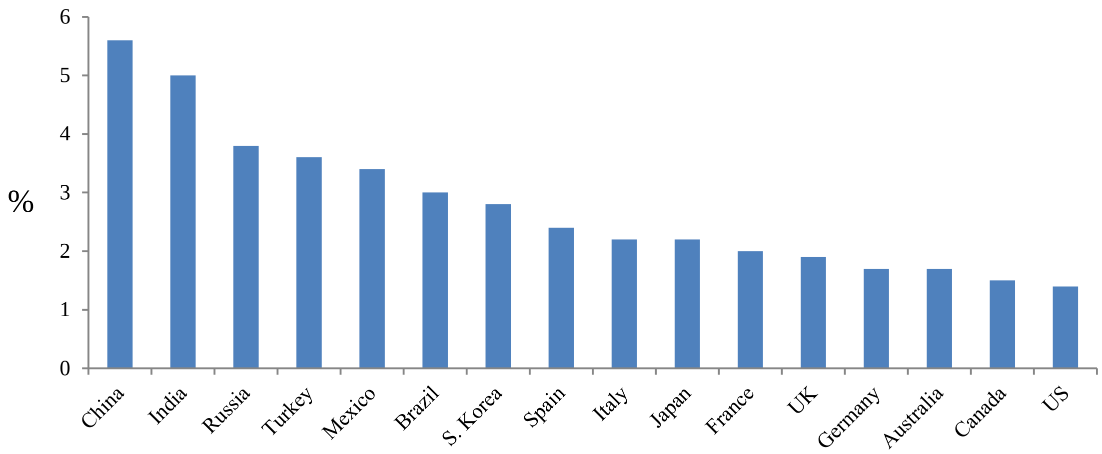


Figure 23 Projected real GDP per capita growth by country for 2010-25 (Hawksworth *et al*., 2009).

Figure 24 presents a comparative projection among economies which are expected to become large emerging economies in 2025 in which the estimation of the percentage of real GDP growth between emerging economies and developed economies can be observed. Figure 23 also shows that the estimated growth of Mexico City may be higher than the growth of cities such as London, New York and Tokyo.

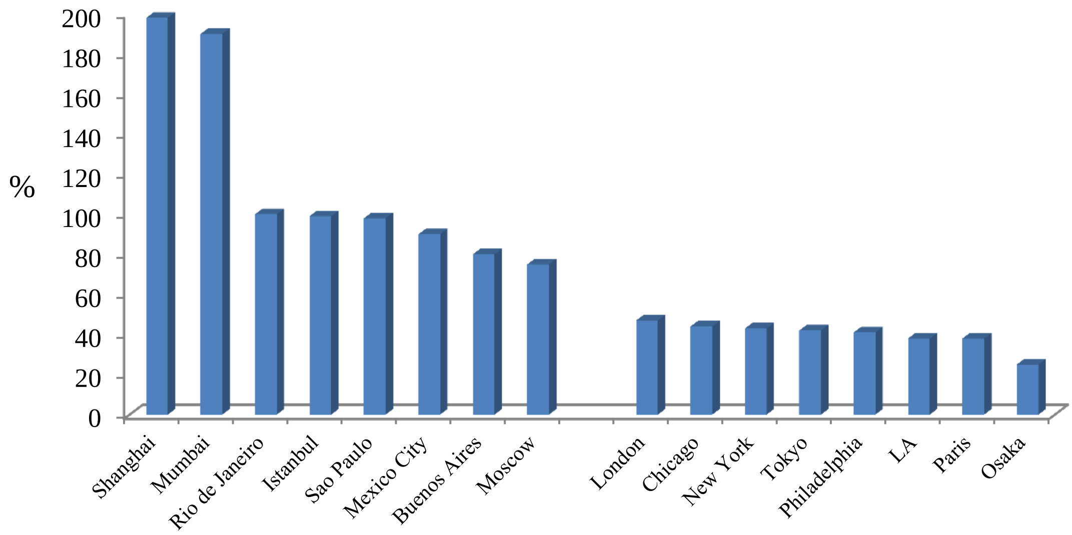


Figure 24 Cumulative projected % GDP growth in 2025 for mega-cities (Hawksworth *et al*., 2009).

Although, these positive projections are based on the reports published by international organisations, Mexico City is immersed in a range of socio-economic problems. Insecurity, corruption, high prevalence of organised crime, pollution and overcrowding can discourage foreign investors. The Human Development Index is measured based on parameters including: life expectancy, literacy, education and standards of living (UNDP, 2013). The Human Development Report, published by the United Nations Development Programme in

November 2011, ranked Mexico in the fifty-seventh place with an index of 0.777. This indicates that Mexico requires the implementation of public policies aimed to improve the quality of life. It should be noted that the HDI was not compared to the economic information given that, although the HDI analyses the gross national income per capita in order to determine disparity and human poverty; the economic analysis specifically was focused on the economic performance of Mexico City given by the business activity, it was not focused on the analysis of individual wealth.

3.5 Summary of Chapter 3

The high population density of Mexico demands a comprehensive provision of public services including waste management. The market conditions in Mexico City in addition to the business activity may represent an attractive target for local and foreign direct investment. The investment should be addressed to undertake new economic activities aimed to decrease environmental impacts. The development of strategies for waste management can take advantage of the current economy in order to consider the inclusion of the private sector within the waste management system. Competitiveness among private enterprises to gain public tenders may represent a key factor to increase the efficiency in waste management services.

Chapter 4

Waste Management System of Mexico City

4.1 Introduction

An excessive growth in the urban sprawl can lead to the emergence of several problems which impact on society and the environment. The higher population and population density the higher demand for public services such as: water, electricity, transportation, waste management, communications, etc. As seen in Chapter 3, Mexico City has such population characteristics. Typically a point is reached when the demand for public services exceeds the capacity. MSW generation in Mexico City is a significant problem related to population levels which must be approached from a wide range of perspectives. The following sections present an analysis and evaluation of the whole MSW management system of Mexico City.

4.2 Generation of MSW

According to data from the Mexican Secretariat of Environment and Natural Resources (in Spanish SEMARNAT), Mexico City accounts for an eighth part of the total MSW generated in Mexico. This large amount of MSW creates grave ecological and environmental imbalances, and economic costs for the government. Based on information from the Secretariat of Environment of the Federal District (2012), the per capita amount of waste in Mexico City has grown in the last 6 decades. In 1950 there was a daily generation of 0.27 kilograms of MSW per person. In 2011 it is estimated that each habitant produces 0.55 kilograms everyday on average. In the Federal District, there is a daily estimated average generation of 13,400 tonnes of MSW. Over the entire Mexico City Metropolitan Area, each day 24,000 tonnes are estimated.

Data from the SEMARNAT shows that MSW generation in Mexico City has grown with a visible upwards trend. Mexico City presented a total MSW generation of 4,891,000 tonnes in 2011 (as can be observed in figure 25). Alone in 15 years there has been an increase in more than 760,000 tonnes of MSW. It must be pointed out that the presented values imply estimated amounts. For the purpose of the analysis, the working figures are presented assuming only estimations from official reports.

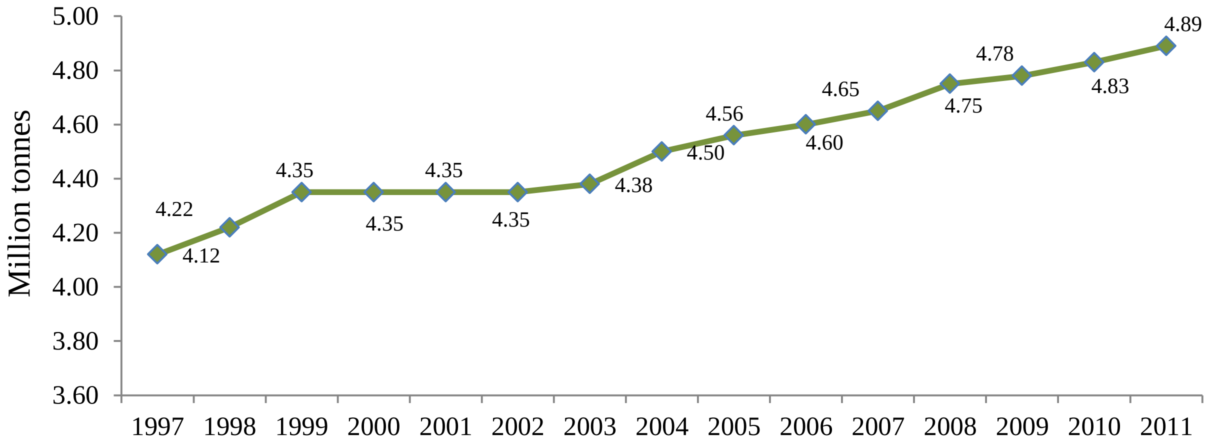


Figure 25 MSW generation in Mexico City 1997-2011
(Constructed with data from SAMARNAT, 2011)

The data places Mexico City as the federal entity with the highest generation of MSW. Figure 26 presents a flow of the MSW, the flowchart was constructed with data obtained from official reports published by the Secretariat of Environment of the Federal District and was complemented and validated with information directly obtained from staff responsible for the waste management in Mexico City. In order to obtain the information, several interviews were conducted based on an interview guide (The guide can be seen in Appendix 2). Although the information from official reports, interviews and visits to facilities, formed the primary data of the analysis, it must be noted that in several stages, the data refer only to estimations due to reporting bias and limitations on the availability of data.

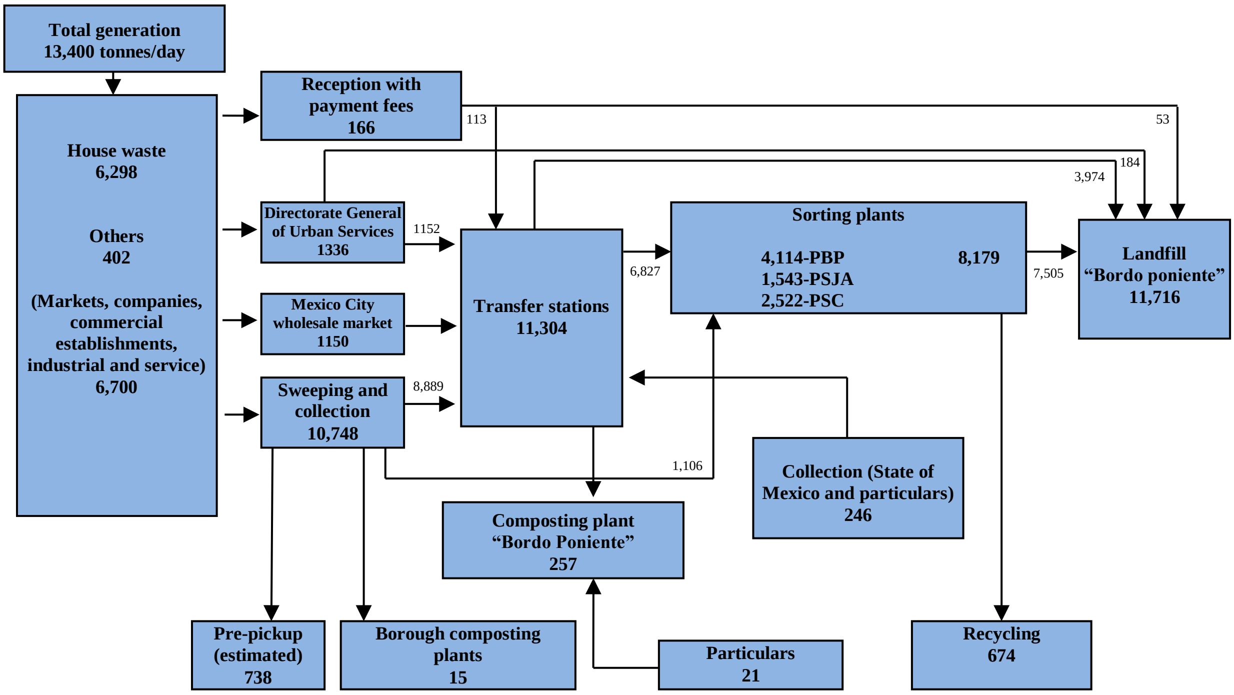


Figure 26 Flowchart of the MSW in Mexico City
(Constructed with data from SE-DF, 2012)

The flowchart starts with an estimated working figure of 13,400 tonnes of total generation per day. The flow shows the different stages in which the waste passes through before arriving to a final disposal site. It can be seen that the waste collected comes almost in a 50/50 relation from households and businesses. The waste is mainly collected by the cleaning and collection service. Approximately the 94% of the waste generation is sent to transfer stations. Although an important part of waste is sent to sorting facilities, the recycling of sub-products is significantly low given estimations of only 674 tonnes of recycled material (approximately 4% of the total generated waste). The waste disposal implies the absence of treatment processes and recycling alternatives given that more than 87% of the waste is sent to the Bordo Poniente Landfill. It must be pointed out that, although 51% of the waste is organic material only 272 tonnes result in compost. In a general appreciation, the flowchart evidences a certain degree of inefficiency of the current waste management system. There is a significant lack of a waste hierarchy and there are not proper treatment alternatives.

4.2.1 Generation per borough

The estimated daily generation of 13,400 tonnes of MSW comes from different boroughs. Figure 27 shows the daily estimated generation per borough in 2012. The three main generators include: Iztapalapa, Gustavo A. Madero and Cuauhtemoc. The generation in the cases of Iztapalapa and Gustavo A. Madero, follows a trend, according to population. As mentioned in section 3.2, Iztapalapa presents the highest population level with 1,815,786 inhabitants, and it is followed by Gustavo A. Madero with 1,185,772. Cuauhtemoc is ranked sixth with 531,831 inhabitants; however, as also mentioned in section 3.3, Cuauhtemoc concentrates 19,289 businesses with the highest business activity of the Federal District. Therefore, the daily generation of 1,906 tonnes of waste, is mainly comprised of waste from commercial and service activities.

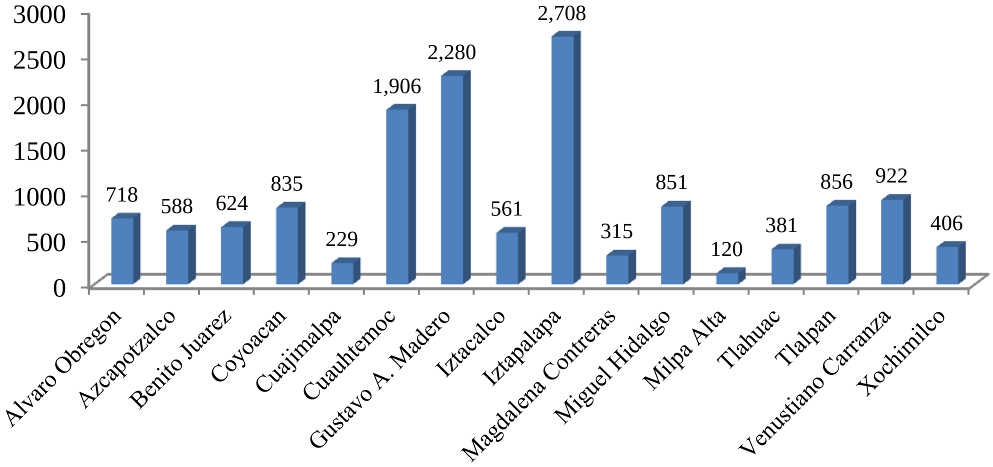


Figure 27 Average MSW generation per day in 2012 by borough
(Constructed with data from SE-DF, 2012)

Milpa Alta is the borough with the lowest generation with 130,582 inhabitants. It generates only 120 tonnes every day. However, as agriculture is the main economic and productive activity; waste comes from nopal cultivation and it is composed of more than 95% by organic material (Escamilla, 2010).

4.2.2 Generation per sector

MSW generation comes from different economic sectors (Figure 28). Commercial activity in the city generates approximately 6,700 tonnes of MSW (50% of the total MSW which are generated daily). Approximately 60% of the total waste from economic activities comes from service establishments.

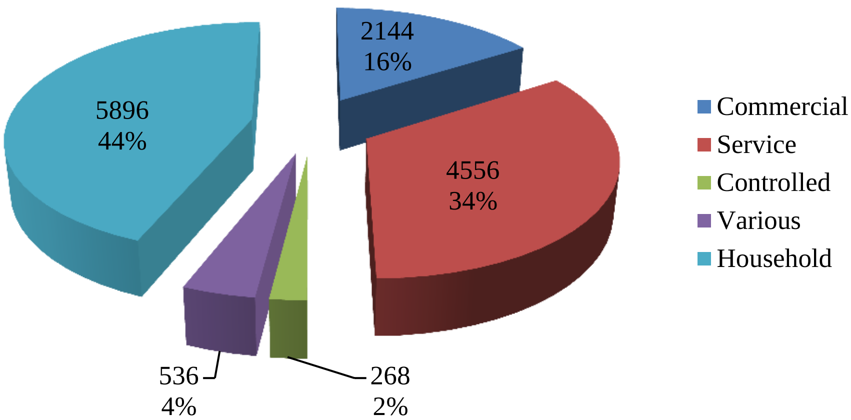


Figure 28 Estimated MSW generation in tonnes per type of source
(Constructed with data from SE-DF, 2012)

The service sector together with households, represents estimations of 78% of the total waste. Population levels in Mexico City as analysed before are not expected to decrease, then, as long as the level population increases more MSW may be generated.

4.2.2.1 Public markets

The commercial sector is mainly represented by markets in the city. It must be pointed out that “Central de Abasto” (Spanish for supply centre) is the biggest market in Latin America (A Panoramic view of the market can be observed in figure 29) with an average trade of 30,000 tonnes of merchandise daily which represents the 80% of the consumption of all Mexico City. As market, it is the second largest trade centre in the country after the Mexican Stock Exchange (BMV), according to the Trust for the Construction and Operation of “Central de Abasto” (in Spanish FICEDA), approximately 30% of the national fruit and vegetable production is commercialized, and an annual economic movement higher than 8 or 9 billion of dollars is estimated (Diaz, 2005).

Figure 29 Aerial view of “Central de Abasto” market in Mexico City
(Picture taken with Satellite view of Google Maps in 2014)

Another big market in Mexico City is “Nueva Viga” which is the largest seafood market in America and the second in the world just after of the Tsukiji fish market in Japan (Paquotte & Lem, 2006). It is estimated that 1,500 tonnes of seafood are daily sold in “Nueva Viga” market which represents approximately 60% of the total seafood market in Mexico, amount that increases in lent season up to 2,500 tonnes of seafood daily (EDF, 2014).

Therefore, together, “Central de Abasto” and “Nueva Viga” markets daily generate approximately 1,100 tonnes of waste from which approximately 80% is organic waste. However, as observed in figure 25, only 272 tonnes of all organic waste in Mexico City are composted. Therefore, there is a relevance in the adoption of proper alternative techniques which can be especially focused on organic waste from public markets due to high volumes of generation. It must be noted that an integrated waste management strategy must be equally focused on the recycling of organic waste as almost the totality of organic matter can be recycled (Zhou et al., 2011).

4.3 Composition of MSW

MSW is made up of different types of waste. Figure 30 shows the different composition of MSW, it can be observed that food waste and organic waste are the main source of MSW with 51% of the total. The second source is labelled as “Other”; this field is mainly formed from waste such as nappies, tetra-pack and other packaging. It can be seen that paper and cardboard represent a 15% whilst metal and textile waste only represent 3% and 2% respectably. The identification of the different types of waste can help to design strategies for management which must be developed according to the special characteristics of each waste.

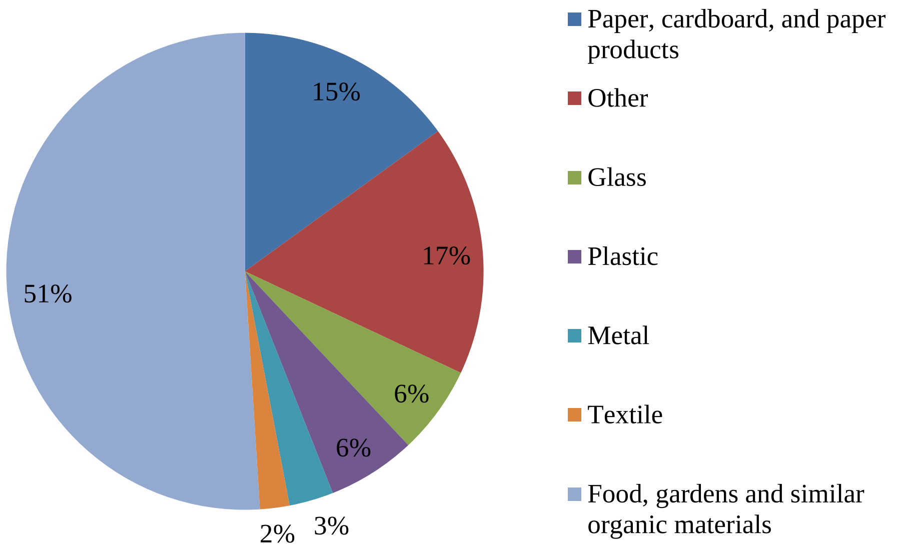


Figure 30 Composition of the MSW in Mexico City
(Constructed with data from SEMARNAT, 2012)

4.4 Separation at source

Furthermore, separation activities may present several deficiencies that impact on the performance and efficiency of subsequent stages. Table 5 shows the separation yields obtained from 2004 to 2010 in the main sources of sorted waste including schools, governmental buildings, markets and households. The figure was constructed with information from the SE-FD and it presents thousands of tonnes of separated waste per each type of source. The waste sorted consists only of: plastic (PEV), paper, glass. No further detailed data were available.

Year/ Source	Households	% of separation *	Governmental Buildings	% of separation *	Public Schools	% of separation *	Public Markets	% of separation *	Total % of separation**
2004	49,000	1.09	20,000	0.44	254,000	5.64	24,000	0.53	7.71
2005	96,000	2.11	37,000	0.81	471,000	10.33	28,000	0.61	13.86
2006	143,000	3.11	89,000	1.93	498,000	10.83	43,000	0.93	16.80
2007	153,000	3.29	110,000	2.37	559,000	12.02	57,000	1.23	18.90
2008	109,000	2.29	197,000	4.15	348,000	7.33	42,000	0.88	14.65
2009	89,000	1.86	183,000	3.83	444,000	9.29	30,000	0.63	15.61
2010	111,000	2.30	187,000	3.87	310,000	6.42	78,000	1.61	14.20

Table 5 Sorted plastic, paper, and glass by source of origin.

*The % of separation refers to the amount of sorted waste per type of source in terms of the total waste generated per year (Such date is presented in Figure 24)

** The % of separation refers to the total amount of sorted waste all sources in terms of total waste generated per year

As can be observed, the total separated waste at source presented different variations during the period 2004-2010. The amounts of waste have not been consistent. Although there was an increment of approximate 100% from 2004 to 2010 (7.71% to 14.20), the separation is low. In 2010 (last year available) sorted waste at source reached only 686,000 (14.20% of the total MSW generated that year). It can be also observed that public schools have presented the highest levels of sorted waste; in contrast, public markets have shown a low level, the reason is that, as discussed in section 4.2.2.1, the waste generated in public markets is formed mainly of organic material. At schools, separation can be monitored by direct supervision by teachers and administrative staff. A similar situation may occur in governmental buildings with the design of campaigns for separation with direct supervision. However, the case of public markets and households present certain difficulties to control and supervise the separation.

It must be noted that such amounts of sorted waste can be also affected by the lack of a proper separate collection and an efficient collection system. The following section discusses the current status of the collection system of Mexico City.

4.5 Collection system

According to information from the Secretariat of Environment of the Federal District, the urban services department operates 2,449 trucks assigned exclusively for cleaning and collection activities (Figure 31). Each truck must carry out two trips a day on average in order to transport MSW to transfer stations. Table 6 shows the routes and neighborhoods with separate collection. The table was constructed with data from the SE-FD; it shows firstly the number of total collection routes per each borough. Then, it shows how many of the total routes, are routes with separate collection (Separate collection refers to the collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment), the third column is the percentage of progress which simply refers to the numbers of routes with separated collection from the total. In the same way, the total of neighbourhoods per borough is presented with the same description of separate collection. The table aims to enable a rapid identification of separate collection per borough, either per collection routes or per neighbourhood.

Borough	Total routes	Routes with separate collection	% of progress (routes)	Total of neighbourhoods	Neighbourhoods with separate collection	% of progress (neighbourhoods)
Alvaro Obregon	150	72	48	257	66	26
Azcapotzalco	78	78	100	91	91	100
Benito Juarez	87	24	28	57	18	32
Coyoacan	76	3	4	140	5	4
Cuajimalpa	42	18	43	41	15	37
Cuauhtemoc	120	41	34	34	26	76
Gustavo A. Madero	222	36	16	244	35	14
Iztacalco	61	14	23	36	7	19
Iztapalapa	249	59	24	157	64	41
Magdalena Contreras	79	13	16	51	8	16
Miguel Hidalgo	188	90	48	81	27	33
Milpa Alta	75	75	100	12	12	100
Tlahuac	45	35	78	72	61	85
Tlalpan	125	48	38	243	96	40
Venustiano Carranza	92	8	9	70	14	20
Xochimilco	41	19	46	47	19	40
Total	**1,730**	**633**	**37**	**1,633**	**559**	**34**

Table 6 Routes and neighbourhoods with separate collection
(Constructed with data from SE-DF, 2012)

It can be observed that the borough with the majority of routes is Iztapalapa; which presents the highes rate in terms of MSW generation (Figure 27). However, the route distributions follow a different pattern in other boroughs. The borough of Cuauhtemoc is ranked third in tems of generation of MSW, and it has 120 routes, which contrasts with boroughs: Alvaro Obregon, Miguel Hidalgo and Tlalpan that present a higher number of routes even though they generate lower amounts of MSW. The business activities in such borough is also low; therefore, the assignation of routes proves a lack of proper planning according to characteristics and needs of each borough.

Figure 31 Vehicles for waste collection in Mexico City

From the 1,730 routes in the city only 37% have separate collection. The remaining 63% implies a mixed collection of MSW. Figure 32, shows graphically the routes with separate collection. It can be noted that the progress in the implementation of separate collection has been low. Only Azcapotzalco and Milpa Alta present a fully separate collection, nevertheless the generation of waste is low in comparison with other boroughs.

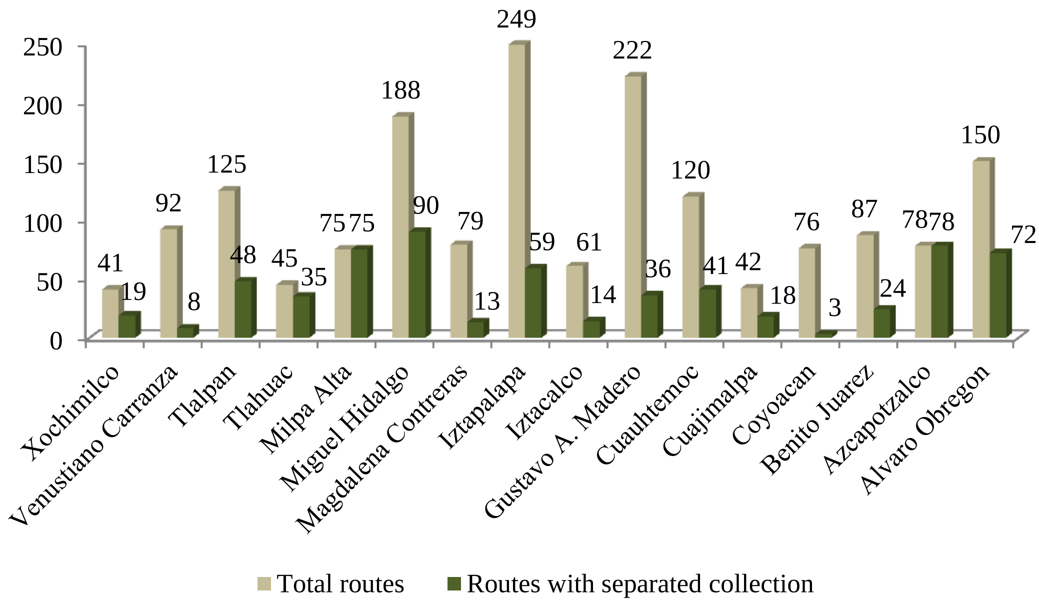


Figure 32 Routes with separate collection
(Constructed with data from SE-DF, 2012)

Figure 33, shows the total number of collection trucks, which are assigned to each borough. From the total vehicles in operation, only 7.7% (182) are equipped with dual compartments for sorted waste. The lack of vehicles to carry out separate collection, impacts not only directly on the collection system, but also on the efficiency of the whole management system. It must be noted that the separate collection is a key element of a proper waste management system. The separate collection enables the provision of specific treatment given the sorting of waste according to type, nature and characteristics. A proper separate collection can provide a dynamic waste management because MSW can be transferred directly to treatment facilities, avoiding additional activities of sorting and transfer, which can represent not only delays in the system but also economic expenses (UN-HABITAT, 2010). The analysis of routes and vehicles showed the lack of planning aimed to improve the collection fleet.

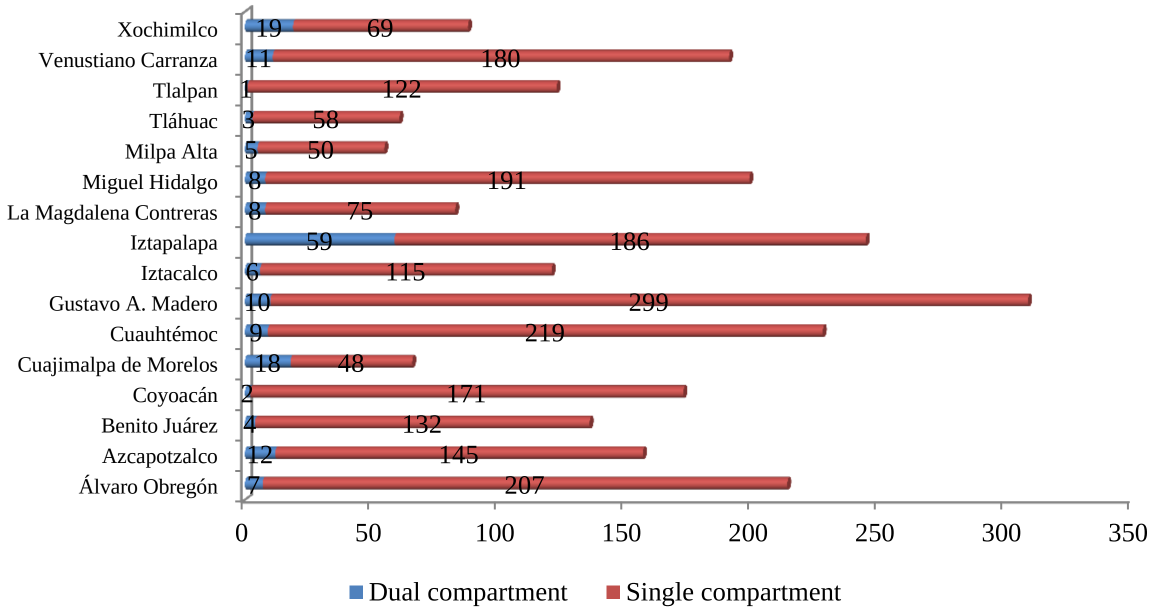


Figure 33 Total of vehicles in service for MSW collection
(Constructed with data from SE-DF, 2012)

The modernization of vehicles for collection has been slow. In 2012, the government designated US$ 1.3 million for the urban services department, an insufficient budget to improve and modernize facilities with new equipment. The modern vehicles that were acquired by the government with less than 5 years in operation, have been only small-size vehicles and steer loaders to be used in some transfer stations.

4.6 Facilities for waste management

4.6.1 Transfer stations

Transfer stations were aimed to provide a solution for the concentration of small collection vehicles in order to transfer the waste into bigger transportation systems. Initially, the transfer station were designed with the aim of fulfilling specifics actions which included (INE, 1996): (1) To reduce overall transportation costs and hours of unproductive labour, (2) To reduce downtimes of collection vehicles on their way to the disposal site, (3) To increase life and decrease maintenance costs of collection vehicles, (4), To increase efficiency of the collection service, using a coverage homogenous and balanced collection routes, (5) Greater consistency in the collection service, due to reduced damage to axles, springs, suspensions and tires that suffered when journeying to the final disposal site, (6) Reduction in environmental pollution, (7) Reduce the effects on public health.

By 2014, there are 13 transfer stations in operation in Mexico City (Figure 34). The transfer stations are operated by the Secretariat of Works and Services of the Federal District (SWS-FD). The boroughs of Tlahuac, Cuajimalpa and Magdalena Contreras lack transfer stations and two transfer stations are located in Iztapalapa.

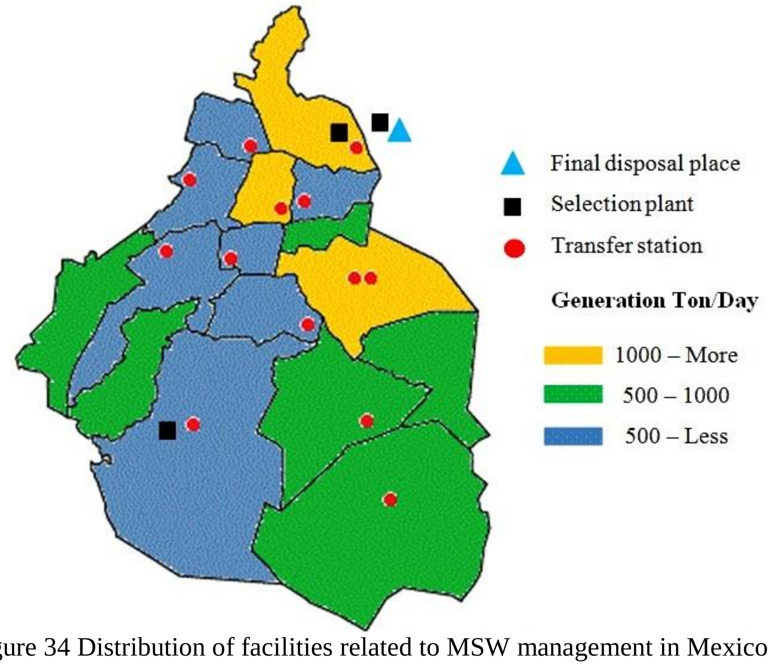


Figure 34 Distribution of facilities related to MSW management in Mexico City (Constructed with data from SE-DF, 2012)

Although transfer stations in Mexico City were designed based on a cost-benefit analysis; the lack of planning and proper maintenance of such facilities had led transfer station to become obsolete and inefficient. Figure 35 shows part of the transfer station of Iztapalapa.

Figure 35 Interior of the transfer station of Iztapalapa

Each station has a large reception area for the collection vehicles and the majority of the stations operate with a direct discharge system (Figure 36) to transfer MSW into large vehicles with an estimated capacity of 20/25 tonnes. This method involves the reception of vehicles which are registered and weighed according to estimations due to lack of scales. Transfer vehicles are directed from the ramps access to the loading area, where servers (hoppers) discharge waste into the vehicle. Large tarps in full are installed on the top of the vehicles in order to prevent dispersion of waste during the journey to the next facility.

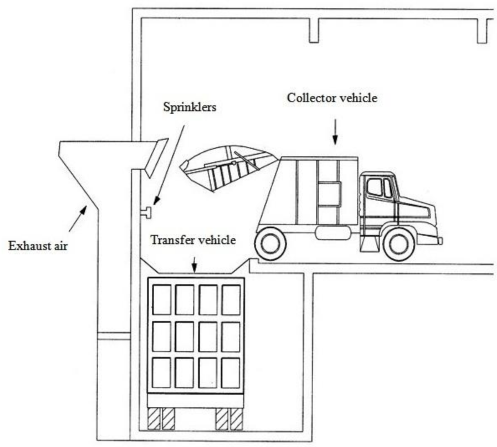


Figure 36 Direct discharge station of Mexico City (Adapted from INE, 1996)

As these types of stations lack storage areas, transfer vehicles are required to be in continuous availability in order to avoid waiting periods and delays. In addition, the lack of equipment makes vehicles to queue at peak times.

The indirect discharge is only used in a small number of transfer stations in Mexico City. In these facilities the waste is loaded into transfer vehicles with auxiliary equipment. Collection trucks are registered and also weighed with estimations. The efficient operation procedure would imply the accurate weight of vehicles with computerized scales to subsequently carry out the tipping of waste into a pit. The vehicle would return to the scale and it would be weighed again in order to obtain the exact amount of waste transferred. However the absence of such equipments leads to obtain imprecise measures. After tipping, the waste is removed from the pit with cranes or dozer tractors to transfer cases (Figure 37) which are moved by a forklift to a tipping area.

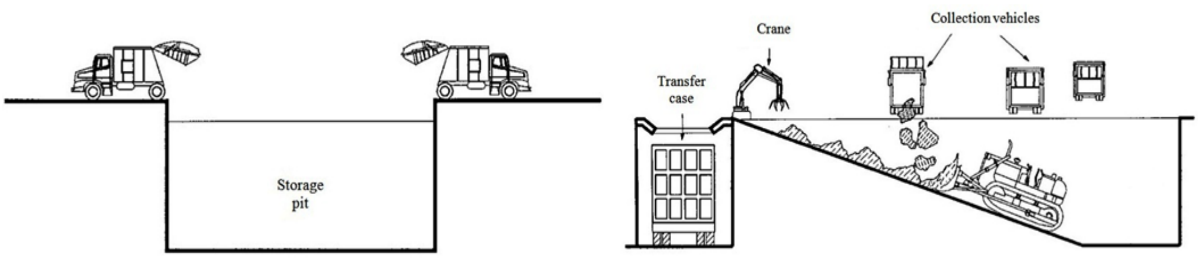


Figure 37 Indirect discharge station in Mexico City (Adapted from INE, 1996)

The needed equipment in indirect discharge station is more expensive than equipment in direct station. There are different types of transfer stations as analysed in section 2.5.1. Some of them operate with high-technology machinery. However, the transfer stations in Mexico

City use the simplest method (direct discharge) which also implies a low cost of investment. There is a lack of technology and improvement of methods and procedures. Most equipment is old and obsolete. In addition, the operation of the station is unsupervised; consequently the efficiency of the process is compromised.

4.6.2 Sorting plants

By 2014, there are three sorting plants of MSW in Mexico City. The plants are operated by the SWS-FD. The installed capacity is estimated at approximately 6,500 tonnes per day (SE-FD, 2012) . The plants are located in Bordo Poniente (figure 38), San Juan de Aragon and Santa Catarina (location can be seen in the figure 34). The sorting plants aim to receive MSW from the transfer station in order to separate recyclable materials prior the use of final disposal sites. Approximately 20 recyclable materials are sorted and subsequently commercialized by unregulated selectors commonly known as “pepenadores” a word which can be translated to English as “scavengers”. The sorted materials include: aluminium fret, solid scrap, profile, aluminium boat, boat ferrous iron, sheet metal, copper, wire, soda and beer bottles, amber glass, clear and green, cardboard, paper, PVC, PET, nylon and hard plastic or vinyl. The remaining material is transported to the final disposal site of Bordo Poniente.

Figure 38 Sorting plant of Bordo Poniente

Data from the Secretariat of Environment of the Federal District (SE-FD) shows low levels of sorted material. It must be noted that there is not available data, related to the amounts of sorted waste by type of material; therefore there is not available information of recycling per type of waste either. Available data only include total amounts of waste sorted within the plants.

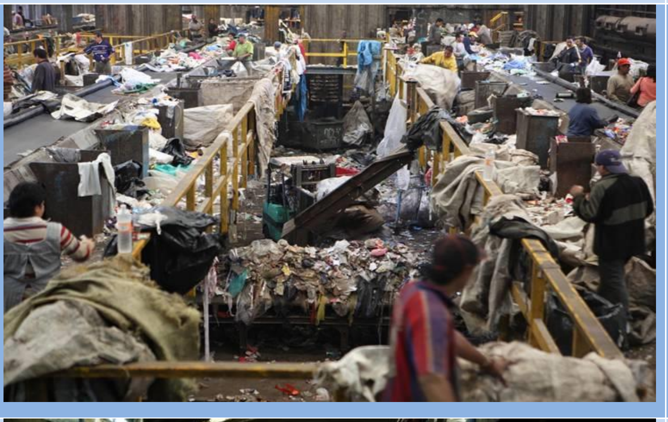
Plant	Activity	Year 2011
Bordo Poniente	Input	609,339
	Sorted	60,934
	Output	548,405
	% of sorting	10
San Juan de Aragón	Input	484,500
	Sorted	48,450
	Output	436,050
	% of sorting	10
Santa Catarina	Input	636,635
	Sorted	63,663
	Output	572,971
	% of sorting	10
Totals	Input	1,730,473
	Sorting	173,047
	Output	1,557,426
	% of sorting	10

Table 7 Total of tonnes of separated waste in sorting plants (SE-FD, 2012)

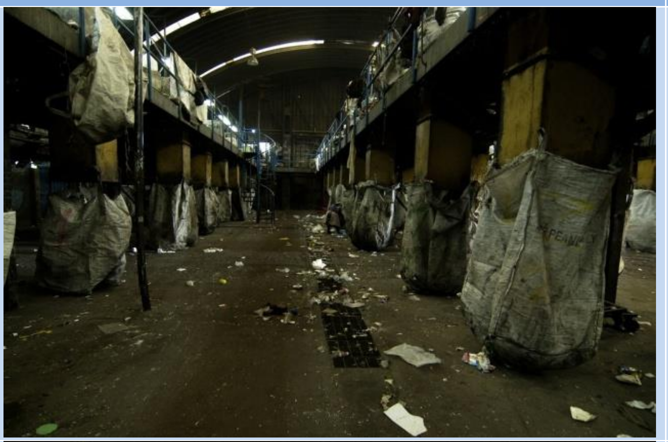
Table 7 shows the total amounts of sorted waste in the three facilities. The information was taken from the official reports published by the SE-FD. It can be observed that the three plants present the same amount of sorted material in percentage terms (10%). This similarity in values seems unrealistic due to, although the amount of sorted waste is low; the same level of sorting in three different facilities with different capacities is unlikely. Therefore, this issue was approached during the interviews conducted with the staff of the SE-FD. The validation of the information was limited due to the SE-FD acknowledged that the accurate amount of sorted waste is unknown, and there are not data since 2008. Previous years showed an average of sorting of 7.5%; therefore the SE-FD acknowledged the utilisation of 10% as a general indicator for sorting (and recycling) since 2009 (Detailed tables related to inputs, sorting and outputs of MSW in sorting plants are presented in appendix 3).

The reason for the lack of information on sorting and recycling is related to the presence of unregulated sorters (scavengers). The presence and interaction of this group of people implies several aspects including: (1) This group controls the sorting activities inside and outside the plant (Figure 39 describes in a general overview the operations carried out in the sorting plant of Bordo Poniente); (2) The political pressure has led the government to allow this group of people to continue working on sorting facilities; (3) Social impacts on the group have indirectly stopped the improvement of facilities, (4) The performance of such people is intended to obtain economic profits for themselves, (5) The group detracts from the importance of proper handling of waste and environmental impacts.

The operation begins with the reception of vehicles coming from transfer stations. The wastes are tipped on the main entrance of the plant. Large piles of waste are formed. This procedure shows a lack of general awareness of operational methods. Vehicles normally tip the MSW on any space available. In addition, the absence of scales implies that the accurate amount of waste in the piles is unknown.



The wastes are transported from the main entrance inside the plant. The sorting activities are carried out with the hand-picking method. The conveyor belt used to transport waste is broken, therefore certain people are responsible for feeding and cleaning belts after the material has been sorted.



There is a lack of movers, loaders and equipment aimed to transport material inside the plant. The activities are carried out using large bags to transfer and dispose the waste. This operation is also carried out in order to transport waste inside and outside the plant

After separation, recyclable material is stacked until it is sold to private recyclers. The recycling activities are carried out in most cases by unregulated stakeholders. The rest of the waste is transported to the landfill.

Figure 39 Description of operation procedure in the sorting plant of Bordo Poniente

It must be noted that, although there is no data on recycling in sporting facilities, in 2013, the government initiated a programme called "islands or recycling" which aims to avoid illegal dumping of waste in primary and secondary roads. The islands (formed by five containers) were located mainly in public parks, subway exits and residential units. The sorted and recycled materials include:

Material	Tonnes
Paper	80.3
Tetra Pack	98.55
Metal	175.2
PET	226.3
Cardboard	339.45
Plastic	438
Glass	576.7
Total	**1,934.5**

Table 8 Material collected and recycled in "islands of recycling" in 2013 (SE-FD, 2014)

It can be observed, that the total amount of collected and subsequently recycled material is low. The total 1,934.5 tonnes represent less than 1% of the almost 4.9 millions of tonnes generated yearly. Low levels of recycling can be associated to recycling attitudes of people. The recycling attitude of people is influenced by dissemination and availability of proper knowledge related to opportunities, benefits, existing facilities and general information of recycling techniques and methods. In addition, the recycling behaviour is also influenced by inconveniences including lack of time, lack of facilities, and indolence towards environmental issues. A previous recycling experience based on general concerns and commitments of maintaining a health and well-being of the neighbourhood can also lead to positive recycling behaviours which impacts directly on recycling levels in sorting and sorting facilities (Tonglet *et al.*, 2004). The waste management system of Mexico City lacks strategies focused on changing recycling attitudes, and intended to develop pro-environmental behaviours.

4.6.3 Bordo Poniente landfill

The Bordo Poniente is a non-engineered landfill and the only facility for final disposal of MSW in Mexico City. The landfill has received up to 13,000 tonnes per day; however, the amount of waste received has gradually decreased to amounts ranging among 6000 and 9000 tonnes per day (SE-FD, 2012).

The construction of the landfill goes back to 1983 when the government of the Federal District identified the need for a new final disposal site due to the closure of other landfills. In addition, a significant earthquake occurred in 1985, which led the government to create a place to dispose waste caused by the disaster. An area of 1,000 hectares in the vicinity of the city was selected to dispose the waste; such a place would become the Bordo Poniente Landfill (Vargas & Vilella, 2013). After the earthquake of 1985, the place was used as an unlicensed landfill until 1994 when it started licensed operations with a service life projected until 2001. Prior the expiration date, the government obtained a 3-years extension. However, in 2004, environmental issues appeared. The operation of the site resulted in damage to the hydraulic structures in Lake Texcoco. Pollution in the drainage channels of the surrounding municipalities of Nezahualcoyotl and Chimalhuacan was identified (JICA, 1999).

In 2005, the Mexican Secretariat of Environment and Natural Resources granted a 3-year extension to the government of Mexico City. In 2007 the National Water Commission warned that a greater volume of waste at Bordo Poniente landfill may impact on the channels available for flood control in the Valley of Mexico (CONAGUA, 2011). In addition, high presence of MSW generates leachate that can be filtered to groundwater (Ramírez-Sosa *et al*., 2013).

The landfill lacks proper guidelines and infrastructure of a sanitary landfill as analysed in section 2.53. The continuous operation of the landfill may cause a ground displacement affecting water channels. A greater weight on the banks of the channels of the surface drains, which is caused by an increase in the height of the landfills, would generate additional burdens on the soil (CONAGUA, 2007). The inadequate waste disposal can change the chemical soil composition and affect germination and growth of vegetation and crops. In addition, air pollution is caused through decomposition of the organic material which generates a dispersion of bacteria (Calvo *et al*., 2005).

Figure 40 Bordo Poniente landfill

In 2012, the Federal Attorney for Environmental Protection (in Spanish PROFEPA) initiated an operation to verify that the Government of the Federal District fulfils the gradual closure of the landfill. The closure project involves a gradual reduction in the amount of waste received from 6,000 tonnes to 4,700 tonnes per day. The Steering Committee of the National Bank of Public Works and Services (in Spanish BANOBRAS) granted 361 million pesos (approximately US$ 27.3 million) to the government of Mexico City to complete the closure of the landfill; In addition a concession of 400 acres of federal land was granted for the last stage of closure and decommissioning of the landfill. The final stage related to the closure of the landfill is intended to generate management and registration of projects for the exploitation of biogas for power generation in order to obtain carbon credits (CONAGUA, 2011). If provisions are ignored, the Water National Commission could fine the government of Mexico City with 200 pesos (approximately 15 US dollars) per each additional tonne of waste, the penalty would be estimated at 20 million pesos per month (approximately $US 1.5 million).

Due to the closure of Bordo Poniente, the government of Mexico City has signed agreements of two years with private landfill operators in the State of Mexico, the operators are "Tecnosilicatos de México" and "Reciclados Integrales Ambientales" (in English "Tecno-Silicates of Mexico" and "Integral Environmental Recycling"). The agreement involves the daily disposal of 2,500 tonnes of waste in four different facilities in the State of Mexico: Cuautitlán Izcalli, Ixtapaluca, Xonacatlán y Tecámac. The agreement considers an average cost estimated in 130 pesos (approximately US$10) per tonne of MSW. According to the Secretariat of Works and Services of the Federal District, by 2014, the expenditure for the use of private landfills in the State of Mexico is estimated in US$ 6.2 million per 270,000 tonnes of MSW, resulting in high expenditures related to disposal of waste.

4.7 Evaluation of the system

The analysis of aspects of the waste management system in Mexico City evidenced a number of problems and management deficiencies that impacts on the efficiency of the system. The general evaluation conducted, can be summarized by listing the main findings, according to each main aspect of the system. At the end of each discussion, a recommendation is formulated.

- **Guidelines of operations**

The current waste management system in Mexico City lacks guiding principles to support all the initiatives and actions. There is an important need for categorized guidelines on aspects related to the operation, technology and information. The 3R's hierarchy has been unsuccessfully implemented and the current system ignores the adoption of alternative treatment methods. The current strategy also ignores a specific policy intended to diversify legal frameworks related to waste management and environmental protection.

Recommendations: It is necessary to define main guidelines to support specific actions. It is important to establish guidelines aimed to set responsibilities to mitigate environmental impacts. Therefore, it is advisable to define specific lines of operation for the whole waste management system. Programmes and initiatives must be based on specific guidelines or public policies to ensure a proper performance and to achieve effectiveness.

- **Waste management programme**

The current waste management programme lacks accurate strategies and it is not supported by comprehensive legal frameworks to cover fundamental aspects related to waste generation. The evaluation of the system evidenced: 1) a large number of activities based on empirical experience of operators, 2) rudimentary methods in the absence of detailed procedures, 3) absence of monitoring programmes, 4) lack of alignment with federal actions.

Recommendations: The current programmes require incorporating all stakeholders and the initiatives must be defined considering the different stages of the waste management. Therefore, it is necessary to design a new integrated waste management programme focused on minimization and prevention of waste generation. The programme must incorporate detailed handling plans for MSW with specific goals, responsibilities and specific actions which must emphasize minimization and prevention of waste.

- **Information system**

The current data system provides outdated information and the reliability of data is compromised.

Recommendations: It is important to consider the provision of information related to waste management as a strategy to promote effective communication in order to disseminate not only generation data but also actions and initiates intended to change behaviours. The improvement of the system can provide a platform to develop environmental education campaigns which subsequently help in the sensitization through training programmes designed for reduction, reuse and recycling.

- **Separation of waste**

Separation focuses only on schools, markets, public buildings with limited results. The use of bins for separation has not been highly used. The lack of information and detailed programmes leads to discourage participation of society in sorting activities.

Recommendations: It is necessary to implement a strategy focused on separation at source with proper measures of supervision. The separation at source must be implemented in order to reduce the amount of mixed waste and which would facilitate sorting and recycling activities. The strategy for waste segregation must be accompanied by a complete improvement in collection vehicles which enables to undertake separate collection according to the characteristics of each borough.

- **Recycling**

The existence of an important number of unregulated intermediaries in the recycling chain generates impacts on the recycling levels. The incoming waste in sorting facilities normally lacks valuable and recyclable materials due to previous sorting carried out by unregulated parties. The separation of recyclable materials carried out by unregulated stakeholders, aims to obtain economic profits by selling the materials in black markets.

Recommendations: Recycling should be based on proper use of bins and recycling centres. The recycling strategy, which should be part of an integrated waste management programme, must consider aspects including : (1) the use of alternative technologies for recycling and treatment of waste, (2) the prevention of pollution that is caused by the lack of recycling, (3) the improvement of environmental legislation and the design of new legal frameworks to support recycling activities, (4) the institutional coordination among agencies and organisations to unify recycling efforts, (5) the regulation of markets.

- **Collection system**

Routes and neighbourhoods with separate collection present a low advance of progress. The collection of waste is carried out mainly by vehicles with a single compartment. Most collection (especially from households) is carried out directly from container of mixed waste due to absence of trash bags. In addition, more than the 30% of the vehicles are more than 20 years of service.

Recommendations: It is necessary to improve the separation routes through modernization of the fleet; such an aspect may improve the selective collection and separation, and also may help to reduce the amount of pollutants released into the atmosphere given the use of modern vehicles. A specific part, related to improvement of the collection system, must be considered in future programmes.

- **Transfer stations**

Computerized scales are required to prevent estimations based on capacity of vehicles. The queues at peak-times generate delays not only in the operation of the station, but also involve interruptions in the collection service. In addition, mismanagement causes inefficient performance of operational activities.

Recommendations: The diversification in methods can be exploited given that the direct discharge method results in shortcomings. It is necessary to design handbooks, manuals and any other supporting document aimed to specify the methods and procedures of operation. The modernisation of technology in transfer stations should be considered in future programmes.

- **Sorting plans**

The sorting facilities show inefficient results of separation. The sorting activities are carried out in the absence of auxiliary equipment. There is a marked need to improve and update machinery and equipment. The majority of workers are “scavengers” who work in the absence of a proper labour scheme from the government.

Recommendations: The improvement of facilities should consider the modernisation of technologies aimed to separate specific materials. The amount of waste handled can involve diversifying the sorting methods. In addition, the proposal to improve the sorting facilities must pay significant attention to “scavengers”. The new initiatives should consider the integration of this group in the waste management system under a regulated scheme. This involves an extensive training and provision of working conditions, including employment opportunities according to received training.

- **Landfills**

The Bordo Poniente landfill not only has exceeded its capacity, but also presents important environmental impacts due to inefficient operation and management. Bordo Poniente lacks proper conditions to operate as a sanitary landfill.

Recommendations: The environmental impacts demand the rectification of the error through the development of feasible treatment options. An integrated waste management programme must incorporate strategies focused on the development of new treatment methods such as waste-to-energy facilities. The Bordo Poniente landfill must integrate procedures and control methods to avoid environmental impacts during the closure. The use of landfills must cease in future years; however, given the current status of the waste management system, the integral disuse of those facilities may take long. Therefore, the design and operation of new potential landfills must include all legal and environmental provisions to construct engineered landfills.

- **Supervision of activities**

The current system lacks proper supervision measures to monitor all activities related to waste management. The lack of vigilance/evaluation of programmes contributes to generate inefficiency in the system.

Recommendations: The Secretariat of Environment of the Federal District and the Secretariat of Work and Services must design guidelines to ensure the fulfilment of operational and legal provisions. It is necessary to set an evaluation scheme within the waste management system in order to correct problems and improve the proposed strategies and actions.

4.8 Summary of Chapter 4

In section 1.2, the problem definition highlighted the main negative issues related to an inefficient and obsolete waste management system in urban settlements. As predicted, the case of Mexico City presents particularities including high population levels, which has led to high rates of waste generation. The main findings related to the evaluation of the current waste system in Mexico City are related to the deficiencies in management and infrastructure. If unattended, such deficiencies would significantly impact on the environment of the city in addition to generate health risks. The problem described at the beginning of the thesis aligns with the principal problems identified in this Chapter. The development of the recommendations, is based on the results of the evaluation of different waste management models in addition to the system of Mexico City.

Chapter 5

Analysis of Waste Management Systems in Selected Cities

5.1 Introduction

Once the waste management system of Mexico City has been analysed, the analysis of different systems in selected international cities can provide a comparative scheme of actions and programmes. It must be noted that, although there are cities with similar demographic characteristics in transitional economies, such as Beijing, Sao Paolo, and Mumbai, the analysis focuses on large cities in developed countries. The selected cities include: London, Berlin, Tokyo and New York. The choice of the cities was based on the following criteria:

1) Similarities in demographic levels: New York, London and Tokyo presents population rates over 9 million and metropolitan areas with even higher population.
2) Significant performance in recycling activities: Especially the case of Berlin has proven records of good performance levels of recycling, according to environmental reports from the Commission of Environment of the European Union (European Environment Agency, 2015).
3) Economic performance: The four cases present a dynamic regional economy. New York, London, Tokyo and Mexico City are ranked within the urban agglomeration with high estimated Gross Domestic Product.
4) Business activity: The selected cities have similarities due to a high business activity, which aligns with Mexico City; this is an important element due to possible similarities in waste composition.

5) Availability of information: In spite of the differences between the languages, in all cases there were available documents in English.

6) Participation of the private sector: The evaluation of the participation of private partners is a key element to determine a possible inclusion of the private sector in waste management activities in Mexico City. Therefore, it was fundamental to focus the analysis on cities with a scheme of cooperation between local governments and private sector.

The aim of the analysis is not only to determine the operation and structure of the waste management systems, but also to identify possible aspects to consider when designing a new proposal to improve the system of Mexico City. The analysis focused on recurrent points, including legislation, plans, programmes, strategies, facilities and participation of the private sector.

5.2 London

The city of London is the biggest city of the United Kingdom; according to the Office for National Statistics in England, including the metropolitan area, in 2011 the estimated population was 13,709,000 inhabitants (ONS, 2011). The MSW generation per day is estimated at 11,000 tonnes (GLA, 2011).

5.2.1 Strategy for waste management

The waste management system divides the city in four sectors with the installation of joint waste authorities (Table 9). Such authorities are responsible for the waste management and the supervision of actions carried out by licensed private companies. There are 12 local authorities in London, which are responsible for the collection and disposal (Unitary authorities). The remaining 21 waste authorities are responsible for the collection; with arranged disposal (GLA, 2011).

Authority	Borough
East London	Newham, Barking and Dagenham, Redbridge, Havering
North London	North London Barnet, Camden, Enfield, Islington, Hackney, Haringey, Waltham Forest
West London	Brent, Ealing, Harrow, Hillingdon, Hounslow, Richmond
Western Riverside	Hammersmith and Fulham, Kensington and Chelsea, Lambeth, Wandsworth
Unitary Authority	City of Westminster, City of London, Bexley, Bromley, Croydon, Greenwich, Kingston, Lewisham, Merton, Southwark, Sutton, Tower Hamlets

Table 9 Waste authorities in London (GLA, 2011)

Authorities in London are aware that population levels will grow significantly in the next 15 years. Therefore, the strategies aim to reduce the amount of waste generation in London, in order to increase recycling and composting; in addition to reduce waste in landfills and subsequently to generate new sources of alternative energy (GLA, 2010). The different public policies align with the Waste Framework Directive (Directive 2008/98/EC) from the European Union.

The Greater London Authority (GLA) stipulates the main waste management strategy. In 2011 the Mayor of London published The Mayor's municipal waste management strategy which includes six main public policies:

1. Informing producers and consumers of the value of reducing, reusing, and recycling municipal waste.
2. Reducing the climate change impact of London's municipal waste management.
3. Capturing the economic opportunities of municipal waste management.
4. Achieving high municipal recycling and composting rates resulting in the greatest environmental and financial benefits.
5. Stimulating the development of new municipal waste management infrastructure in London, particularly low-carbon technologies.
6. Achieving a high level of street cleanliness.

Each policy has specific proposals, in force since 2010, which are aimed to reduce to zero the amount of MSW in landfills by 2025. The Greater London Authority works closely with the Department for Environment, Food and Rural Affairs (DEFRA) to ensure the alignment of strategies. Each of the six policies enacted in London correlates with statements from the national waste policy review published by DEFRA in 2011.

The environmental strategies within Greater London have involved significant participation of the private sector under regulations of the GLA. In the particular case of London, an important part of the waste management activities are carried out mainly by: Cory Environmental, Terra Firma and Veolia Environment Services.

5.2.2 Transfer stations

Among the largest transfer facilities in London, the transfer stations of Brent, Bromley, Greenwich and Rian ham can be listed. Such facilities are operated by Veolia Environment Services. The station of Brent operates 24 hours a day with an estimated capacity of 170,000 tonnes per year.

The Walbrook Wharf transfer station, which is operated by Cory Environmental, manages approximately 15% of the MSW in London. The operation process involves the reception of waste coming from households and businesses. The waste arrives in collection vehicles, then it is disposed of within the transfer station. The station utilises an indirect discharge procedure that involves compaction of waste into large containers (ISO containers). The station is located in Upper Thames Street in the City of London, from where barges are used to transport waste across the river to the Belvedere incineration plant. Commingled materials are separated into different containers to be recycled by the private company Ideal Waste Paper Co. Ltd. in the Teardrop Centre Swanley (ESA, 2010).

Other transfer stations in London include: Smugglers Way, Cringle Dock, Pensbury Place and Northumberland Wharf and Tower Hamlets (all operated by Cory Environmental). Each station accepts a specific range of wastes, some stations accept commercial and industrial waste in addition to MSW.

5.2.3 Recycling centres

The Reuse and Recycling Centres (RRC) represent an important part of the infrastructure for waste management; such facilities are aimed to carry out recycling for separated materials (Figure 41 shows an active RRC in Southwark, London). RRC are operated mainly by private companies. The received material include: aluminium, paper, plastic, fabric and glass; the received waste can also include: car batteries, computer monitors, cooking oil, engine oil, fluorescent tubes, fridges and freezers, furniture, gas bottles, low energy light bulbs, mobile phones, paint, printer and toner cartridges, scrap metal, small electrical items, televisions, wood and timber (DEFRA, 2005).

Figure 41 Southwark reuse and recycling centre

The RRC scheme is identified as an effective model due to the free reception of materials, provision of a reused-products market and sale of compost and compost bins. The RRCs complement the actions of transfer stations. It is important to mention that Mexico City lacks the facilities for the disposal of specified wastes. These kinds of products represent a problem for the people, inasmuch as an extra fee must be paid in order to be collected in Mexico City.

5.2.4 Landfills

Approximately 40% of the MSW generated in London goes to landfills. In 2011 it was estimated that approximately 1,289,000 tonnes of MSW were sent to different landfill sites around London. Table 10 shows the estimated distribution of MSW in landfill sites. It can be observed that 17 landfill sites are used to dispose 1,289,000 (approximately 70% of all waste sent to landfills). The 17 landfills sites of table 10 are located outside London, mainly in the south and east of England and spread over 6 different counties. This landfill capacity is due to expire by 2025. The remaining 30% of waste sent to landfill is sent to two landfill sites inside London: Rainham (Havering) and Beddington Farm (Sutton). Such sites are expected to close by 2018 and 2021 respectively, and there are no plans to consider new landfill capacity within London (GLA, 2011).

Waste management Authority	Landfill of destination	County where landfill is located	Annual waste transfer (tonnes)
East London	Bletchley	Buckinghamshire	74,000
	Stewartby	Bedfordshire	23,000
North London	Calvert	Buckinghamshire	168,000
West London	Bletchley	Buckinghamshire	100,000
	Calvert	Buckinghamshire	212,000
	Bicester	Oxfordshire	8,000
	Abingdon	Oxfordshire	178,000
	Gerrards Cross	Buckinghamshire	10,000
Western Riverside	Standford-le-Hope	Essex	335,000
Unitary Authority (London boroughs)	Redhill	Surrey	43,000
	Sevenoaks	Kent	33,000
	Standford-le-Hope	Essex	32,000
	South Ockendon	Essex	6,000
	Pitsea	Essex	36,000
	Brogborough	Bedfordshire	19,000
	Bletchley	Buckinghamshire	12,000
Total			**1,289,000**

Table 10 Distribution of MSW to landfill sites around London (Constructed with data from GLA, 2011).

- **Landfill tax**

According to the GLA the cost of landfill use for 2011 was estimated at £265 million (GLA, 2011). An amount that has increased in 2014 as landfill tax has risen from £56 per tonne in 2011 to £80 per tonne by 2014.

The UK Landfill Tax (and the related Landfill Tax Credit Scheme) was introduced in October 1996. The tax was aimed to price landfill waste disposal in order to reflect environmental costs, which can help to develop different sustainable approaches to waste management (Morris *et al*., 1998). The landfill tax started with a rate of £7 per tonne for active waste and £2 per tonne for inactive/inert waste. Inactive/Inert waste includes: rocks, soils, ceramic or concrete materials, minerals, furnace slags, ash, low activity inorganic compounds, calcium sulphate, calcium hydroxide and brine. Active waste refers to all other taxable waste (HMRC, 2012). Landfill tax is placed on every tonne of waste sent to landfill; however, one aim of the tax is to achieve encouraging more businesses to move toward recycling, re-use and waste minimisation. Although there have been concerns related to possible evasions and lack of transparency and independence (Morris *et al*., 2001), the landfill tax can lead private organisations and local waste management authorities to invest in different minimisation techniques and research projects on recycling (Read *et al*., 1997).

5.2.4 Energy generation from waste

Approximately 21% of the MSW generated is sent to incinerators. It must be noted that in the UK, incineration of MSW involves some form of energy recovery either electricity and/or heat (DEFRA, 2007). Approximately 920,000 tonnes per year are sent to two large incinerators (Enfield and Lewisham). In 2010 it was estimated that incinerators generated 564 kWh of electricity per tonne of waste incinerated, enough electricity to power approximately 130,000 homes (Murphy & McKeogh, 2004). The proportion of approximately 21% of MSW sent to incinerators has been gradually increasing as Riverside Resource Recovery (RRR) plant in Belvedere opened in 2011.

The RRR plant is operated by Cory Environmental with a contract running until 2025. The estimated capacity is 585,000 tonnes of MSW per year. The plant is expected to generate a net of approximately 66MW of electricity to serve approximately 100,000 homes; it would also contribute to a reduction in the emissions of CO_2 to the environment due to the substitution of 100,000 heavy vehicles for large barges (EAE, 2008).

5.2.5 Interesting projects and initiatives

The identification of interesting projects and initiatives can create similar schemes to be applied in Mexico City. The possibility to adapt programmes currently in use can help to mitigate the waste generation not only in households, but also in small shops and large companies. Within the waste management scheme of the GLA, there are several initiatives that have helped to support waste reduction, interesting projects include:

- **Clean City Awards Scheme (CCAS)**

The CCAS aims to award small and large businesses which: have minimized waste generation, have implemented reuse and recycling, or have developed any other initiatives aimed to reduce contamination. The CCAS does not provide financial rewards; however, it has been a useful incentive to encourage business to undertake sustainable activities and to help to reduce the waste generation in London. There are three categories for the CCAS (small, medium, large) with the following distinctions: (1) Chairman's cup, (2) Platinum special commendation, (3) Platinum awards, (4) Sweeper of the year, (5) Waste operative of the Year (6) Gold special commendations, (7) Gold awards (GLA, 2011).

- **Waste & Resources Action Programme**

The Waste & Resources Action Programme (WRAP) is a not-profit independent programme with funding from DEFRA and other governmental institutions in the UK and in the European Union. It was created in 2000 and aims to work together with individual, communities and businesses in order to help them to understand benefits not only of reducing waste but also of developing sustainable products. WRAP also aims to make recycling easier for people, repair and reuse as much as possible, and to enable them to recover all the economic value possible from waste. Important initiatives include "Recycle Now" that is aimed to create a market for recycled materials; and "Love Food Hate Waste" which aims to reuse and reduce food waste (WRAP, 2012).

5.3 Berlin

Berlin is the biggest city in Germany in population terms, according to the Federal Statistical Office in Germany, in 2010 there were 3,460,725 inhabitants in the city and more than 6,000,000 in the metropolitan area (BI, 2011). Berlin has almost twice the population of Hamburg and Munich, the second and the third largest cities respectively. Although population levels are not as large as the levels of Mexico City, the efficiency and performance of the recycling system are noteable.

According to the Senate Department for Urban Development and the Environment of Berlin, the city produces approximately 1 million tonnes of waste each year (SDUDE, 2013). 70% comes from households, and 30% from the commercial sector. In a stark contrast to Mexico City, the amount of waste generation in Berlin has been declining year by year. A key factor in the effectiveness of the waste management system is BSR (in German, Berliner Stadtreinigungsbetriebe), which is one of the largest waste management companies in Europe. It is important to point out the all households in Berlin are obligated by law to use the services of BSR, only private companies and business have the option to hire different waste management companies.

5.3.1 Legislation

Current waste regulation in Germany was developed in 1996. The Closed Substance Cycle and Waste Management Act (KrW-A/AbfG) is the main legislation in the matter and it is complemented by a number of ordinances. The improvements in the law are based on the 2008/98/EC Directive from the European Union. The legislation aims to prevent waste generation, it also emphasizes the improvement in a separate collection of recyclable materials and the energy recovery from waste.

Waste legislation in the European Union is focused on the waste hierarchy according to the Waste Framework Directive. Therefore, local regulations in Berlin take into consideration the responsibility of the producer of waste. By law producer and distributor of any product are required to minimise waste during the production process and during subsequent activities.

Producers and distributors are also responsible for packaging materials. Since 2003 consumers have to pay a deposit on all drinks packages which are disposable, a situation that has generated the use of returnable beverage packaging. Laws allow government to enforce any initiative with more ordinances, administrative decrees and fines (Zhang *et al*., 2010).

Regarding to the waste disposal, German legislation uses the Ordinance on Environmentally Compatible Storage of Waste for Human Settlements. This regulation specifies that if the waste cannot be recycled, it should be disposed of under conditions to prevent environmentally harmful decomposition. It is mentioned that the disposal of biodegradable waste without previous treatment to prevent pollution is strictly forbidden (FME, 2001). In 2009 landfills, which could not fulfil any requirement specified in the law at reasonable cost, were closed. According to the Senate Department for Urban Development and the Environment of Berlin (SDUDE) in 1970 there were more than 50,000 landfills in Germany; in 2012 there were only 160 in operation.

5.3.2 Strategies and plans

The Federal Ministry for Environment (FME) has overall responsibility for the design of strategies and public policies for waste management. Every five years the FME re-evaluates existing strategies in order to structure a robust long-term waste management plan (normally 10 years). The waste management plan always incorporates the new trends and demographic framework conditions in order to ensure the consideration of all factors that can affect waste generation, therefore, predictions help to estimate the future needs of the facilities.

Berlin government has defined the following policies as actions that must be achieved (SDUDE, 2013):

- The prevention of waste and the avoidance and minimisation of harmful substances in waste,
- The highest possible level of recovery and recycling from unavoidable waste without harm, depending on the type and composition of the waste and to the extent that this is technically and economically feasible.

- The treatment of non-recoverable waste in order to reduce the quantities and the harmfulness, and the disposal or environmentally-compatible stowage as close as possible to their place of origin.
- The protection of natural resources and the promotion of product responsibility in accordance with the law during the development, production, processing and distribution of products.

A significant part of the initiative is focused on manufacturers, which are asked to produce products, avoiding the use of unnecessary packaging in order to re-use materials and manufacture packaging with longer shelf life. This strategy has resulted in recycling levels of 60% for MSW and 80% for packaging materials (SDUDE, 2013). In contrast to England where the goal is to stop the use of landfills by 2025, the German government has established the same goal by 2020.

5.3.3 Collection system

BSR (Berliner Stadtreinigungsbetriebe), founded in 1951, is the largest waste management company in Germany. Since 1994, it has operated as the statutory body for waste management in Berlin for all households and some commercial and trade businesses. The infrastructure for collection includes 1,500 vehicles and approximately 5,500 employees. The capacity of BSR is estimated at 1 million tonnes of waste each year. The main activities of BSR include: the promotion of waste prevention, recovery and recycling for waste, safe disposal and road sweeping (BSR, 2009). BSR finances its operation from collection fees and other charges; however, it is not allowed to generate any profit from its activities. Services for waste disposal in large containers are subject to the following fee:

Type of waste	Container Volume (Lts)	Fee (€ Euro)
Household waste	60	64.08
	120	76.94
	240	98.59
	660	224.07
	1100	309.34
Organic waste	60	30.50
	120	31.40
	1100	35.40
Special hopper container	120	504.62
Slag	660	94.99
Organic waste (Commercial)	1100	77.90
	120	93.40
Recyclables	240	0.00
	660	0.00
	1100	0.00

Table 11 Standard fees for waste collection in Berlin
(Constructed with original data from BSR, 2013)

The tariffs used by the BSR are determined by the Senate Department for Urban Development and the Environment of Berlin. They must be paid for every weekly collection or every 14-days collection. Those standard rates are applicable for every container located no further than 15 metres from the boundary line of collection. The standard rates from table 11 are applicable, provided that the container does not present any obstacle for its collection, otherwise, a standard fee of €15.30 rate must be paid for additional and special collections. The premise of "who generates more, pays more" is applicable. However the law allows every household to have a 30lt container collected every 14 days free of charge (BSR, 2013).

The collection service is divided, according to the type of waste, into: domestic waste, trade waste, commercial waste, bulky waste, and waste from road sweepings. The type of collection vehicle varies according to type of waste (Figure 42).

Figure 42 Vehicles for waste collection in Berlin (Adapted from SDUDE, 2013).

5.3.4 Waste treatment plants

The MHKW Ruhleben station receives approximately 50% of all MSW generated. The facility (operated by Fisa Babcock Environment) has five incineration lines and was opened in June 2012 with an estimated capacity of 520,000 tonnes per year. The majority of the waste is delivered by the BSR, a smaller proportion is delivered by other private companies. The high-pressure super-heated steam produced is passed on to the neighbouring Reuter Power Station, where it is used to generate electricity and for district heating (SDUDE, 2013).

The organic part of the MSW is treated at the biogas fermentation plant in Ruhleben. The plant (operated by the BSR) has an estimated capacity of 60,000 per year, which represent the 100% of organic waste collected in Berlin. The plant was opened in 2013 and it replaced composting procedures in order to reduce emissions of greenhouse gases. The dry fermentation method used, favours the treatment of kitchen waste from Berlin households. The biogas obtained in the process is cleaned, treated and concentrated in order to be fed into the gas supply of the BSR vehicles.

Additional waste treatment facilities in Berlin include:

- Sorting plant for recyclable materials
- Mechanical treatment plant Köpenick
- Paper sorting plant Neukölln
- Two mechanical-physical stabilisation plants (MPS)
- Two plants for the disassembly of refrigerators and the recycling of electrical and electronic appliances

5.3.5 Landfills

Under current regulations, only waste not capable of being recycled or recovered are allowed to be disposed of in landfills. The waste must be treated in order to eliminate any harmful impact on the environment. It must be pointed out that the city of Berlin lacks landfill facilities. This decision is based on the lack of suitable areas for building such types of facilities. In addition, the legislation is intended to decrease the use of landfills. Only in particular cases, the government of Berlin outsources a landfill in the state of Brandenburg (SDUDE, 2013).

5.3.6 Recycling system

According to the European Commission of Environment, one of the best performances in recycling is held by Germany with estimated rates of recycling and composting in 2013 of 48% and 18% respectively. Rates of recycling of 65% in household waste and 70% in construction waste are expected to be achieved in 2020 (IEEP, 2010). Figure 43 shows the decrease in the waste that is disposed of in landfills and the increase in the amount of recycled waste. The increase of recycled waste has presented a significant growth, from approximately 10% in 1992 to more than 40% in 2007.

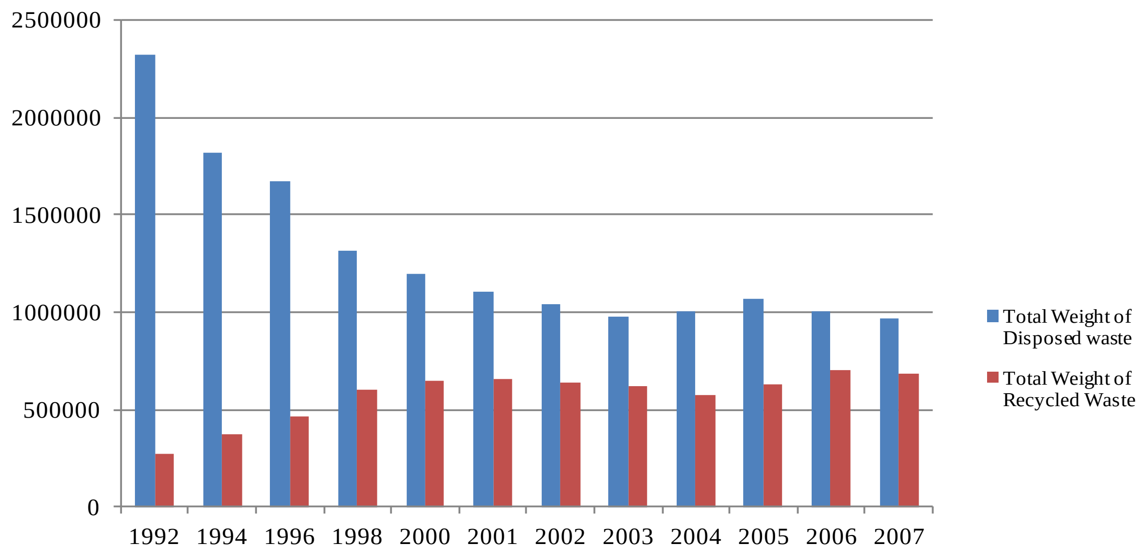


Figure 43 Total weight of recycled and disposed of waste in Berlin 1992-2007
(Constructed with date from SDUDE, 2013)

5.3.7 Initiatives

The efficient performance of recycling systems in Berlin is supported by separation at source. The separation process includes different categories: (1) paper, (2) glass, (3) packaging, (4) compost. It must be noted that the separation activity is supported by the participation and commitment of the stakeholders involved. The efficiency of the recycling system is based on a strong civic duty of Berliners. The case of a strong commitment towards recycling in Berlin shows that a proper and wider knowledge of environmental issues related to the consequences of mismanagement of waste, can improve recycling and subsequently achieve the waste minimisation and re-use of waste (Barr *et al.*, 2001). As the separation system has resulted in efficient recycling, the government has continued with public policies focused on separation. Since 2013 the German government has developed a strategy to introduce a new yellow bin for materials such as wood, plastic and metal. The initiative of introducing new bins is aimed to separate special items including: toys, keys, or small domestic appliances. Such a service would be an equivalent of the service that is provided in the Reuse and Recycling Centres in London. The target is to diversify the type of waste that can be separated at source. According to Berlin government the use of new bins could increase in, up to seven kilograms of recycled material per person each year and it is expected that by 2016 the five separated bins be applicable in all Germany.

5.4 Tokyo

Tokyo is the capital city and one of the 47 prefectures of Japan. Tokyo is one of the greatest metropolitan areas in the world; a census in 2011 estimated a population of 13,185,502 in Tokyo and 35,682,460 in the Tokyo Metropolitan Area. According to the Ministry of the Environment of Japan (MEJ) the estimated generation of MSW in 2008 was approximately 4.45 million tonnes.

5.4.1 Legislation

The waste legislation aims to promote the 3R strategy among local governments. The principal laws include:

- Law for the promotion of effective utilization of resources
- Container and packaging recycling law
- Home appliance recycling law
- Construction waste recycling law
- Food recycling law
- ELV recycling law

Each law has a specific field of application and empowers the Tokyo Metropolitan Government (TMG) with legal frameworks to develop new plans and strategies related to waste management. The container and packaging recycling law, has helped to improve the recycling performance, and subsequently to reduce waste generation. Whereas in 1989, 6.13 million tonnes were generated, in 2010 average levels were around 4 million tonnes of waste, resulting in a significant reduction of more than 2 million tonnes. On the other hand, since the application of the construction waste recycling law in 2002, the recycling rate for concrete is approximately 95% (Sondari *et al*., 2012).

Waste legislation has helped to gradually reduce generation levels; however, even with a reduction of approximately two million tonnes in 20 years, the current generation levels are estimated at approximately 4 million tonnes each year. It must be noted that such a large amount of waste generation requires long-range plans. The case of Tokyo exemplifies that the base of any initiative must incorporate a comprehensive legal framework.

5.4.2 Plans and strategies

The TMG has focused its efforts on the reduction of industrial waste. Altought the recycling initiatives for household waste have increased, waste plastics, sludge and construction waste are still disposed of in landfills. The TMG has formulated the Tokyo Metropolitan Waste Management Plan, which presents the target to become Tokyo into a “sustainable material-cycle society”. The plan is aimed to convert Tokyo into an advanced environmental city with the lowest environmental load in the world (Fujita & Hill, 2007).

In order to achieve the target goal, the waste management system is based on three main principles (TMG, 2012):

1. Renewable resources should be used to the maximum extent possible, and should be used within a level that allows for their renewal in the long term.
2. If unavoidable, non-renewable resources may be used within a level that allows them to be substituted by other materials or energy sources.
3. Environmental impact of human activities should remain within the capacity of the environment to restore itself.

Figure 44 shows the principal factors involved in the process. The control in using natural resources in production processes and in other economic activities is evidenced as a key factor to reduce the amount of resulting waste. The intermediate disposal phase aims to re-use and subsequently, either to recycle or to recover waste through thermal processes. The strategy of "sustainable material-cycle society" mainly focuses on the responsibility of society to reduce the consumption of natural resources with the premise of: "to less consumption of natural resources, less waste generation".

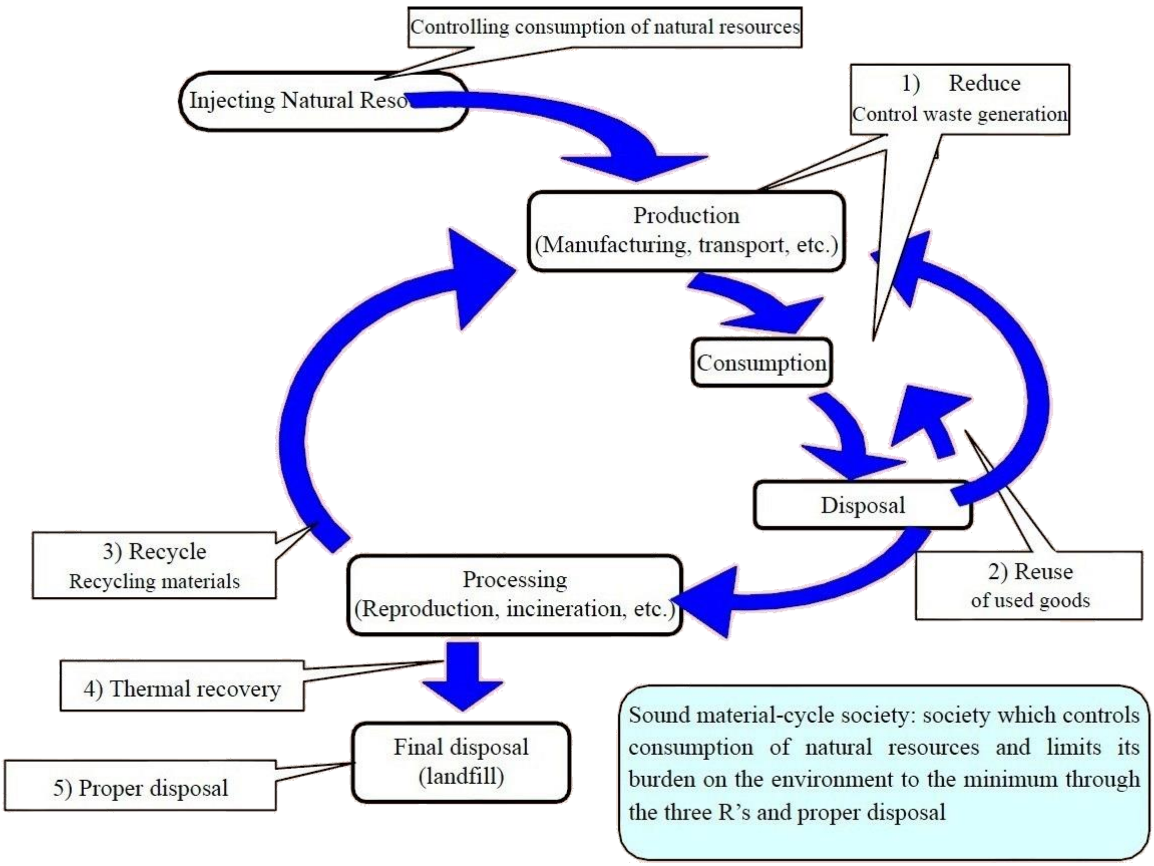


Figure 44 3R strategy applied by TMG (Adapted from TMG, 2012)

5.4.3 Collection service

The Ministry of Environment provides the collection service. In order to be collected, waste must be separated in different categories (TMG, 2009):

- Combustible trash (Wood, grass, kitchen waste, etc.) – once or twice a week
- Non-combustible trash (Glass, metals, porcelain, etc.) – once or twice a month
- Recyclable waste – once a week
- Bulky waste – collection only by previous reservation of the service

Waste from households should be disposed of in special rubbish bags that are designed and provided by local authorities. The bags must be picked up in a designated point at a scheduled time; if waste is disposed of in a different bag might not be collected. To dispose special items such as: bicycles, furniture, or similar goods, oweners should contact the local authority to ask for a special pickup service. The special service charges a fee depending on the characteristic of the item.

In addition, for home appliances including: TVs, fridges, washing machines, air conditioners, microwaves or any other similar device, two options are available: (1) if the disposal is due to a replacement of the good, the owner of the good must ask the store to collect the old item, if there is not a new purchase, the good must be disposed of in the place where it was originally bought; (2) if the disposal is carried out without the purchase of a new item and/or the owner ignores information of the original purchase, the owner must contact the Home Appliance Recycling Centre and follows the appropriate procedure. Computers are disposed of under a similar procedure. The TMG requires computing stores and manufacturers to provide the costumer with detailed instruction to dispose computer equipments (TMG, 2009).

5.4.4 Incinerators

Waste incineration has been highly used in Tokyo. The infrastructure is composed of 21 incinerators (almost one per each ward in Tokyo). Since 2002 the incinerators have operated with an ash melting furnace, which enables to turn the bottom and fly ash intro vitrified slag.

This procedure is intended to increase the efficiency of the energy recovery. Incinerators use plasma arc technology to create high temperatures and break down organic molecules in order to encapsulate toxic components. The slag can be used in construction activities as sub-base for roads or as a constituent in manufacturing of blocks (Chiou e*t al*., 2009).

Shinkoto is the largest incinerator in Tokyo with an estimated capacity of 1,800 tonnes per day. Table 12 shows the 21 incinerations in Tokyo which have an estimated combined capacity of 12,450 tonnes of waste per day.

The waste management strategy in Tokyo is significantly based on the operation of incinerators. The identification of the type of waste by labelled bags allows the collection service to transport waste directly to incinerators. It must be noted that all facilities generate power from the incinerations of waste. Incinerators provide sub-products and supply heat and cooling systems to nearby welfare facilities. In average terms, incineration facilities present an estimated efficiency of more than 20% in power generation (Granatstein & Sano, 2000).

Incinerators	Location	Capacity (daily volume x facility)
Chuo Incineration Plant	Harumi, Chuo-ku	300t×2
Minato Incineration Plant	Kounan, Minato-ku	300t×3
Kita Incineration Plant	Shimo, Kita-ku	600t×1
Shinagawa Incineration Plant	Yashio, Shinagawa-ku	300t×2 , melting: 90t×2
Meguro Incineration Plant	Mita, Meguro-ku	300t×2
Ota Incineration Plant	Keihinjima, Ota-ku	200t×3
Tamagawa Incineration Plant	Shimomaruko, Ota-ku	150t×2, melting: 30t×1
Setagaya Incineration Plant	Okura, Setagaya-ku	150t×2 , melting: 60t×2
Chitose Incineration Plant	Hachimanyama, Setagaya-ku	600t×1
Shibuya Incineration Plant	Higashi, Shibuya-ku	200t×1
Suginami Incineration Plant	(under construction)	300t×3
Toshima Incineration Plant	Kamiikebukuro, Toshima-ku	200t×2
Itabashi Incineration Plant	Takashimadaira, Itabashi-ku	300t×2, melting: 90t×2
Nerima incineration plant	(under construction)	300t×2
Hikarigaoka Incineration Plant	Hikarigaoka, Nerima-ku	150t×2
Sumida Incineration Plant	Higashisumida, Sumida-ku	600t×1
Shin-Koto Incineration Plant	Yumenoshima, Koutou-ku	600t×3
Ariake Incineration Plant	Ariake, Koutou-ku	200t×2
Adachi Incineration Plant	Nishihokima, Adachi-ku	350t×2, melting: 65t×2
Katsushika Incineration Plant	Mizumoto, Katsushika-ku	250t×2 , melting: 55t×2
Edogawa Incineration Plant	Edogawa, Edogawa-ku	300t×2

Table 12 Incinerator plants in Tokyo (TMG, 2012)

In addition to incinerators, other facilities for waste management in Tokyo include:

- Shinagawa cleaning facility for night soil
- Keihinjima Island incombustible waste processing centre

- Chubo ash-melting facility
- Chubo incombustible waste processing centre
- Pulverization processing plant for large-sized waste

5.4.5 Landfills

The Tokyo Bay landfill is the only disposal facility which is operated by the TMG. The landfill is composed of two blocks; block A with a surface of 199 hectares and the Block B with 72 hectares. In 2010, the block A ceased operations, and the block B reduced the amount of incoming waste. The closure of blocks A and B would lead the opening of four new blocks (C-D-E-G). Each block is intended to operate with a reduced capacity. The site occasionally receives industrial waste, however, approximately 61% of the industrial waste is treated and disposed of in facilities outside Tokyo. The use of landfills has decreased; whereas in 1998 approximately 1 million tonnes were disposed of in landfills, approximately 400,000 tonnes were disposed of in 2010 (MEJ, 2012).

5.4.6 Private sector

The estimated cost of waste management in Tokyo is considerably high. In 2009, the cost for collection and incineration was estimated in ¥37,341(approximately US$ 355) per tonne, and the cost of treatment and landfill activities in ¥27,789 (approximately US$ 264) per tonne. The total estimated cost of waste management was approximately ¥59,130 (approximately US$ 719) per tonne (TMG, 2012). The high costs led the government to develop strategies to include the private sector in the waste management activities. The Tokyo Super Eco Town Project (TSETP) was developed in 2002, and is aimed to increase the private participation in waste management activities in order to obtain efficient treatment and disposal methods. The TSETP also aims to be a fundamental factor within the “sustainable material-cycle society” initiative, with the construction of new facilities for a highly reliable recycling and waste treatment. By 2014, eight companies operate in different fields of activity within the waste management system (Table 13).

Facility/Company	Line of business	Capacity	Power generation
Tokyo Waterfront Recycle Power Co., Ltd.	Pyrolysis and Gasification Waste-to-Energy Plant	550 t/day 100 t/day	23,000 kW
Japan Environmental Safety Corporation.	PCB waste treatment	N/A	N/A
Bioenergy Co., Ltd.	Biogas power generation from food waste	110 t/day	1,000 kW
Alfo Co., Ltd.	Animal feed from food waste	140 t/day	N/A
Future Ecology Inc.	E-waste recycling	300 t/day	N/A
Re-Tem Corporation		36 t/day	N/A
Takatoshi Corporation	Construction and demolition waste recycling	928 t/day	N/A
Recycle Peer Co., Ltd.		961 t/day	N/A

Table 13 Member companies of the Tokyo Super Eco Town Project (TMG, 2012).

The TSETP is supported by the certification system for superior industrial waste management companies. The system was implemented in 2009, and it is aimed to certify good industrial waste treatment companies and companies that promote activities to reduce, recycle, and decrease environmental impacts. In 2010, 107 companies were certified as “industrial waste experts” and 77 companies as “industrial waste professionals”. Similar to the case of the Clean City Awards Scheme, which is applied in London, the certification in Tokyo is intended to generate business benefits including: prestige, reassessment of brands, and reduction in cost related to management of own waste.

5.5 New York

New York City is the largest city in population terms of the United States of America. According to the United States Census Bureau, in 2009 there were 8,244,910 inhabitants and 18,897,109 considering the metropolitan area. According to the Department of Environmental Conservation of the State of New York (NYS-DEC) the estimated generation is approximately 13,000 tonnes of MSW.

5.5.1 Composition of waste

According to the NYS-DEC, the waste stream is divided into commercial and residential waste as presented below:

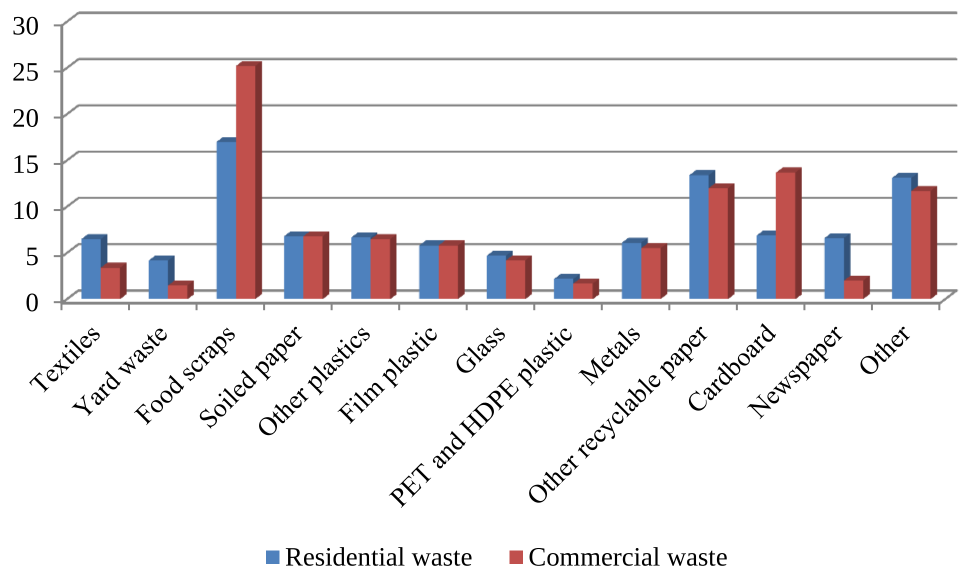


Figure 45 Composition of waste of New York per source in % (Constructed with data from NYS-DEC, 2013)

Figure 45 shows the composition of waste in term of percentage from the total generated and according to the source (residential and commercial). It can be noted that a significant part of the waste is represented by food scraps (organic waste), in addition paper and cardboard present important generation rates. The residential waste is collected by the government using a fleet of over 2,000 vehicles and the staff the collection system is integrated by nearly 6,000 workers The commercial waste is collected by private companies. The increase in the waste generation has resulted in annual bills of approximately US$ 1,250 million (NYS-DEC, 2013).

5.5.2 Logistics in the waste system

Figure 46 shows the waste flow since the generation until the final disposal. It can be noted that the landfills used are located significantly far from the City. Therefore, the use of large transportation vehicles used to travel large distances, implies the release of pollutants given the burning of fossil fuels.

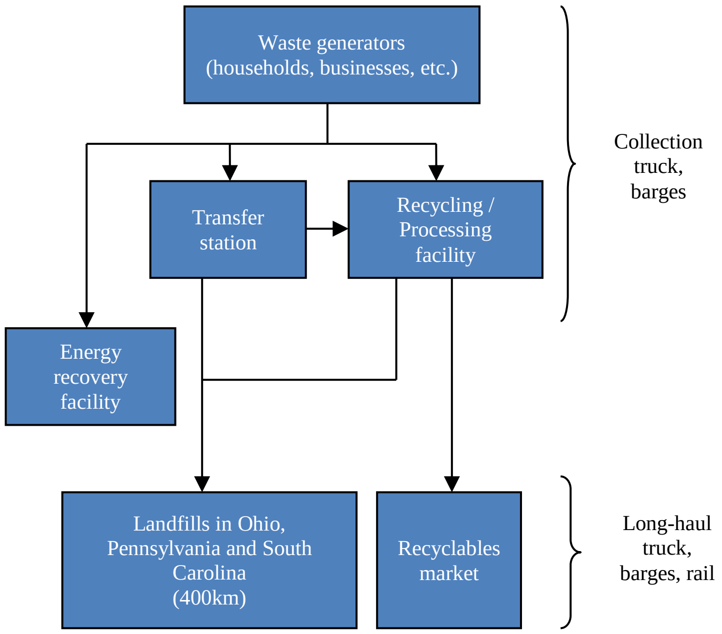


Figure 46 Solid waste logistics in New York City (NYS-DEC, 2013).

It can be observed that the waste management system of New York City basically involves the utilization of regular vehicles for collection, the use of transfer stations, and the use of large trucks to transport waste to final disposal sites located outside the city (NYS-DEC, 2010).

5.5.3 Waste management policy

The NYS-DEC focuses the development of programmes and projects on twelve key factors (NYS-DEC, 2010):

1. Set new goals and define new metrics.
2. Update and clarify recycling and green purchasing requirements for stage agencies authorities.
3. Clarify the Solid Waste Management Hierarchy.
4. Generate and allocate new resources to move “Beyond Waste”.
5. Reinforce recycling requirements for all generators.
6. Supplement the “economic markets” clause in the current law with a designated list of recyclables.
7. Increase DEC’s authority and resources to enforce recycling requirements.

8. Ensure that every permitted facility maximizes recycling and reuse and otherwise affords opportunities to manage waste at the highest possible point in the hierarchy within the facility's service area.
9. Establish disposal restrictions on bulk quantities of mandatory recyclable materials and other materials, including hazardous products, where recovery options are readily available or achievable.
10. Require local solid waste management planning.
11. Authorize local governments to franchise private materials management services.
12. Expand the Waste Transporter programmes to place specific requirements on transporters of municipal solid waste (MSW), recyclables, construction and demolition (C&D) debris and historic fill.

As can be observed, there is an emphasis on recycling. The current public policies aim to achieve the following goals:

- Double residential and institutional waste diversion from landfills from 15% to 30%
- Reduce waste sent to landfills by more than 500,000 tonnes annually
- Save up to $186 million, including $51 million in reduced export costs
- Reduce GHG emissions associated with solid waste by 7%

In order to achieve the goals, the Government of New York City has been focusing on three main strategies (1) Invest in city's waste reduction and recycling infrastructure, (2) Increase access to waste reduction programmes, (3) Create incentives and engage public in reducing waste.

The development of the strategies is based on the segregation of responsibilities and activities. Similar to the waste authorities in London, the government of New York created Units of Local Solid Waste Management Planning (LSWMP).

The LSWMP enables boroughs to set up solid waste planning units to monitor for (at least) a ten-year period, the performance of strategies, advances and fulfilment of goals related to waste management. The LSWMP must provide specific and clear actions of procedures and technology to be used, and timescales to observe chronological progress.

Each plan must provide the following information: (1) Description of the planning unit responsible for waste management, (2) Characterization of the waste to be managed in each area, (3) Existing facilities and programmes, (4) Concerns, views and comments from stakeholders, (5) A detailed recycling analysis, (6) Description of the plan and system to be used according to each type of waste, (7) Identification of the responsible parties to implement any aspect of the plan with their respective duties and activities, (8) A detailed time table, (9) Description of the participation of local government in the plan, (10) Description of implemented measures to secure participation of neighbouring jurisdictions.

Waste planning units should present and submit a compliance report every two years to the NYS-DEC. The reports must include achievement of goals and waste management needs. The validation of the presented plans is intended to result in the revalidation of operation permissions for future years.

5.5.4 Waste management programme

The policies presented in section 5.5.3 are addressed with the implementation of a waste management programme called “Beyond Waste”. The four main points of the plan involve (1) a broad policy aimed at preventing waste generation, (2) information campaigns to instruct householders and businesses how to reduce waste generation and increase recycling, (3) special policies and programmes focused on recycling food waste and any other organic material, (4) an important emphasis on using recyclable packaging and less toxic materials by assigning more responsibility to manufacturers.

The programme was announced in 2010 and most activities initiated in 2012; therefore, although the real effectiveness of the programme requires a longer period of time to be measured properly, the preliminary results and progresses include:

- Signing of long-term contracts for the export of City-collected waste by rail from the Bronx and Staten Island, and part of Brooklyn.
- Three new waste management facilities on Hamilton Avenue in Brooklyn, North
- Shore in Queens and South Brooklyn Marine Terminal (under construction).

- Extension of agreement with Visy paper recycling mill on Staten Island.
- Creation of the Office of Recycling Outreach and Education to increase recycling participation.

5.5.5 Transfer stations

There are 168 transfer stations regulated by the NYS-DEC in the State of New York. The combined capacity of all transfer stations is estimated in 9.9 million of tonnes per year. The transfer stations utilise direct and indirect discharge methods. The stations must present an annual report related to operation, procedures and the amount of handling waste (EPA, 2011).

A significant issue regarding transfer stations in recent years has been complaints related to location. The transfer stations are mainly located in low-income neighbourhoods. The New York City Environmental Justice Alliance (NYC-EJA) conducted a study to highlight the location of transfer stations and other waste management facilities in relation to concentration of low-income population (The complete map can be observed in appendix 4). Several waste management facilities that are located in the Bronx and Queens, present the greatest concentration of low-income population. Therefore, waste management facilities have become into a social issue due to allegations of discrimination (NYC-EJA, 2007).

5.5.6 Landfills

The closure in 2001 of the main landfill in New York City (Fresh Kills) led the government to use different disposal sites in the vicinity of the city. The current infrastructure for waste disposal involves 27 active MSW landfills, 16 industrial waste landfills, 14 construction and demolition landfills and 3 ash landfills. The majority of such landfills is operated by Republic Services Inc. (the second largest private waste management company in the United States). Waste Management Inc. also operates 10 facilities for waste management in the State of New York. Landfills for MSW in the State of New York reported in 2001 a remaining estimated combined capacity of 220 million tonnes, with an annual estimated reception of 7.7 million tonnes; the capacity is expected to be exceeded in 2027 (CUEI, 2001).

The MSW landfill facilities are located outside New York City. The waste exportation scheme which has been used by the government of New York involves movement of heavy vehicles on small roads and emission of contaminants to the atmosphere due to combustion of diesel. In addition, the Government of New York City reported an increase in taxes for waste disposal from $42 to $70-$100 per tonne. The cost for disposal has grown by more than $100 million since 2001 (Louis, 2004).

5.5.7 Incinerators

By 2014, 10 incineration facilities operate in the State of New York. In 2010, such facilities reported an estimated amount of processed waste of 3.9 million of tonnes with an estimated energy generation of 2 million MW. The facilities receive waste from New York City and waste from different cities in the state of New York and surrounding states. The 10 plants which are located in the State of New York include waste-to-energy plants which are divided into incinerators, pyrolysis plants, and plasma-gasification plants (NYS-DEC, 2010).

5.5.8 Other waste management facilities

- Construction and demolition debris processing facilities: Facilities used for friable solid waste that can be pulverized or reduced to powder
- Household hazardous waste collection and storage facilities: Facilities aimed to collect HHW in order to provide temporary storage before being packaged and transported to a final treatment facility.
- Materials exchanges: Facilities aimed to interchange used items.
- Metal Salvage Facilities: Facilities used to process scrap metal and recover metals from sludge.
- Organic Waste Recycling Facilities: Facilities aimed to receive organic material in order to produce compost or any other treatment to get a chemical stabilization of the waste.
- Recyclables Handling and Recovery Facilities: Reception facilities of waste previously separated from households, business and general waste from boroughs in order to receive recycling treatment.

5.6 Comparative analysis of the selected systems

The analysis of selected cities allowed the author to identify key aspects within the waste management systems. In a general overview the system used in London is highly supported by the private sector. The cooperation between public and private sector evidenced a robust base to achieve efficiency in the system. In addition, the regulatory framework related to landfill tax can significantly help to reduce the waste disposal. The creation of waste authorities allows the government to assign responsibilities to different stakeholders.

In contrast, the waste management system in Berlin is supported by the efficiency of the BSR and by a significant participation and high commitment of people. The recycling levels in Germany are achieved by the cooperation of householders and businesses in separation. It must be pointed out that, the participation of people in activities of separation may be given through a punitive model. Higher fees and fines for waste collection may have led householders to separate. The case of Tokyo is presented as a highly expensive waste management system with estimated costs for waste management of US$719 per tonne. The participation of private companies has distributed the costs. It must be noted that the rapid response of the private sector only in 3 years is given by the economic and market conditions of Japan.

The case of New York presents significant similarities with Mexico City. Both cities present similar levels of population and waste generation. In addition, the use of large landfills was evidenced (Bordo Poniente in Mexico City and Fresh Kills in New York City). The waste management system in New York evidenced a large diversity of facilities for waste management; however the closure of Fresh Kills landfill also evidenced the lack of proper and detailed plans for waste management. The exportation of waste to nearby landfills has been highly used since 2001. The design and implementation of the “beyond waste” plan in 2010, present significant improvement proposals to the system, however the results and effectiveness of the programme require a long-term analysis.

Table 14 shows the main aspects identified in each system. As can be observed, Mexico City presents the highest generation levels and the use of landfills as the main strategy. The system of Mexico City evidenced the lack of initiatives and low participation of local governments. In addition, whereas in the selected cities companies are considerably involved in waste management activities, in Mexico City the participation is significantly low.

City	Population	Waste generation (Yearly)	Main Strategy	Important Initiatives	Private sector	Negative factors
Mexico City	1. 8,851,080 2. 20,116,842	4,891,000	Landfill	• Market of rubbish (locally)	Little involved, only one company which manages the 3.2% of the MSW	Lack of a sustainable strategy
London	1. 8,174,100 2. 13,709,000	4,015,000	Landfill Incineration Recycling	• CCAS • WRAP	Highly involved, all the facilities are operated by the private sector	Dependence on private sector
Berlin	1. 3,515,473 2. 6,000,000	1,000,000	Recycling	• BRS Operation • Waste Bins strategy	Highly involved in the final phase of waste management (Treatment and disposal)	High cost of collection
Tokyo	1. 13,185,502 2. 35,682,460	4,450,000	Incineration	• Super Eco Town Project	Moderately involved, but increasing with the Super Eco Town Project	Low recycling system
New York	1. 8,244,910 2. 18,897,109	4,745,000	Waste exportation Landfills	• Local Solid Waste Management Planning • Solid Waste Planning Units	Moderately involved, operation of landfills and incinerators	Highly use of landfills

1. City
2. Metropolitan area

Table 14 Main aspects of selected systems

5.7 Summary of Chapter 5

The Chapter evidenced the interrelation among principles, policies and key factors of selected systems. In a general appreciation, each system has its particularities due to the characteristic of the geographical location and the commitment of the stakeholders. Nevertheless, the knowledge of each system allowed the author to identify key factors which helped to develop recommendations. Aspects of each system can serve as a base to structure similar initiatives which are aimed to develop the efficiency in the waste management system of Mexico City.

The following chapter presents a proposal for an integrated waste management programme which was built on fundamental aspects identified in the analysis of the selected system and which is aimed to correct the deficiencies of the current system of Mexico City that were shown in Chapter 4.

Chapter 6

Proposal for an Integrated Waste Management Programme for Mexico City

6.1 Introduction

The development of an integrated programme is intended to generate a robust basis to enable a progressive improvement of the Municipal Solid Waste management system of Mexico City. An integrated system must consider important elements related to waste management. Sustainability of systems can be achieved with proper consideration of operational, financial, social, institutional, political, legal and environmental aspects. The integrated approach to waste management issues must link waste management between stakeholders (government, citizens, businesses, and organisations) and specific aspects of the local context. Therefore, the integrated programme for Mexico City is based on elements that cover all the aspects previously mentioned. The following sections describe the design and construction of the programme. Different elements provided information to formulate specific strategies which are developed within the programme referencing specific actions, responsibilities and prospective timescales.

6.2 Development of the programme

The analyses presented in the previous sections (Chapter 4 and 5) generated information to identify important elements that can impact on the proper performance of a waste management system. The programme builds on key aspects that were identified in previous sections, mainly on three different elements. The first element that enabled the construction of the programme was the analysis of Chapter 4 since it identified the significant deficiencies in the current system of Mexico City (see section 4.7), the main recommendations to address such deficiencies included:

Aspect	Recommendation
Separation of waste	Reduction of mixed waste
Recycling	Development of recycling centres. Proper use of bins. Improvement of environmental legislation Regulation of markets.
Collection system	Improvement in collection vehicles Increase separate collection.
Waste management facilities (Transfer stations, sorting plants and composting plants)	Diversification in operational methods with proper supervision and training.
Landfills	Development of engineered landfills Incorporation of waste-to-energy technologies.
Guidelines of operations	Definition of the specific lines of operation for the whole waste management system.
Waste management programme	Incorporation of all stakeholders. Greater emphasis on prevention. Strategies with specific goals, responsible and specific actions.
Information system	Development of proper communication system Institutional coordination among agencies and organisations.
Supervision of activities	The Secretariat of Environment of the Federal District and the Secretariat of Work and Services must design evaluation and supervision programmes.

Table 15 Main recommendation to deficiencies identified in the MSW system of Mexico City

In addition to such recommendation, a SWOT analysis (constructed with information from Chapter 3 and 4 and that represents the second element) was conducted in order to identify the strengths, weaknesses, opportunities and threats within political, economic and social contexts that can impact on the waste management system of Mexico City (the SWOT matrix can be observed in appendix 5). The SWOT analysis resulted in concrete actions that should be addressed:

- Improvement of legal framework.
- Provision of training and information campaigns
- Significant linkage among local, state and federal governments
- Actions according to characteristics of each borough

- Regulation of markets
- Rewards and fines schemes
- Participation of all sectors involved
- Participation of private sector

Therefore, the general recommendations from Chapter 4 present similarities with the results of the SWOT matrix. The SWOT analysis also provides important new aspects to be considered in the integrated programme, including the participation of the private sector and the implementation of rewards and fines schemes.

Finally, the third element that enabled the development of an integrated programme was the identification of similarities and shared aspects among system in selected cities (Chapter 5). The identification of guidelines and public policies generated a comparable scheme described in the following tables as follows:

LONDON	BERLIN	TOKYO	NEW YORK
L1. Informing producers and consumers of the value of reducing, reusing, and recycling municipal waste **L2.** Reducing the climate change impact of London's municipal waste management **L3.** Capturing the economic opportunities of municipal waste management **L4.** Achieving high municipal recycling and composting rates resulting in the greatest environmental and financial benefits **L5.** Stimulating the development of new municipal waste management infrastructure in London, particularly low-carbon technologies **L6.** Achieving a high level of street cleanliness	**B1.** The prevention of waste and the avoidance and minimisation of harmful substances in waste. **B2.** The highest possible level of recovery and recycling from unavoidable waste without harm, depending on the type and composition of the waste and to the extent that if is technically and economically feasible. **B3**. The treatment of non-recoverable waste in order to reduce the quantities and the harmfulness, and the disposal or environmentally-compatible stowage as close as possible to their place of origin. **B4.** The protection of natural resources and the promotion of product responsibility in accordance with the law during the development, production, processing and distribution of products. **B5.** The Implementation of the exemplary role of the public sector, among others for high-quality recovery under applicable regulations, and advising and informing the waste generator according to regulations.	**T1.** Renewable resources should be used to the maximum extent possible, and should be used within a level that allows for their renewal in the long term **T2.** If unavoidable, non-renewable resources may be used within a level that allows them to be substituted by other materials or energy sources **T3.** Environmental impact from human activities should remain within the capacity of the environment to restore itself	**N1.** Set new goals and define new metrics **N2.** Update and clarify recycling and green purchasing requirements for stage agencies authorities. **N3.** Clarify the Solid Waste Management Hierarchy **N4.** Generate and allocate new resources to move "Beyond Waste" **N5.** Reinforce recycling requirements for all generators **N6**. Supplement the "economic markets" clause in the current law with a designated list of recyclables. **N7.** Increase DEC's authority and resources to enforce recycling requirements **N8**. Ensure that every permitted facility maximizes recycling and reuse and otherwise affords opportunities to manage waste at the highest possible point in the hierarchy within the facility's service area. **N9.** Establish disposal restrictions on bulk quantities of mandatory recyclable materials and other materials, including hazardous products, where recovery options are readily available or achievable. **N10.** Require local solid waste management planning **N11.** Authorize local governments to franchise private materials management services. **N12.** Expand the Waste Transporter programmes to place specific requirements on transporters of municipal solid waste (MSW), recyclables, construction and demolition (C&D) debris and historic fill

Table 16 Main principles, policies and key factors of waste management systems in selected cities

It must be noted that the Table 16 was constructed with the identification of the main strategies, public policies and guidelines of each system. Each system is identified by a number and letter in order to facilitate the comparison among them. Therefore, the analysis is summarised as follows:

Aspects	Main emphasis
L2, B3, B4, T1, T2, T3	Environment preservation (protection of natural resources and reduction of greenhouse gases)
L3, B2, N6	Maximizing of economic benefits by environmental actions
L1, B5	Development of information systems
L1, B1, T1, N3	Waste hierarchy
L1, L4, B2, N2, N5, N6, N8	Improvement of recycling
L5, B3, N8	Diversification of treatments and adoption of new technologies
N5	Participation of all generators
L4, B2	Economic and financial feasibility

Table 17 Main aspects of interest of principles, policies and key factors of selected systems.

As can be observed in Table 17, similar to the previous cases, the analysis resulted in the identification of key aspects. Therefore, in addition to the elements from the recommendation and the SWOT matrix, the aspects from selected cities generated the underlying basis to formulate guiding principles and specific strategies.

Each result of the three elements (recommendations, SWOT matrix, and selected cities) was located in a general category in order to create the final principles and strategies of the programme. Recurrent aspects in the three different elements were identified, therefore, it was necessary to categorise ideas in order to provide the key foundations for the integrated programme. Table 18 shows the categorisation of each result according to a guiding principle, and to a strategy focused on the specific element. As can be seen, some elements are covered in different guiding principles and in different strategies, this represents the idea of an integration of actions due to each element should be understood as a particular activity but with significant relation with other components of the waste management system.

Element	Principle	Strategy
Recommendations		
Reduction of mixed waste	• Prevention and minimization.	• Minimization and prevention of generation. • Separation at source.
Development of recycling centres. Proper use of bins. Improvement of environmental legislation Regulation of markets.	• Exploitation and commercialization. • Development and technological innovation. • Self-sufficiency.	• Minimization and prevention of generation. • Selective collection. • Appraisal and use of alternative technologies.
Improvement in collection vehicles Increase separate collection.	• Self-sufficiency. • Safe and proper management.	• Selective collection. • Improvement of infrastructure.
Diversification in operational methods with proper supervision and training.	• Development and technological innovation. • Self-sufficiency. • Safe and proper management.	• Appraisal and use of alternative technologies. • Control of pollution.
Development of engineered landfills Incorporation of waste-to-energy technologies.	• Development and technological innovation. • Self-sufficiency. • Soil protection. • Safe and proper management.	• Appraisal and use of alternative technologies. • Prevention and control of pollution. • Improvement of infrastructure.
Definition of the specific lines of operation for the whole waste management system.	• Communication, education and training. • Policy harmonization. • Share responsibility.	• Minimization and prevention of generation. • Communication and environmental education.
Incorporation of all stakeholders. Greater emphasis on prevention. Strategies with specific goals, responsible and specific actions.	• Prevention and minimization. • Share responsibility. • Social participation. • Quality and transparency of information.	• Minimization and prevention of generation. • Legal framework. • Evaluation and feedback.
Development of proper communication system Institutional coordination among agencies and organisations.	• Communication, education and training. • Quality and transparency of information. • Sustainable development and metropolitan coordination. • Policy harmonization.	• Communication and environmental education. • Institutional coordination.
The Secretariat of Environment of the Federal District and the Secretariat of Work and Services must design evaluation and supervision programmes.	• Policy harmonization. • Quality and transparency of information.	• Institutional coordination. • Inspection and vigilance. • Evaluation and feedback.
SWOT matrix		
Participation of all sectors involved	• Share responsibility. • Policy harmonization. • Social participation.	• Communication and environmental education. • Legal framework.
Participation of private sector	• Share responsibility. • Development and technological innovation. • Self-sufficiency.	• Improvement of infrastructure. • Legal framework.
Actions according to characteristics of each borough	• Policy harmonization.	• Minimization and prevention of generation. • Selective collection. • Separation at source.
Provision of training and information campaigns	• Communication, education and training. • Quality and transparency of information. • Social participation.	• Communication and environmental education. • Minimization and prevention of generation.
Rewards and fines schemes	• Social participation. • Polluter pays.	• Minimization and prevention of generation. • Legal framework. • Control of pollution.
Significant linkage among local, state and federal governments	• Policy harmonization. • Share responsibility. • Sustainable development and metropolitan coordination.	• Institutional coordination.
Regulation of markets	• Social participation. • Self-sufficiency.	• Legal framework.
Improvement of legal framework.	• Prevention and minimization. • Policy harmonization.	• Legal framework.
Selected cities		
Environment preservation (protection of natural resources and reduction of greenhouse gases)	• Soil protection. • Development and technological innovation. • Policy harmonization.	• Control of pollution. • Legal framework.
Maximizing of economic benefits by environmental actions	• Exploitation and commercialization.	• Appraisal and use of alternative technologies. • Improvement of infrastructure.
Development of information systems	• Communication, education and training. • Quality and transparency of information.	• Communication and environmental education.
Waste hierarchy	• Prevention and minimization.	• Minimization and prevention of generation. • Legal framework.
Improvement of recycling	• Prevention and minimization. • Exploitation and commercialization.	• Appraisal and use of alternative technologies. • Improvement of infrastructure.
Diversification of treatments and adoption of new technologies	• Development and technological innovation. • Self-sufficiency. • Safe and proper management.	• Appraisal and use of alternative technologies. • Improvement of infrastructure.
Participation of all generators	• Share responsibility. • Policy harmonization. • Social participation.	• Communication and environmental education. • Legal framework.
Economic and financial feasibility	• Exploitation and commercialization. • Development and technological innovation.	• Appraisal and use of alternative technologies. • Improvement of infrastructure.

Table 18 Guiding principles and strategies of the programme, according to elements from previous analyses.

Table 18 shows how results from the three different analyses (which can be detailed in previous chapters of the thesis) are integrated as guiding principles and strategies. These principles and strategies are the key foundations to develop the integrated activities within the programme. The guiding principles and strategies obtained in Table 18 are described in the following sections.

6.3 Guiding principles of the programme

- **Operation**

Principle of waste prevention and minimisation: involves the adoption of operative measures for handling which allow the population to reduce MSW, not only in amount but also in the environmental damage potential. Such measures can comprise: substitution of raw material and products, redesign of processes and products, valorisation, reuse, recycling, separation etc.

Principle of exploitation and commercialisation: is applied to waste which can be susceptible to exploitation and can be assigned a monetary value through the existing infrastructure and treatment methods, thus reducing the amount of waste in final disposal sites and encouraging the use of secondary raw materials.

The polluter pays principle: provides that each person, or organisation, is responsible for the consequences of their actions which are associated with environmental impacts. It will be also responsible for the costs of environmental impacts that are caused by the restoration of the impacted sites and soils; the responsibility shall not be transferred to other members of society or future generations.

Principle of soil protection: involves the development of measures to prevent and control the pollution of soil and groundwater, which is caused by improper and uncontrolled disposal of solid wastes.

Information

Principles of communication, education and training: involves the development of actions to promote knowledge and awareness related to the problems of waste management, promoting the training of specialists in the field in order to establish a culture of minimisation and of an integrated management, thus leading to a change in the behaviour of society.

Principle of social participation: promotes the participation of society, through established schemes to prevent generation, increase separation, and monitor undertaken actions of the government of the Federal District.

Principle of quality and transparency of information: involves the systematization, analysis, sharing and dissemination of information regarding to the generation, characterization and integrated management of solid waste, in addition, the information of programmes and activities that are carried out in the field. Furthermore, it must ensure the reliability of the data from environmental authorities, and the free access of citizens to information that shall be available for consultation on public sources.

- **Technology**

Principle of development and technological innovation: suggests management improvements which must be based on the results of the scientific and technological researches that are conducted in educational institutions of the Federal District, governmental institutions, and private sector. The development of technology shall aim to use state-of-the-art technology for waste management resulting in the prevention and minimization of MSW generation from industry, services, businesses and the general public.

Principle of self-sufficiency: states that there must be infrastructure and the equipment necessary to ensure compliance with the outlined strategies of the programme.

Principle of safe and environmentally proper management: requires that waste management is carried out with proper infrastructure through the different stages of the process in order to avoid the transfer of pollutants from one environmental sector to another.

- **Coordination**

Principle of sustainable development and metropolitan coordination: The sustainable development shall be addressed with a metropolitan coordination. Federal, state and local authorities shall develop joint works considering economic, social and cultural dimensions.

Principle of policy harmonization: suggests congruence between environmental policies (territorial and ecological, urban development, environmental agenda of Mexico City, green plans, etc.) and the integrated waste management of MSW in the Federal District.

Principle of shared responsibility: involves the recognition of responsibility and participation of producers, importers, exporters, traders, consumers and the three levels of governmental authorities in order to achieve efficiency and effectiveness in the integrated waste management.

6.4 Main strategies of the programme

The following strategies represent the main aspects to be addressed within the integrated programme. Although in the theoretical approach, the undertaking of actions should follow a logical and chronological order, the practical development of the strategies involves the simultaneous performance of different activities. Therefore, the following listing of strategies is based on the premise that in the practice, each element is as important as any other, and are presented as follows:

- **Communication and environmental education:** Strengthening of the participation of society through education and sensitization training programmes which are designed for involved parties, and thus establishing a culture of separation, reduction, and reuse.
- **Minimization and prevention of generation:** Increase the fulfilment of plans for an integrated waste management that is based on reduction goals establishing deadlines and responsibilities of all involved parties. To minimize generation at source through the redesign of packaging, and procuring the use of biodegradable and recyclable materials.
- **Separation at source:** Strengthening all sectors of society the separation into waste classification according to the guidelines from the Law of Municipal Solid Waste of the Federal District.
- **Selective collection:** Developing integration schemes that enable the operation of selective collection according to the characteristics of each borough and taking into consideration the modernization and optimization of the vehicles fleets through extensions in collection routes.
- **Improvement of infrastructure:** Improvement of the existing facilities for waste management through the development of complementary works to optimize capacity and achieve efficiency in all facilities.
- **Appraisal and use of alternative technologies:** Encouraging the evaluation and adoption of alternative technologies for waste management, promoting scientific and technological research mainly in the field of recycling and treatment of waste.
- **Prevention and control of pollution:** Designing processes or methods to prevent pollution that is caused by inappropriate disposal of waste.

- **Legal framework:** Strengthening current environmental legislation in order to improve legal guidelines and to diversify the coverage and scope of laws related to waste management.
- **Institutional coordination:** Generating plans to unify efforts and works related to waste management in order to eliminate bureaucratic barriers and make efficient actions and activities.
- **Inspection and vigilance:** Ensuring the fulfilment of the provided guidelines of the integrated waste management programme through constant inspections of any irregularity in the waste management process and infringements of applicable legislation.
- **Evaluation and feedback of the programme**: Designing a scheme of indicators in order to measure the performance of the programme and to ensure the validity of information.

6.5 Foundation of the programme

The programme aims to develop activities to achieve an improvement in the waste management system of Mexico City. Section 6.2 showed how the guiding principles and strategies were designed according to the results of different evaluations. However, it is important to locate the basis of the programme in the international context in order to demonstrate a proper consideration of elements within the guiding principles and the strategies.

Different international organisations have developed recommendations and observations related to waste management. The recommendations aim to encourage waste prevention and minimisation techniques in order to generate sustainability. International organisations are aware of the importance that an integrated approach to waste issues can impact significantly on the sustainable consumption of human resources. Therefore, three international organisations were analysed, the organisation and the related publications included:

- Solid Waste Management in the World's Cities 2010 - United Nations Human Settlements Programme (UN-HABITAT)

- Report of the first expert group meeting assessment of the economic benefits of solid waste management in selected Caribbean Countries - Economic Commission for Latin America and the Caribbean (ECLAC)
- Strategic waste prevention - Organisation for Economic Co-operation and Development (OECD)

UN-HABITAT
• Solid waste modernization processes involve the "reinvention" of recycling. • Developing world cities are serviced by numerous intermediaries (often informal-sector players). • Effective disposal should be guaranteed in order to minimize health risks. • In order to optimize the working conditions, it is necessary to improve the infrastructure and to consider occupational health aspects. • Municipalities could not successfully collect and remove waste without active cooperation from the service users. • Adoption of technologies for waste management depends on the institutional, political frameworks. • Low and middle-income countries must extend collection coverage, and increase infrastructure. • Industrialized countries reduce their consumption of natural resources, limit the generation, increase recycling and avoid all exports of waste and technologies contributing to climate change. • Supporting of projects and technologies that divert organic waste from landfills • Recognize the critical and productive role that the recyclers contribute to the mitigation of climate change. • Invest resources in programmes for sorting at source that ensure a dignified way of life for all workers and traders from the recycling industry.
ECLAC
• Waste manage should be linked to other challenges, including climate change, water pollution, wetlands protection, reef protection and public health. • Waste classification should integrate office/commercial, open markets, event related waste, household hazardous waste, yard and street-cleaning waste. • Changes in retailing, packaging and shorter product lifecycles should be explored. • Significant gaps in the status of waste legislation should be addressed immediately. • The informal role that waste pickers played in the overall system, in addition the prevalence of illicit dumping is a characteristic of Latin America and Caribbean Countries. • Feasibility of waste-to-energy in the region should be explored, according to cost/benefit studies. In addition, landfills are potential sources of capturing the gas for carbon credits. • Non-engendered landfills involve that the rate of decomposition of waste is retarded, which compromised the caloric value of the waste, rendering it an ineffective methane capture process. • Composting is a viable waste management process for the region, if managed properly. • Robust business plans to improve infrastructure should include target markets and defining proper systems. Small-scale operations might be better suited to the region. • The proper provision of data and information would help to facilitate the development of the waste management sector in the region.
OECD
• Fostering environmentally advantageous changes in production and consumption patterns. • Inducing deployment of technologies that lead to less natural resource extraction and associated "hidden" material flows. • Freeing up financial resources for other priorities by lowering waste management costs. • Stimulating market demand for environmentally improved products and services through greener procurement practices. • Minimising human and ecological health risks from waste avoiding treatment and disposal. • Reducing social conflict associated with the creation of new landfill and incineration facilities. • Promoting co-operative approaches between stakeholders to meet waste prevention targets • Fostering environmentally advantageous changes in production and consumption patterns.

Table 19 Main recommendation and observation related to waste management from three international organisations (UN-HABITAT, 2010; ECLAC, 2011; OECD, 2000).

Table 19 shows the main recommendations and observations from selected international organisations. Recurrent aspects can be observed among the recommendations. In the case of Mexico City, several points are applicable, including the informal role of waste pickers, the numerous intermediaries in the recycling chain, the significant gaps in the status of waste legislation, the lack of a proper collection coverage and infrastructure.

In addition, other observations are also applicable to the system in Mexico City were evidenced. Therefore, the guiding principles and the strategies formulated in the previous sections, align with the main recommendations and observations from international organisations. The guiding principles and strategies were built on results from evaluations (as shown in section 6.2); however, the formulation took also into consideration the proper coverage of different aspects identified by these international organisations in order to generate the integrated approach to the waste management issue.

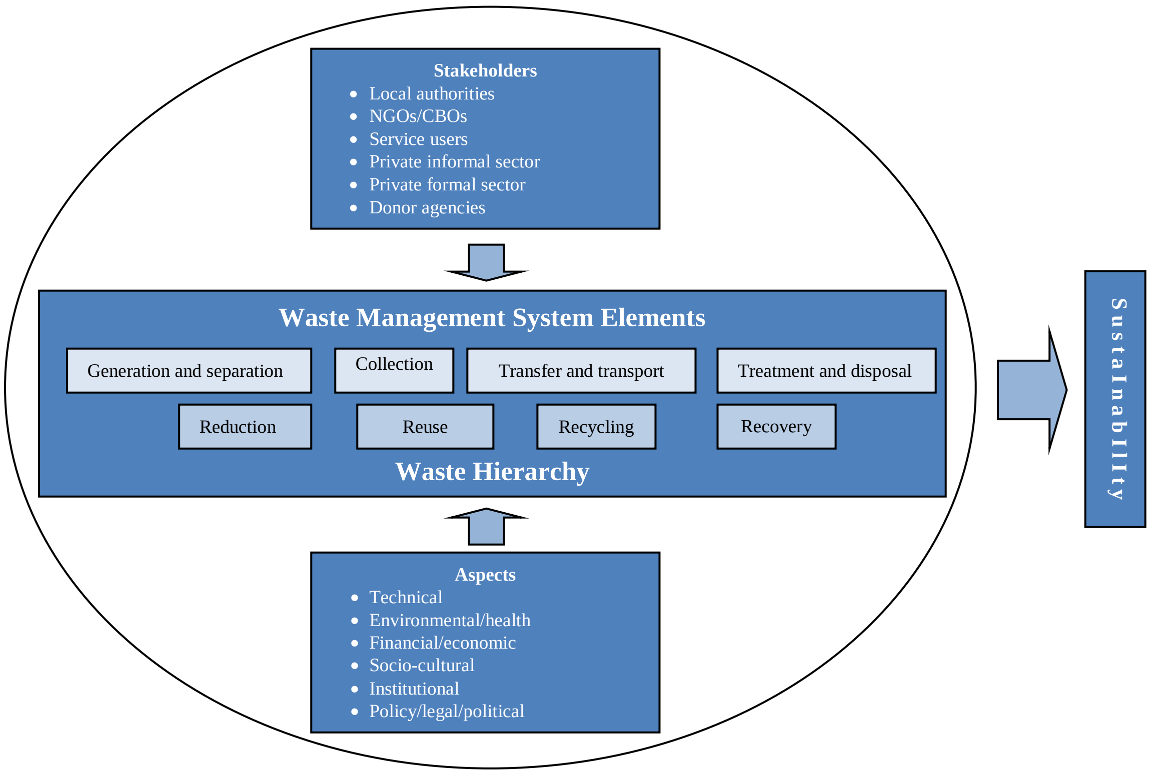


Figure 47 Integrated sustainable waste management (Adapted from UN-HABITAT, 2010)

Figure 47 represents the integrated waste management system. It can be noted that the waste management should be based on the waste hierarchy. Several stakeholders including government, waste producers (householders and private sector) and organisations, interact within a context with technical, environmental, financial, socio-cultural, political and legal aspects.

The integrated programme is intended to consider all those aspects and the direct interaction of all stakeholders in order to achieve a sustainable system and thus, to increase the quality of life in Mexico City. The following sections specifically focus on the formulation of the general objective, the scope and the development of the strategies through the determination of specific actions, responsibilities and tentative timescales.

6.6 Scope of the programme

The programme concerns individuals, institutions and organisations that generate, store, transport, separate, reuse, recycle, treat, dispose or carry out any activity related to Municipal Solid Wastes in the Federal District. The programme is also applicable to all governmental institutions, and departments of government of the Federal District, which within their scope, have relation to the waste management of the City. In the same way, manufacturers, producers, distributors, importers, exporters, marketers and service providers, which directly or indirectly, generate and handle MSW. Solid wastes which are considered in the programme do not include hazardous wastes which should be handled and treated according to the specifications of the General Law for Ecological Equilibrium and any other applicable legislation. The first stage of the programme involves 6 years long since its date of application, after which, strategies and activities should be reviewed in order to provide continuity.

6.7 General objective of the programme

To contribute to the improvement of the quality of life of the residents and to the environment within the Federal District, ensuring the effective coverage and efficiency of the waste management system. Also, minimising both the generation and disposal of waste through an efficient and modern integrated management system that is based on the participatory planning of all sectors of society.

6.8 Development of strategies

6.8.1 Communication and environmental education

Environmental education and communication are essential to develop the strategies, from section 6.4. Education and communication must be in accordance with the technical-operative strategies. The main objective of this strategy is to promote the effective participation of all stakeholders in the actions mentioned in the different strategies of the programme.

6.8.1.1 Effective communication

Effective communication is able to generate and motivate changing attitudes and behaviours. Therefore, it must be considered as a constant factor in integrated waste management in order to strengthen the dissemination of actions. The educative communication of the programme is given in two types of coverage: (1) focused coverage related to actions consistent with the identified requirements for specific targets, (2) wide coverage related to information from permanent campaigns.

Objectives:

- To develop a strategy of communication focused on promoting separation, reuse and recovery of organic and inorganic waste.
- To develop waste reduction campaigns encouraging the individual demand of products with less packaging and with valorisation or reuse.
- To disseminate actions and results in integrated waste management in order to encourage continuity in the participation of different sectors of the population.
- To strengthen knowledge of the legal framework related to waste management in the Federal District.
- To reinforce the environmental communication and the education strategy throughout the application of the integrated programme.

Goals:

- From the second quarter of year 1 to the last quarter of the year 6, campaigns aimed to constitute the permanent communication plan shall be in continuous operation.
- At least 75% of the population of the Federal District must be informed of proper waste management by year 3 and 100% by year 6.

Specific activities:

1. Develop perception studies related to campaigns.
2. Design and grant a special award for boroughs focused on separation activities
3. Design and distribute in all households of the Federal District flyers and brochures related to proper separation.
4. Implement plans to generate participation in the handling planning.
5. Organise an annual event focused on the waste management.
6. Design special campaigns and programmes for bulky waste.
7. Organise an annual event for interchanging products that can be re-used.
8. Organise an event to celebrate the World Environment Day.
9. Design campaigns for specific types of waste (plastic, glass, organic etc.).
10. Promote discussion forums where all inhabitants can express concerns, doubts and opinions.
11. Organise a fair for entrepreneurs focused on waste management activities.
12. Spread information related to the dangers and negative factor of clandestine landfills.
13. Create a public service centre dedicated to receive 24/7 concerns from the general public.
14. Design communication campaigns every time a change or update is carried out in any programme, legislation or strategy.
15. Organise an event to communicate progress and activities carried out to be known to the inhabitants.
16. Build an updated database with accurate and reliable statistic information related to (generation, recycling, reuse, treatment), and any other waste management activity to be consulted online by all public.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD								■				■				■				■				■
2	SE-FD		■			■				■				■				■				■			
3	SE-FD, SWS-FD, PB			■	■					■				■				■				■			
4	SE-FD					■	■							■								■			
5	SE-FD							■				■				■				■				■	
6	SE-FD, PB					■	■							■								■			
7	SE-FD, PB				■				■				■				■				■				■
8	SE-FD, SWS-DF						■				■				■				■				■		
9	SE-FD, SWS-DF	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
10	PB					■		■		■		■		■		■		■		■		■		■	
11	SE-FD					■				■				■				■				■			
12	SE-FD, PB	■	■	■	■	■	■	■	■	■	■	■	■	■											
13	SE-FD		■	■	■	■	■																		
14	SE-FD			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
15	PB					■				■				■				■				■			
16	SWS-FD, SE-DF INEGI			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District
PB=Political Boroughs
INEGI=National Institute of Statistics and Geography

Table 20 Timescales and responsible for effective communication

6.8.1.2 Training

Training for integrated waste management requires specific objectives according to the target audience and, to the desired behaviour or action. The training approach is modular, in order to solve large and complex issues through the modification of different factors obtaining results in a permanent training scheme.

Objectives:

- To form a group of trainers in solid waste management, which carry out the proposed training actions of the programme.
- To establish training guidelines of an integrated waste management focused on different sectors of society in the Federal District.
- To strengthen the training model considering staff of boroughs, environmental agencies, public officials, civil organisations, research institutions, industry, civil judges and public safety personnel.
- To incorporate solid waste as compulsory in training of all staff in the government of the Federal District.

Goals:

- ➢ 160 trainers-promoters of municipal solid waste for the Federal District (Ten per borough).
- ➢ At least 1,815 trained local promoters (at least each per neighbourhood)

- At least seven differentiated special courses related to waste management activities (separation, reuse, collection, transfer, recycling, treatment, disposal)
- Handbooks for every differentiated course developed (instructor and participant).
- Brochures to guide the training activities.
- Evaluation systems to measure the effectiveness of the courses.

Specific activities:

1. Find an agreement with experts and specialists in the matter to train 160 promoters.
2. Organise the logistic to train local promoters in each neighbourhood in the Federal District.
3. Provide differentiated special courses (Develop a handbook for each course).
4. Teach a course related to operation of regulated collection centres (Elaborate brochure).
5. Teach a course of legislation and laws related to waste management (Elaborate brochure).
6. Design and implement the evaluation to determine the level of knowledge and preparation of the all staff related to waste management.

	Responsible	**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Year 5**				**Year 6**			
1	GFD, SE-FD			■	■	■				■				■				■				■			
2	SE-FD, PB			■	■	■				■				■				■				■			
3	Trainers-promoters				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4	Trainers-promoters Local promoters				■	■			■	■			■	■			■	■			■	■			
5	Trainers-promoters Local promoters				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
6	DE-FD, Trainers-promoters								■				■				■				■				■

GFD=Government of the Federal District
SE-FD=Secretariat of Environment of the Federal District
PB=Political Boroughs
SWS-FD=Secretariat of Works and Services of the Federal District

Table 21 Timescales and responsible for training

6.8.2 Minimization and prevention of generation

6.8.2.1 Handling plans

Handling plans should be used as management instruments which aim to efficiently handle MSW. Such plans should take into consideration activities related to prevention and minimization and the reuse of waste as raw materials in different processes. Plans mainly should focus on waste of high volume from special operations of commercial and services activities. There is a need for developing plans to cover special waste, including batteries, mobiles, electronic devices, tyres, PET, bulky waste among others.

Objective:

- To increase the development of handling plans focused on the high volume generation and special waste in order to reduce waste, improve integrated handling and increase separation.
- To create an information systems among institutions related to handling plans.

Goals:

- ➢ By the end of year 6 all governmental documents related to handling plans shall be revised and improved.
- ➢ In the third quarter of year 1, commercial establishments which aim to collect, handle, treat, reuse, recycle, and dispose of waste, shall be registered and authorized to operate in the Federal District.
- ➢ To focus plans on establishments which produce more than 500kg of wastes, later, generators of waste between 250 and 500 kg, finally generators between 50 and 250 kg.
- ➢ To increase the regulation of high volume generators through handling plans by year 5, in at least 50%.
- ➢ To regulate small generator of hazardous waste.
- ➢ By year 2, coordination mechanisms among institutions shall be implemented to systematize and transfer information related to waste management, special waste, and hazardous waste.

Specific activities:

1. Design and establish the format of handling plans.
2. Strengthen and improve procedures to obtain environmental licenses.
3. Define a procedure to register and authorize new establishments related to waste management.
4. Verify that any handling plan was developed according to the guidelines of environmental licenses.
5. Establish information systems for data from handling plans.
6. Cooperate with federal institutions to cover hazardous waste management.
7. Create a structured schedule to revise handling plans periodically.

8. Determine specific staff intended to help to structure handling plans.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD			■																					
2	SE-FD			■	■																				
3	GFD, SE-FD, SWS-FD			■	■																				
4	SE-FD	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	SE-FD			■	■																				
6	SE-FD, Trainers-promoters	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
7	SE-FD		■			■				■				■				■				■			
8	SE-FD	■	■																						

GFD=Government of the Federal District
SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District

Table 22 Timescales and responsible for handling plans

6.8.2.2 Handling of special waste

Handling plans are documents which are considered in the Law of Municipal Solid Waste of the Federal District. Such plans can help to prevent generation by handling of special wastes.

Objectives:

- To develop a scheme of plans for handling of special waste focused on the incorporation of the private sector as a co-responsible generator in order to guarantee the proper treatment and disposal.
- To consolidate and promote the existing plans

Goals:

- ➢ By year 6, there must be handling plans for construction waste, sludge, electronic waste, medical waste, oils, and any other required.
- ➢ By the third quarter of year 5, a handling plan shall be managed by focusing on enterprises which produce waste with high level of environmental impact in order to prevent negative impacts on the environment.
- ➢ A sensitization campaign shall be launched to promote participation in handling plans among all involved stakeholders.

Specific activities:

1. To design at least 7 plans for handling of special waste: (1) Construction waste, (2) Sludge, (3) Electronic devices, (4) Batteries, (5) Medicines, (6) Oils, (7) Furniture, (8) any other necessary.
2. Establish criteria to use recycled material (if applicable).
3. Name special staff focus on the revision of plans

4. Develop management mechanisms to supervise the fulfilment of the plans.
5. Coordinate the joint work between private sector and public sector.
6. Evaluate the implementation of penalties programmes for whose causes negative impacts to the environment.
7. Promote the existing plans and seek the participation of more stakeholders.
8. Design an auditory programme to control the application and fulfilment of plans.

	Responsible	**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Year 5**				**Year 6**			
1	SE-FD	■	■	■	■																				
2	SE-FD	■																							
3	SE-FD	■																							
4	SE-FD	■				■				■				■				■				■			
5	SE-FD, Private sector	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
6	SE-FD	■	■	■	■																				
7	SE-FD, PB	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
8	SE-FD, Private sector			■	■				■				■				■				■				■

SE-FD=Secretariat of Environment of the Federal District
PB=Political Boroughs

Table 23 Timescales and responsible for handling of special waste

6.8.2.3 Handling of demolition waste

Approximately each year 1,400 tonnes of demolition waste are disposed of in an uncontrolled manner. The incoming MSW in transfer stations and sorting facilities may include demolition waste. Demolition waste can be recycled; activities in the integrated programme must consider the recycling process for demolition waste.

Objective:

- To generate increased re-use and recycling of waste from demolition and construction activities in order to decrease the uncontrolled disposal of such wastes.

Goal:

- By year 6, recycling sector focusing on demolition waste shall be created.

Specific activities:

1. Create an NOM (Spanish for Official Mexican Standard, which is legal directive from an specific governmental agency) to establish a proper final disposal of demolition and construction waste.
2. Selection and evaluation of final disposal sites.
3. Promote the proper separation and disposal of demolition waste.
4. Encourage the use of recycled materials in the construction industry.

5. Stipulate presentation of handling plans of demolition waste, prior the issue of construction licenses.
6. Issue certificates of completion of work only after wastes have been properly disposed of.
7. Allow the participation of the private sector to handle demolition and construction waste.
8. Implement the use of recycled materials in contracts for construction in the public sector. Materials can include: glass, plasterboard, plastics, wood, aggregates, paper, compost and other organics, rubber, cement replacement (eg pulverised fuel ash and ground granulated blast furnace slag).
9. Promote joint work among other federal entities for the handling of demolition and construction wastes.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	GFD, SE-FD, SWS-FD, SEMARNAT					■	■	■	■																
2	SE-FD					■	■	■	■	■	■														
3	SE-FD					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4	SE-FD					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	SE-FD, SWS-FD						■																		
6	SE-FD, SWS-FD						■																		
7	SE-FD, Private Sector					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
8	SE-FD					■	■																		
9	GFD, Federal government					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

GFD=Government of the Federal District
SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District
SEMARNAT= Secretariat of Environment and Natural Resources

Table 24 Timescales and responsible for handling of demolition waste

6.8.2.4 Reduction of plastic bags

Although the Law of Municipal Solid Waste of the Federal District recommends that the distribution of polyethylene plastic bags in commercial establishment should include a charge in order to discourage in the use; a significant estimation of plastic waste in the Federal District is composed of polyethylene plastic bags. The use of stricter measures can help to reduce the use of polyethylene plastic bags. Polyethylene plastic bags are highly used by establishments due to low costs of production. The integrated programme is intended to reduce the amount of polyethylene plastic bags through the production of lasting bags with recyclable materials.

Objective:

- To encourage the use of recycled bags to reduce the use of plastic bags.

- To promote the production of plastic bags using only recycled materials.
- To promote campaigns to sensitize people of the environmental implications of plastic bags.

Goal:

- By year 6, there must be a significant reduction in the amount of plastic bags disposed of.

Specific activities:

1. Launch a campaign related to the benefits of alternative bags and the negative aspect of plastic bags.
2. Elaborate a NOM to produce plastic bags with recycled material.
3. Create especially collection centres of plastic bags.
4. Contact the commercial sector to feedback the programme.
5. Evaluate the development of programmes focused on limiting the distribution of free plastic bags in commercial establishments.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD	■	■	■	■	■	■																		
2	SE-FD			■	■	■	■																		
3	SE-FD			■	■																				
4	SE-FD, Private sector				■																				
5	SE-FD	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

SE-FD=Secretariat of Environment of the Federal District

Table 25 Timescales and responsible for reduction of plastic bags

6.8.2.5 Reduction of paper in governmental institutions

Due to the documents, files, reports, among other stationery materials, the generation of paper waste can be managed in order to increase separation and recycling. Governmental institutions can apply a number of different actions to control the use of paper.

Objectives:

- To increase the amount of recycled paper in governmental institutions.
- To consolidate a programme to recycle paper and cardboard.

Goal:

- By year 6, the amount of paper and cardboard in governmental institutions must be reduced by, at least 50%.

Specific activities:

1. Estimate the consumption levels of paper to determine trends.
2. Run the programme as a pilot test in some institutions to evaluate performance.
3. Apply the programme to all institutions.
4. Monitor results and review the programme.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE, GFD	■	■	■	■																				
2	SE-FD, Institutions					■	■	■	■																
3	SE-FD, Institutions									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4	SE-FD, PB								■				■				■				■				■

SE-FD=Secretariat of Environment of the Federal District
GFD=Government of the Federal District
PB=Political Boroughs

Table 26 Timescales and responsible for reduction of paper in governmental institutions

6.8.2.6 Reduction of PET

A high percentage of plastic waste is formed by bottles, containers, and other packaging products which are made of PET. The programme contemplates a weight reduction of the total PET. This can be achieved by producing lighter products in order to use the minimum possible plastic.

Objective:

- To reduce the weight of any container made of PET.

Goal:

- ➢ By year 6, the amount of PET must be reduced in at least 30% in terms of weight.

Specific activities:

1. Organise an expert group aimed to identify the opportunities to reduce PET.
2. Organise a meeting with the principal producers of PET materials.
3. Carry out adjustments in the law to give the initiative a legal base.
4. Launch a dissemination campaign.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD	■	■	■	■	■	■																		
2	SE-FD, Private sector			■	■	■	■																		
3	SE-FD, GDF	■	■	■	■	■	■	■	■																
4	SE-FD, PB								■	■	■	■	■												

SE-FD=Secretariat of Environment of the Federal District
GFD=Government of the Federal District
PB=Political Boroughs

Table 27 Timescales and responsible for reduction of PET

6.8.2.7 Reduction of newspapers

Technological advancement has helped to reduce the number of printed newspapers and magazines due to the possibility of electronic readings. The international trend is focused on printing with a standard weight of 45g/m^2. However, just a few newspapers circulating in the Federal District follow this trend of weight as they are higher than the standard. Therefore, there is a need to reduce the amount of used paper.

Objective:

- To reduce the weight of printed newspapers in the Federal District.

Goal:

- By year 6, there must be a reduction of at least 30% by weight.

Specific activities:

1. Organise meetings with main editors and printers of newspapers.
2. Present optional design for lighter newspapers.
3. Carry out adjustments in the law to give the initiative a legal base.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD, Private sector				■	■	■	■																	
2	SE-FD	■	■	■	■																				
3	SE-FD, GFD	■	■	■	■																				

SE-FD=Secretariat of Environment of the Federal District
GFD=Government of the Federal District

Table 28 Timescales and responsible for reduction of newspapers

6.8.2.8 Economic incentives

The reduction in the generation and the final disposal of MSW can be achieved through the application of environmental actions which are accompanied by programmes to reward initiatives and proper performance in waste management activities.

Objectives:

- To promote a change in the behaviour of waste generators, in order to produce self-awareness of environmental protection and sustainable development.
- To grant incentives to whose carry out actions which aim to reduce, reuse and recycle MSW, and whose use technologies environmentally friendly for MSW treatment.

- To promote social equity in the distribution of costs and benefits related to the generation and integrated handling of MSW.
- To reinsert into the market products which, according to their characteristics can be reused and recycled.

Goals:

- ➢ By year 6, there must be economic-fiscal instruments aimed to benefit environmental practices.
- ➢ By year 6, a complete incentive scheme for waste management shall be created.

Specific activities:

1. Design economic-fiscal instruments to provide incentives.
2. Design a scheme of awards for efficiency in waste management.
3. Organise an event to award winners and participants.
4. Measure, feedback and improvement of the programme.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD, SFPC, GFD	■	■	■	■	■	■	■	■																
2	SE-FD, PB	■	■	■	■																				
3	SE-FD								■				■				■				■				■
5	SE-FD					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

SE-FD=Secretariat of Environment of the Federal District
SHCP=Secretariat of Finance and Public Credit
GFD=Government of the Federal District
PB=Political Boroughs

Table 29 Timescales and responsible for economic incentives

6.8.3 Separation at source

The separation directly at source involves the avoidance of mixed wastes. The separation into organic and inorganic (including different categories) helps to improve the subsequent activities of collection and selection. This activity must be carried out by the producer of the waste according to the provided guidelines in the law.

6.8.3.1 Neighbourhoods of the Federal District

The Federal District is divided into 16 boroughs which are formed by neighbourhoods and towns. There are 1,775 neighbourhoods and 40 towns in the Federal District. The separation at source should be carried out in the households and businesses prior collection.

Objectives:

- To separate MSW into organic waste and different categories of inorganic waste.
- To dispose of segregated MSW into separate containers.
- To deliver separated waste to the clean public system or any collecting enterprise authorized.

Goals:

- The inhabitants of the Federal District shall separate waste, otherwise the waste shall not be collected.
- By year 6, at least 80% of waste should be separated before collection.

Specific activities:

1. Organise local committees (per each borough or per neighbourhood).
2. Distribute special containers and bags to population.
3. Train staff of the cleaning department and local committees on selective separation and collection.
4. Inform the population of the selective separation and collection.
5. Adapt transfer stations to receive separated waste.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD	■	■																						
2	SE-FD, SWS-FD			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3	Local promoters	■	■																						
4	SE-FD, local trainers	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	SWS-FD	■	■	■	■	■	■	■	■																

SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District

Table 30 Timescales and responsible for separation at source in neighbourhoods of the Federal District

6.8.3.2 Commercial, industrial and service establishments

Objective:

- To separate MSW into organic waste and in different categories of inorganic waste.
- To dispose of separated MSW into specific separated containers.
- To deliver separated waste to the cleaning department or any authorized collecting enterprise.
- To develop authorized handling plans when necessary.
- To encourage the building of compost centres in places with high volume generation.

Goals:

- Enterprises and establishments which are required to submit handling plans, must separate waste in organic, inorganic or special wastes within their own facilities prior collection.
- By the second quarter of year 2, all commercial, industrial and service establishments should have handling plans that are authorized by the Secretariat of Environment of the Federal District.
- All establishments shall operate according to their authorized handling plans.
- If possible, the Secretariat of Environment the Federal District shall encourage the creation of compost centres within the facilities of producers with high volume of waste.

Specific activities:

1. Offer training and advice services to establishments related to separation and handling of waste.
2. Install special containers to separate waste.
3. Elaborate, present, improve and update handling plans.
4. Verify and authorize handling plans.
5. Apply measures of handling plans according to the law.
6. Elaborate a date base related to the high volume generators.
7. Organise meetings with high volume generators to plan compost centres.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD			■	■																				
2	SWS-FD			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3	Generators					■				■				■				■				■			
4	SE-FD					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	Generators			■	■																				
6	SE-FD			■	■																				

SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District

Table 31 Timescales and responsible for separation at source in commercial, industrial and service establishments

6.8.3.3 Schools, universities and research centres

Objectives:

- To promote separate waste collection among research, administrative and academic community of all education levels.
- To develop a specific handling plan for waste separation in educative institutions.

Goals:

- ➢ Provide information to sensitize students, teachers and administrative staff in education centres related to the environmental benefits that can be achieved with efficient separation.
- ➢ By year 2, all schools in the Federal District should have handling plans.
- ➢ By the second quarter of year 2, all schools in the Federal District should separate and manage their waste according to handling plans.

Specific activities:

1. Offer training and advice services to schools related to separation and handling of waste.
2. Install special containers to separate waste.
3. Elaborate, present, improve and update handling plans.
4. Verify and authorize handling plans.
5. Apply measures for handling plans, according to the law.
6. Elaborate a datebase related the high volume generators.
7. Organise meetings to plan compost centres.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD					■	■																		
2	SWS-FD					■	■											■	■						
3	Generators					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4	SE-FD					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	Generators					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
6	SE-FD			■	■	■	■																		
7	SE-FD, IE			■	■	■	■																		

SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District
IE=Institutions of Education

Table 32 Timescales and responsible for separation at source in schools, universities and research centres

6.8.3.4 Marketplaces, street markets and shops in public thoroughfare

Objectives:

- To separate into specific categories all waste in public thoroughfares in order to be properly collected and disposed of.

Goals:

- ➢ Marketplaces, street markets and shops in public thoroughfares in all the Federal District should separate waste and develop handling plans when necessary.
- ➢ By year 3, all marketplaces, street markets and shops in public thoroughfares in the Federal District shall apply the provided measures in the developed handling plans when necessary.

Specific activities:

1. Elaborate a database of marketplaces, street markets and shops in the public thoroughfare.
2. Train and advise marketplaces in separation and handling of waste.
3. Install special containers to separate waste.
4. Elaborate, present, improve and update handling plans.
5. Verify and authorize handling plans.
6. Apply measures related to handling plans, according to the law.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD, PB					■	■																		
2	Local promoters					■	■	■	■																
3	SWS-FD								■	■												■			
4	Generators				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	SE-FD				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
6	Generators				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

SE-FD=Secretariat of Environment of the Federal District
PB=Political Boroughs
SWS-FD=Secretariat of Works and Services of the Federal District

Table 33 Timescales and responsible for separation at source in marketplaces, street markets and shops in public thoroughfare

6.8.3.5 Bulky waste

Bulky waste is defined as voluminous waste that can include household goods, furniture or any waste that, due to the large size, requires special collection.

Objectives:

- To collect all bulky waste in the Federal District
- To create special centres with the aim of collecting bulky waste.

Goals:

- ➢ By year 3, a plan to operate a collection of bulky waste must be consolidated and permanently activate.

Specific activities:

1. Elaborate an operational plan to collect bulky waste.
2. Design an information campaign of bulky waste.
3. Create special collection centres for bulky waste.
4. Coordinate and train special staff to collect bulky waste.
5. Design an special service to collect bulky waste.

	Responsible	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
1	SE-FD						
2	SE-FD, local promoters						
3	SE-FD, Private sector						
4	SE-FD, local promoters						
5	SE-FD, Private sector						

SE-FD=Secretariat of Environment of the Federal District

Table 34 Timescales and responsible for bulky waste

6.8.3.6 Collection centres

A collection centre is a specific place to store waste for a period of time. Collection centres aim to receive, change and sell items from waste separation. Centres that are focused on reception of paper, plastic, metal, wood, cardboard, PET, glass among others, require a regulated scheme to operate in proper conditions. The creation of authorised and regulated collection centres may improve recycling and reuse activities.

Objectives:

- To create authorized and regulated collection centres.
- To gradually increase the amount of collection centres.
- To increase the amount of waste in collection centres.
- To generate a commercialisation, reuse and recycling culture of waste, among the population of the Federal District.
- To promote the use of collection centres.

Goals:

- ➢ By year 2, there must be a database of collection centres.
- ➢ By year 2, collection centres operating in the Federal District must be regulated and authorized by the Secretariat of Environment of the Federal District.

Specific activities:

1. Create a database of existing collection centres.
2. Visit collection centres to evaluate operations.
3. Defined operational guidelines to be achieved in order to authorised new collection centres.
4. Elaborate statistical reports to disseminate amount, type and final disposal of waste.
5. Elaborate a plan to increase the amount of waste managed in collection centres
6. Incentive the creation of new collection centres among public and private sector.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD																								
2	SE-FD																								
3	SE-FD																								
4	SE-FD																								
5	SE-FD																								
6	SE-FD, Private sector																								

SE-FD=Secretariat of Environment of the Federal District

Table 35 Timescales and responsible for collection centres

6.8.4 Separate collection

Collection activity is a fundamental part of waste management. The separate collection should be a fundamental part of waste management programmes in order to guarantee the efficiency in the subsequent activities of selection, re-use, recycling, treatment, and final disposal. A proper collection enables to increase the waste that can be commercialised in collection centres. In order to achieve an efficient performance of the waste management service, a significant participation in sorting activities by all generators is required in addition to a proper collection service which is based on organised routes in all neighbourhoods and towns of the Federal District.

6.8.4.1 Collection routes

The collection routes should be properly planned and organised in order to achieve efficient collection and delivery of waste from origin to collection centres, transfer stations, compost plants and selection plants. The planning of routes per borough should include: level of population, estimated amounts of waste generated, business activity, access roads, distances to facilities, availability of vehicles and equipment.

Objective:

- To achieve efficient collection in order to help the commercialisation, reuse and recycling of waste.
- To create an efficient scheme of collection routes, this must be based on the specific characteristics of each borough and neighbourhood.

Goals:

- By year 3, collection routes for separated waste should operate in all neighbourhoods and towns in the Federal District.

- By year 6, there must be a proper collection service characterized by punctuality and efficiency in the collection.
- There must be an efficient joint work among the institutions involved in collection and transportation activities.

Specific activities:

1. Identify and evaluate the existing routes of collection.
2. Train staff of urban service department in selective collection.
3. Design an education campaign door to door to inform about selective collection.
4. Coordinate joint work among collection staff and transfer station and collection centres staff.
5. Elaborate a new and improved route scheme to cover all neighbourhoods taking into consideration characteristics of each zone.
6. Elaborate a scheme to supervise and evaluate the collection periodically.
7. Develop handling plans for public and special events which generate high amount of wastes.
8. Plan for collection in emergencies.
9. Create accurate schedules and timetables for collection.
10. Allow population to access information related to the collection service (characteristics, routes, timetables, schedules).

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD, SWS-FD	■	■	■	■																				
2	Local promoters			■	■	■	■																		
3	Local trainers	■				■				■				■				■				■			
4	SE-FD, SWS-FD	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	SE-FD, SWS-FD	■	■	■	■																				
6	SE-FD, SWS-FD	■	■	■	■																				
7	SE-FD, SWS-FD	■	■	■	■																				
8	SE-FD, SWS-FD	■	■	■	■																				
9	SE-FD, SWS-FD	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
10	SE-FD, SWS-FD	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District

Table 36 Timescales and responsible for collection routes

6.8.4.2 Vehicle fleets

The vehicles should present optimal operational conditions to carry out collection and transportation activities. The obsolescence of the vehicles leads to an inefficient collection and represent negative environmental impacts due to the pollutants that are caused by the mechanical problems in the operation of old vehicles.

Objectives:

- To improve the collection system through updating the vehicle fleets.
- To renovate the fleets with vehicles that are designed and constructed with environmentally friendly technology.

Goal:

- ➢ All vehicle fleets must be replaced or equipped with all features to guarantee the efficient separation, collection and transportation of waste, in a period not longer than 10 years after the application of the integrated programme.

Specific activities:

1. Evaluate the status of the current vehicle fleet.
2. Elaborate a plan of replacement and update vehicle fleet.
3. Design a schedule to renovate the entire fleet in not longer than 10 years.
4. Contact and organise meetings to agree terms of renovation with producers of collection vehicles.
5. Design a plan to dispose old vehicles.
6. Implement a service schedule to give mechanical service for all vehicles.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD, SWS-FD	■	■	■	■																				
2	SE-FD, SWS-FD					■	■	■	■																
3	SE-FD, SWS-FD									■	■														
4	SE-FD, SWS-FD, Vehicle producers									■	■														
5	SE-FD, SWS-FD									■	■														
6	SE-FD, SWS-FD									■	■														

SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District

Table 37 Timescales and responsible for vehicle fleets

6.8.5 Improvement of infrastructure

6.8.5.1 Transfer stations

Objective:

- To guarantee an efficient performance of all transfer stations in the Federal District through the modernisation and improvement of facilities and procedures of operation.

Goals:

- ➢ By year 2, improvements in transfer station should start.

- ➢ By year 6, transfer station must operate with state-of-the-art technology and with improved and efficient operational processes and methods.

Specific activities:

1. Evaluate the status of all transfer stations.
2. Evaluate the operational processes in the transfer stations.
3. Elaborate procedure manuals for all transfer stations.
4. Elaborate a plan to improve technology and methods of transfer stations.
5. Carry out the technological improvements in the stations.
6. Design a programme to certify transfer stations.
7. Supervise periodically the operation of transfer stations.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD, SWS-FD	■	■	■	■																				
2	SE-FD, SWS-FD	■	■	■	■																				
3	SE-FD, SWS-FD				■	■																			
4	SE-FD, SWS-FD			■	■	■																			
5	SE-FD, SWS-FD				■	■																			
6	SE-FD, SWS-FD				■	■																			
7	SE-FD, SWS-FD					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District

Table 38 Timescales and responsible for improvement of transfer stations

6.8.5.2 Sorting plants

Objectives:

- To improve the operational processes in sorting facilities by the design of procedural manuals.
- To integrate the informal sector into the sorting activities under a regulated scheme.
- To update and modernize existing facilities with proper technology and equipment.

Goals:

- ➢ By year 2, all improvements in sorting plants must start.
- ➢ By year 4, sorting plants must be able to operate by at least 80% of capacity.
- ➢ By year 6, all sorting activities must be carried out with state-of-the-art technology and certified processes.

Specific activities:

1. Evaluate the status of sorting plants.
2. Organise meetings with unregulated “scavengers”
3. Incorporate unregulated sector under a regulated scheme.

4. Elaborate programme to describe the activities for modernization and improvement of the plants.
5. Create a certification scheme for sorting plants.
6. Elaborate procedures manuals for sorting activities.
7. Update and improve the technology, equipments and methods in plants.
8. Establish periodical inspections to sorting plants.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD, SWS-FD	■	■	■	■																				
2	SE-FD, SWS-FD, Informal sector					■	■	■	■																
3	SE-FD, SWS-FD									■	■	■	■												
4	SE-FD, SWS-FD					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	SE-FD, SWS-FD					■	■																		
6	SE-FD, SWS-FD					■	■	■	■																
7	SE-FD, SWS-FD									■	■	■	■	■	■	■	■	■	■	■	■				
8	SE-FD, SWS-FD									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District

Table 39 Timescales and responsible for improvement of sorting plants

6.8.5.3 Compost plants

The compost process involves a treatment where organic waste is aerobically decomposed by the control of physical-chemical factors. According to information from statistical reports of the Secretariat of Environment, in 2011 it was estimated that less of 10% of all organic waste was composted. There are nine registered compost plans which are operated by the government of the Federal District. There is a need for increasing the amount of produced compost in order to generate organic fertilizers to be used in the agricultural regions of Mexico City. The proper production of compost in agricultural areas can represent a sustainable model in particular areas of Mexico City.

Objectives:

- To reduce the disposal amount of organic waste in landfill.
- To increase the compost that is produced in the Federal District.
- To use compost to fertilize green areas and agricultural soils in the Federal District.
- To create compost markets and increase the supply and demand of organic fertilizers.
- To encourage the operation of plants by the private sector.
- To create a general design to open and operate local compost plants.

Goals:

- ➢ By year 6, all compost plants must operate under a controlled process in order to obtain quality compost.
- ➢ By year 6, the number of compost plants in the Federal District must increase at least at 50%

Specific activities:

1. Evaluate the status of compost plants.
2. Design a handbook to set the significant parameters in the compost production.
3. Design a diffusion campaign related to the benefits of compost.
4. Generate incentives for the use of compost among agricultural producers.
5. Provide composting courses.
6. Encourage the opening of regional compost plants by communities or by the private sector.
7. Organise an annual event related to compost.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD, SWS-FD	■	■	■	■																				
2	SE-FD, SWS-FD					■	■	■	■																
3	SE-FD, SWS-FD							■	■																
4	SE-FD, SWS-FD							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	SE-FD, SWS-FD							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
6	SE-FD, SWS-FD, Private sector							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
7	SE-FD							■				■				■				■				■	

SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District

Table 40 Timescales and responsible for improvement of compost plants

6.8.5.4 Final disposal sites

The final stage for wastes involves a proper and controlled final disposal. MSW that is disposed of in engineered landfills must be treated and the allowance of waste in landfills must be based on a waste hierarchy. There is an important need to significantly improve operation, processes, and technology in landfill facilities.

Objective:

- To significantly reduce the amount to waste that is disposed of in landfills.
- To carry our activities to recover areas of uncontrolled landfills.
- To strengthen controls and guidelines to operate engineered landfills.

- To improve existing landfills through robust measures of fulfilment of legislation related to environmental conservation.
- To install technology aimed to capture methane and any other greenhouse gases.

Goals:

- By year 6, the amount of waste disposed of in landfill must decrease in at least 30%.
- By year 6, the existing landfills must operate under controlled and feasible processes.
- The amount of waste that is disposed of in landfills must decrease to less of 10% in a period no longer than 20 years.

Specific activities:

1. Evaluate the status of final disposal sites.
2. Close clandestine disposal sites.
3. Design special legislation and Official Mexican Standars (NOM) to regulate disposal sites.
4. Define a term limit to landfill operators to regulate processes when necessary.
5. Evaluate procedures in landfills.
6. Encourage landfill operator to seek new alternatives of treatment.
7. Verify the installation of technology aimed to capture biogas.
8. Create a certification scheme for landfills.
9. Evaluate the feasibility of a landfill tax, and of a limited allowance scheme for waste in landfills.
10. Periodically reduce the amount of waste in landfills by increasing of fees.
11. Periodically supervise and audit active and closed landfills.

	Responsible	**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Year 5**				**Year 6**			
1	SE-FD, SWS-FD	■	■	■	■																				
2	SE-FD, SWS-FD	■	■	■	■																				
3	SE-FD, SWS-FD	■	■	■	■	■	■																		
4	SE-FD, SWS-FD			■	■																				
5	SE-FD, SWS-FD	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
6	SE-FD, SWS-FD	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
7	SE-FD, SWS-FD											■	■												
8	SE-FD, SWS-FD				■	■																			
9	SE-FD, SWS-FD	■	■	■	■																				
10	SE-FD, SWS-FD					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
11	SE-FD, SWS-FD	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District

Table 41 Timescales and responsible for improvement of final disposal sites

6.8.6 Appraisal and use of alternative technologies

The current work related to waste management has been focused on rudimentary processes. There is a significant need for projects to develop alternative treatment methods which must be focused on the prevention of waste generation. Actions, initiatives and researches must address the lack of actions in order to generate/acquire and apply new technologies in the waste management system.

6.8.6.1 Scientific and technological research to re-use, recover and recycle waste

Scientific and technological research is a key factor to improve the waste management in the Federal District. The current situation requires the establishment of new criteria to study and approach the problem. Scientific and technological research must be a main component to develop new treatment alternatives. Research centres, educational institutions, governmental agencies, and private sector should be encouraged to develop new treatment alternatives and/or to adapt existing technology in waste management activities.

The development/acquisition of specific technologies should be in accordance with the characteristics of the waste. The application of alternative methods must be proven as economically and technically feasible.

Objective:

- To promote through governmental agencies of science and technology the participation of research centres, educational institutions and private sector in the development of projects and research related to waste management.

Goals:

- ➢ By year 2, there must be at least two specific projects to improve waste management activities.
- ➢ By year 2, there must be a specific department in the Secretariat of Science and Technology of the Federal District related to waste management research.

Specific activities:

1. Establish waste management as a priority on the governmental agenda.
2. Contact research centres, educational institutions and private sector to promote collaborations and development of research projects.

3. Define research field based on a priority of topics.
4. Manage financial resources to support research projects when necessary.

	Responsible	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
1	GFD	■					
2	SE-FD, IE, Private sector		■	■	■	■	■
3	SE-FD	■					
4	SE-FD, SST-FD		■	■	■	■	■

GFD=Government of the Federal District
SE-FD=Secretariat of Environment of the Federal District
IE=Institutions of Education
SST-FD= Secretariat of Science and Technology of the Federal District

Table 42 Timescales and responsible for scientific and technological research to re-use, recover and recycle waste

6.8.6.2 Use and commercialisation of the organic fraction

As mentioned in section 6.8.5.3, compost plants must be developed under proper conditions and with proper production processes. However, the diversification of the infrastructure should consider the adoption of different technologies to use the organic fraction of the MSW. The anaerobic digestion can be used as a technique to provide a proper and controlled treatment of segregated biodegradable municipal wastes and commercial food waste. Therefore, there must be projects aimed to evaluate the feasibility in the adaptation of these technologies in spaces with high rates of generation of organic waste.

Objective:

- To analyse and determine the feasibility of setting up a methane capture process and anaerobic digestion technologies to be used instead of composting in selected facilities, including: (1) “Central de Abasto” market, (2) public markets with high generation of organic waste.

Goals:

- By year 3, there must be feasibility studies focusing on validation of methane capture processes in different zones of the Federal District.
- By year 6, there must be methane capture processes in all feasible areas of the Federal District.

Specific activities:

1. Develop of feasibility studies.
2. Identify areas susceptible of methane capture for anaerobic digestion.
3. Manage financial resources to support research and implementation of methane capture process when necessary.

4. Encourage the participation of the private sector.
5. Implement the needed technology and works to capture methane.
6. Supervise periodically the operation of places with methane capture processes.
7. Get accurate information about recovery levels to elaborate statistical reports.
8. Organise an event to promote and disseminate all aspects related to methane capture.
9. Create a market for energy from biogas.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	SE-FD, SWS-FD	■	■	■	■																				
2	SE-FD, SWS-FD																								
3	SE-FD, SST-FD																								
4	SE-FD, Private sector					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	SE-FD, SWS-FD													■	■	■	■								
6	SE-FD, SWS-FD													■	■	■	■	■	■	■	■	■	■	■	■
7	SE-FD, SWS-FD								■				■				■				■				■
8	SE-FD						■				■				■				■				■		
9	GFD, SE, SENER																	■	■	■	■	■	■	■	■

SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District
GFD=Government of the Federal District
SE=Secretariat of Economy
SENER=Secretariat of Energy

Table 43 Timescales and responsible for the use and commercialisation of the organic fraction

6.8.6.3 Recycling programmes

The commercialisation of recycled materials is a fundamental part in the establishment of recycling programmes. Based on the commercialisation options available, materials can be selected for recycling processes. A recycling programme must be integrated by efficient separation and diversity in treatment methods per type of material. There must be a collaboration agreement among participants in the recycling chain. The recycling programme should consider fundamental aspects including: composition of waste, existing recycling methods, market of commercialisation.

The recycling programmes should be elaborated according to specific characteristics of local areas and type of waste. Although the content and structure of recycling programmes may vary, the following procedure and structure is suggested for the development of specific programmes:

1) Planning:

- Objective of the programme
- Legal conditions and justifications
- Integration of teams or work groups

- Analysis of selected waste
  - Generation
  - Composition
  - Percent recyclable
  - Treatment alternatives
- Identification of markets for commercialisation
- Establishment of goals
- Obtaining approvals (if applicable)

2) Education/Promotion

- Dissemination tools (e.g. brochures, fliers, public talks, posters etc.)

3) Collection system

- Mapping of areas
- Logistics
- Collection method (e.g. containers, bins, collection centres, etc.)
- Transportation

4) Recycling

- Selected methods
- Amounts collected and recycled

5) Evaluation of the programme

- Communication of results
- Feedback

Objectives:

- To design integrated recycling programmes.
- To increase and regulate existing recycling establishments.
- To improve the recycling system in the Federal District.

Goals:

- By year 2, there must be integrated recycling programmes in the Federal District for different types of materials.
- The recycling levels must reach at least the 80% in a period not longer than 20 years.

Specific activities:

1. Elaborate a complete market study of recycling.

2. Organise meetings with the informal sector and institutions to achieve agreements in the recycling chain.
3. Elaborate a business plan for each recyclable material.
4. Design recycling programmes.
5. Supervision, evaluation, improvement and upgrade of recycling programmes.

	Responsible	**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Year 5**				**Year 6**			
1	SE-FD, PB	■	■	■	■																				
2	SE-FD, Informal sector, Institutions			■	■	■	■																		
3	SE-FD				■	■	■	■	■																
4	SE-FD									■	■	■	■												
5	SE-FD													■	■	■	■	■	■	■	■	■	■	■	■

SE-FD=Secretariat of Environment of the Federal District
PB=Political Boroughs

Table 44 Timescales and responsible for recycling programmes

6.8.7 Control and prevention of pollution

The MSW generation is given by human activities including: commercial, industrial, domestic, recreational, and other activity that generates waste. An integrated waste management programme should focus on the control of any source of waste which causes pollution and negative impacts on the environment. In the Federal District there are several unregulated and uncontrolled concentrations of waste. Special programmes must be considered in order to prevent and control sources of pollution taking into consideration feasibly methods to recover impacted areas.

The strategies, objectives and actions of the proposed integrated programme must be a reference to develop supporting plans, programmes, strategies and public policies which are aimed to control existing sources of pollution that are generated by inadequate disposal of waste. The plans should consider significant improvements in measures and evaluation instruments in order to prevent pollution in the future.

6.8.8 Legal framework

The complexity of the waste generation issue requires a comprehensive legal framework focusing on all aspects within the waste management system. There must be a significant improvement in order to use: human, economic, technological, judicial, social and political resources to establish a comprehensive legislation. Strengthening of laws and legislation is a fundamental aspect to provide a sustainable basis to the waste management system. Waste management should be based on laws with different characteristics, including: agility, accuracy, legality and transparency. Current legislation should be revised, analysed and improved according to the actual context and according to the waste hierarchy. There is an important need to standardize concepts, provide and reinforce powers, improve instruments and tools, cover not-considered aspects, simplify processes, specify responsible, harden sanctions and punitive models and diversify the existing legislation.

6.8.8.1 Strengthening of legislation

Objectives:

- To strengthen the legal framework related to waste management in the Federal District.
- To create supporting legislation in order to diversify the coverage and scope of the environmental laws.
- To upgrade the Law of Municipal Solid Waste of the Federal District (LMSWFD).

Goals:

- By year 3, the current Law of Municipal Solid Waste of the Federal District shall be revised and ungraded.
- By year 6, there must be specific guidelines to cover all aspects of waste management.
- By year 4, the legal framework related to waste management must be focused on the waste hierarchy and waste minimisation.

Specific activities:

1. Organise an expert group with specialists in the matter (e.g. environmentalists, biologists, environmental engineers, academic staff, researchers and other experts in the field) and participants of all sectors involved.
2. Revise and analyse the content of the LMSWFD and any other applicable environmental legislation.
3. Design a proposal to improve the LMSWFD and other applicable environmental legislation.
4. Present a proposal for the creation of new laws and regulations.
5. Apply the modifications in the law.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	GFD, SE-FD, NWC, SEMARNAT, IE	■	■	■	■	■	■																		
2	GFD, SE-FD, NWC, SEMARNAT, IE	■	■	■	■	■	■																		
3	GFD, SE-FD, NWC, SEMARNAT, IE					■	■	■	■																
4	GFD, SE-FD, NWC, SEMARNAT, IE								■																
5	GFD, SEMARNAT, NIE									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

GFD=Government of the Federal District
SE-FD=Secretariat of Environment of the Federal District
NWC= National Water Commission
SEMARNAT= Secretariat of Environment and Natural Resources
IE=Institutions of Education
NIE=National Institute of Ecology

Table 45 Timescales and responsible for strengthening of legislation

6.8.9 Institutional coordination

Within the waste management activities in the Federal District, several institutions directly and indirectly participate in the design of strategies, plans and programmes. Public institutions include different secretariats, department and units that are linked to waste management. The development of strategies to manage, control, supervise, evaluate and improve the waste management system must integrate all stakeholders in order to generate an alignment of public policies under a scheme of joint work.

6.8.9.1 Institutional unification

The different dimensions of the waste management require the development of strategies for a joint work. The creation of a special institution focusing on waste management is recommended. The existence of a unique agency to attend to the actions related to MSW should answer the necessity of a structured organism focusing on all activities related to waste management. The waste management in the Federal District is divided into two authorities, the Secretariat of Environment and the Secretariat of Works and Services; the integrated programme contemplates a joint work of both institutions, nevertheless in the long-term a unification of both secretariats would be recommended if studies confirm feasibility of merge.

In the same way, each one of the sixteen boroughs should create a specific unit to manage waste. The institutional unification is intended to provide full coverage in waste management services.

Objectives:

- To develop feasibility studies related to a merge of Secretariats and Departments of the Federal District.
- To create specific units related to waste management in the sixteen boroughs.

Goal:

- ➢ By year 6, there must be at least 16 local units related to waste management.

Specific activities:

1. Conduct the feasibility studies.
2. Design structure and functions of local units.
3. Train staff of local units.
4. Supervise operation of local units.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	GFD, SE-FD, SWS-FD	■	■	■	■																				
2	SE-FD, PB	■	■																						
3	Local promoters			■																					
4	SE-FD				■		■		■		■		■		■		■		■		■		■		■

GFD=Government of the Federal District
SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District
PB=Political Boroughs

Table 46 Timescales and responsible for institutional unification

6.8.9.2 Coordination with authorities of the Metropolitan Zone of Mexico City

Due to the significance of the Metropolitan Zone of Mexico City (MZMC), the creation a metropolitan plan to manage waste generation in the area is required. The plan should consider the federal government, the state of Mexico, the state of Hidalgo and the Federal District.

Objective:

- To promote the integrated waste management in the MZMC through the coordination of all involved governments.
- To create a plan focusing on waste management in the MZMC.
- To establish agreements of cooperation and joint work among federal and state governments.

Goals:

- ➢ By year 5, coordinate actions related to waste management in the MZMC shall be considered within an integrated plan.

Specific activities:

1. Analyse and evaluate the current situation of the MZMC in terms of waste management.
2. Organise a meeting with the authorities of the States of Mexico and Hidalgo.
3. Design plans and programmes for metropolitan cooperation.
4. Signing cooperation agreements.

	Responsible	**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Year 5**				**Year 6**			
1	SE-FD, INEGI					■	■	■	■																
2	GFD, GSM, GSH									■	■	■	■												
3	GFD, GSM, GSH													■	■										
4	GFD, GSM, GSH															■									

SE-FD=Secretariat of Environment of the Federal District
GFD=Government of the Federal District
INEGI=National Institute of Statistics and Geography
GSM=Government of the State of Mexico
GSH= Government of the State of Hidalgo

Table 47 Timescales and responsible for coordination with authorities of the Metropolitan Zone of Mexico City

6.8.10 Inspection and vigilance

The integrated programme aims to prevent, decrease and control the pollution from the MSW in the Federal District. Within the programme, the formulated strategies aim to provide efficient actions to minimize the amount of waste. Such actions involve the inspection and vigilance activities in order to avoid mismanagements.

Specialised measures should be carried out to verify the proper performance of activities. The law should empower governmental agencies to conduct monitoring visits to verify efficient fulfilment of waste management, and to apply fines and punitive programmes if irregularities are evidenced.

The strengthening of actions related to inspection and vigilance of the system is a fundamental part to achieve efficiency in actions and strategies. Each borough should inspect the collection routes and the separations at source to identify irregularities. In addition, each borough should report an uncontrolled accumulation of waste in public areas or any other source of pollution, and should elaborate reports periodically to be presented to the SE-FD.

Objectives:

- To design measures of control, vigilance and inspection in order to evaluate the fulfilment of the legal guidelines.

- To create/name a specific organism focusing on the inspection and vigilance.
- To create indicators to measure the fulfilment of the environmental laws.

Goals:

- ➢ By year 3, a scheme of inspection and vigilance shall operate in the sixteen boroughs of the Federal District.

Specific activities:

1. Design indicators to measure fulfilment of goals and objectives.
2. Create a scheme of vigilance and inspection for the activities of the integrated programme.
3. Determine a figure of authority to evaluate activities.
4. Carry out the vigilance and inspection in the Federal District.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	GFD, SE-FD, SWS-FD					■	■	■	■																
2	GFD, SE-FD, SWS-FD					■	■	■	■																
3	GFD								■																
4	Authority designed									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

GFD=Government of the Federal District
SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District

Table 48 Timescales and responsible for inspection and vigilance

6.8.11 Evaluation and feedback of the programme

The evaluation of the programme should provide evidence of effectiveness in the proposed strategies and actions. The results of the evaluation should enable the modification of ineffective activities. The evaluation of the programme should be carried out according to significant indicators of performance and should be carried out by an impartial party.

6.8.11.1 Monitoring of the programme

The monitoring of the programme should be carried out in order to guarantee the updating of information. The updating process includes revision of: scope, guiding principles, strategies, objectives, goals, specific activities, timescale and responsible. The integrated waste management programme should be completely revised and updated, every five years. However, it can be modified at any time whenever necessary and according to an authorized justification of the Government of the Federal District along with the Secretariat of Environment and the Secretariat of Work and Services.

Modifications in the programme may include the adding of sub-programmes, plans, projects or specific guidelines related to waste management. It is advisable the revision of the programme at the beginning of new administrations in the Federal District in order to guarantee continuity in the proposed activities and strategies. The fulfilment of all actions should be a priority in the political agenda of the government. The proposed timescales may vary significantly due to required coordination and agreements. Changes or variations in the expected times must be properly based on approvals of the Secretariat of Environment, the Secretariat of Work and Services and the Government of the Federal District.

Objectives:

- To design a scheme of indicators to evaluate the progress in the programme.
- To measure the effectiveness and performance of the integrated waste management programme.
- To keep a regular updating process of the activities and strategies.

Goals:

- ➢ By year 3, preliminary results of the effectiveness of the programme shall be available for public consultation.

Specific activities:

1. Design an indicator system.
2. Design the electronic monitoring system.
3. Determine a figure of authority to evaluate the programme.
4. Organise periodic meeting to evaluate the performance and progress of the programme.
5. Disseminate results of evaluations.

	Responsible	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
1	GFD, SE-FD, SWS-FD							■	■																
2	GFD, SE-FD, SWS-FD					■	■	■	■																
3	GFD								■																
4	Authority designed												■				■				■				■
5	Authority designed												■				■				■				■

GFD=Government of the Federal District
SE-FD=Secretariat of Environment of the Federal District
SWS-FD=Secretariat of Works and Services of the Federal District

Table 49 Timescales and responsible for monitoring of the programme

Chapter 7

Guidance on Preparing Technology Transfer Projects in the Waste Management Sector

7.1 Introduction

The use of state-of-the-art technology in all economic activities has significantly increased due to the knowledge revolution, which is represented by important technological and scientific advances (Chichilnisky, 1998). Technological developments can significantly improve knowledge and capabilities. In addition, the adaptation of specialized technology in different economic sectors can achieve competitiveness and efficiency in operational processes.

The strategy to improve waste management activities can be approached from the alternative of technology transfer. However, market, economic and political barriers represent significant obstacles for the adaptation of new technologies in emerging economies. A significant challenge that project managers must face is the proper adaptation of ideas intro robust and feasible projects. Technology transfer processes may involve high costs due to specialized equipment and machinery. The structuring of projects should consider several aspects in order to qualify for local or international funding.

This Chapter presents a brief description of technology transfer and provides a guide aimed to help project managers to carry out technology transfer in waste management activities, using a feasibility study focused on Mexico City.

7.2 Technology transfer

Technology transfer is the transfer of skills, technical know-how, machinery and other capital equipment (Wei, 2001). Technology transfer provides the receiver: (1) investment capabilities, (2) operational capabilities, (3) dynamic learning capabilities (Kumar *et al.,* 1999). Technology transfer can be understood as a transfer of capital goods and operating skills to develop technological capabilities which can be in the form of investment and production (Putranto *et al.,* 2003). Technology transfer is usually a base for technical innovation and it is often a form of innovation diffusion (Jasinski, 2009).

Technology transfer can be a lengthy, complex and dynamic process and its success is influenced by several factors which originate from different sources (Saad *et al.,* 2002). Technology transfer can be vertical or horizontal. Vertical transfer refers to transfer of technology from basic research to applied research, development, and production respectively; horizontal technology transfer refers to the movement and use of technology from one place to another context (Ramanathan, 2008).

The author suggests that technology transfer is the action of sharing physical technology, including machinery, equipment, samples of manufacturing, or any other capital good to develop specific capabilities. Technology transfer also includes the transfer of intangible material, including skills, knowledge (know-how), methods and procedures, or any other theoretical ability. The process should be planned by the owner and the receiver. The development a detailed project should consider all possible expected impacts in order to ensure the effectiveness of the process.

The transfer process can be represented by different schemes, including: (1) foreign direct investment (FDI), (2) technology (technical) licensing agreements, (3) imports of capital goods, (4) foreign education and training, (5), turnkey projects, (6) technical consultancies (Bozeman, 2000).

The technology transfer may include five generic categories (Simon, 1991): (1) the international technology market, where independent buyers and suppliers interact to trade with technology developments, (2) intra-firm transfer, where technology transfer is only carried out through joint venture or a subsidiary, (3) government-directed agreements or exchanges, where the participants in the transfers can be private or public sector, (4) education, training, and conferences, where the dissemination of information is carried out through organisation of events addressed to specialized audiences, (4) pirating or reverse-engineering, where technology is obtained directly from the owner of property rights without a real interaction in the market.

7.3 Technology transfer in waste management activities

As mentioned, the technology transfer can be carried out through different channels; however the main goal is the development of capabilities with new technology. The acquisition and adaptation of technology in waste management activities, is aimed to (1) improve infrastructure and facilities, (2) train staff and operators, (3) diversify provided services, (4) increase competitiveness and profitability, (4) decrease environmental impacts.

The structuring of projects in waste management activities is aimed to obtain funding to cover transfer processes in order to achieve a successful application of new technologies. A proper project should mainly include three studies: technical, market and economic (Maylor, 2005). The technical study should include: characteristic of the business; the description of the technology; technical parameters of the infrastructure or plant; and any other aspect directly associated with the operation and with the technical resources. The market study should include: description of the product; specifications and characteristic of the market; identification of potential clients; policy of price; legal conditions of the commercialization; and any other aspect directly associated with the commercialisation strategy. The economic study should include: costs of technology, installation and production; budgets of investment, reinvestment, production and revenues; cash flows; indicators of financial profitability; and any other aspect directly associated with economic parameters. The project should consider the main expected impacts and the possible financial mechanisms to cover the technology transfer (Speser, 2006).

The following sections present a project to obtain funding for technology transfer, which is structured according to technical, market and economic studies. The project is based on the feasibility study of acquisition of an energy generator to be operated in a landfill facility. The project aims to exemplify the development of the technical, market and economic studies, in order to provide a guide that can be adapted to different projects in other waste management activities.

7.4 Feasibility study of energy generation from landfill gas in Mexico City

7.4.1 Technical study

7.4.1.1 Characteristics of the enterprise

The description of the main characteristics of the enterprise must provide robust information related to geographical location, size, and mission and vision statements among other general data. The information enables an easy identification of the activities and procedures of the business. The activities can be carried out in different stages: (1) Stage of collection and transportation; (2) Stage of storage and transfer; (3) Stage of selection and recycling; (4) Stage of treatment of the organic and inorganic part of MSW; (5) Stage of final disposal; (6) Stage of generation of energy; (7) Stage of commercialisation of sub-products.

For the purpose of the analysis, the enterprise will be a final disposal site of MSW. The technology is intended to generate electrical energy from landfills gas which is originated from the organic fraction of the MSW. The election of this activity is given by the absence of waste-to-energy projects in Mexico City.

7.4.1.2 Evaluation of the enterprise

The evaluation of the enterprise aims to determine the optimal size of the project related to installed capacity. The capacity should be expressed in terms of amount per period of time. The optimal size is achieved when the plant operates with the lowest total costs or the highest economic profitability (Baca, 2006). The evaluation of the enterprise can be an extensive part of the project due to different processes and parameters to be measured.

For the purpose of the analysis, the plant is an engineered landfill with estimated installed capacity of 920,000 tonnes of MSW per year (2,500 tonnes per day). The distribution of the service will depend on the geographical location of the landfill. A strategic location for the landfill is on the outskirts of the city, not only for avoiding impacts on households but also for the location of potential clients. Therefore, the analysis considered the following characteristics for the modelling of costs and financial feasibility:

Landfill Characteristics:	
Open Year:	2014
Closure Year:	2034
Waste-In-Place at Closure (tonnes)	18,400,000
Average Waste Acceptance (tonnes/yr):	920,000
Average Depth of Landfill Waste (ft):	65
Area of LFG Wellfield to Supply Project (acres):	10

Table 50 Characteristics of the landfills for the feasibility study

It must be noted that the selection of a landfill with a low capacity was decided since historically, Mexico City has used a single landfill with large capacity. The operation of that large landfill has resulted in significant environmental issues (see section 4.6.3), in addition, the dependency on a single facility has caused important problems of disposal when (due to floods in surrounding roads) the transfer vehicles cannot access to the landfill. The absence of alternatives to dispose waste has led to suspensions in the collection service and to road blocks by heavy trucks. Therefore, the design and construction of new disposal sites should avoid the dependency on large landfills and should diversify alternatives for disposal. In addition, the small scale of the landfill selected for the analysis, is intended to generate financial estimates with low investment flows in order to encourage the gradual adoption of the technology.

7.4.1.3 Description of the technology

Technology is the technical knowledge associated as something physical (hardware) for example a machine, an electrical or mechanical component, or can also be associated with non-physical concept (software) for example a chemical process, codes, a patent, a technique, or even a person (Takim *et al.*, 2008). Technology can be viewed as the technique to support daily activities which are carried out by people or machines (Lamin, 2009). The description of the technology must include characteristics and technical parameters (if physical) in order to provide accurate information related to the item to be purchased, transferred or adapted.

It must be noted that there are several technology options for developing an electricity project. The most common technologies include internal combustion engines, gas turbines, micro-turbines, and small engines. The selection of the technology should be based on accordance with the project size ranges. Small internal combustion engines and micro-turbines are normally used for small power generation whilst gas turbines are best suitable for larger projects. Therefore, for the purposes of the analysis, the selected technology was a set of micro-turbines to be operated in a Combined Heat and Power model, in which the waste heat produced is captured and used. The selection of the technology was decided given that these technologies are intended to provide maximum thermal efficiency from the collected LFG. This implies the exploitation of the steam or hot water produced by the generation of energy. As mentioned in the section 7.4.2.3, the generated energy is intended to be commercialized among industrial parks near the landfill. Therefore, CHP technologies are suitable alternatives to transport and commercialize the final product to users nearby.

Figure 48 Set of micro-turbines (Picture provided by Capstone Turbine Corporation).

7.4.2 Market study

The market study refers to the determination and quantification in supply and demand of the product or service. It involves the detailed description of the parameters of commercialisation including, product, market, clients and price (Luther, 2011).

For the purpose of the analysis, the marketing plan should be carried out in accordance with the specific characteristics of Mexico City. The characteristics of the product (landfill gas) must be considered according to the size of the landfill and the amount of MSW in the facility. The opportunity to establish cooperation agreements between industries must be also considered. The future estimations of electricity and strategies to increase the potential market are key aspects to diversify the offered product.

7.4.2.1 Product

The description of the product must provide specific information related to the main characteristic of the final service or item. The information must be clear, the product or service should be defined by a brief description of the use and features.

For the purpose of the analysis**,** the product is defined as "electrical energy from LFG (landfill gas)". The main features can be described as follows: Biogas is a reliable source of energy, inasmuch as it can replace fossil energy such as petroleum and diesel in industrial activities. The use of clean alternative energies can improve processes and generate eco-friendly activities. Landfill gas (biogas) is presented as an efficient alternative to solve the energy shortages of small areas (Yang *et al*., 2012) and its production implies different advantages such as the treatment of organic materials avoiding the release of greenhouse gases to the atmosphere.

7.4.2.2 Market

The market description should include detailed information related to the current status of commercialisation schemes. The market refers to the physical place where the product or services would be commercialized; the project must be clearly associated with a geographical place. The market description also involves socio-economic, political and governmental circumstances that can impact on the effectiveness and successful performance of the commercialisation (Sabou, 2010).

For the purpose of the analysis, the market is focused on the energy generation. The market of electric energy is determined by the Federal Electricity Commission (in Spanish CFE) which is the official provider or energy in Mexico. The CFE generates more than 90% of the total and distributes 100% of the electricity (SENER, 2013). It is estimated that more than 20,000 MW of additional capacity would be required in the future to cope with the expected growth in the demand. (Santoyo-Castelazo *et al.*, 2011). This is a key factor that supports the development of projects aimed to explore alternative sources of energy.

The current market of energy is based on the generation from renewable and non-renewable sources. According to records from the CFE, the main source of energy is hydrocarbons with more than 40% of the total generation (Ramos & Montenegro, 2012). Of the total sales, 99.7% are from the local market and only 0.03% is exported. From the local consumption, 88% of the clients are grouped in the domestic sector; however, it only represents 25.20% of the total sales. The industrial sector, which is the 1% of the clients represents 58.77% of total sales (Detailed tables of the effective capacity of energy generation; sales of energy and generation by source can be observed in appendix 6)

The effective capacity of generation evidenced that the participation of independent power producers has increased in recent years. Alternative generation sources of clean and eco-friendly energy have been poorly explored. Therefore, the development of the electricity generation market in Mexico is given through dynamic diversification of sources of energy including waste treatment processes with energy recovery.

7.4.2.3 Potential clients

The description of clients should consider the group of people or organisations which are intended to receive the product or service. The analysis should explain why the service or product is appropriate for the group of clients. The description can include detailed information of low cost, significant benefits, advantages of the acquisition, easy maintenance or any other aspect related to the identification of consumer targets (Dienemann & Wintz, 1992).

For the purpose of the analysis, the electrical energy from landfill gas is aimed to be commercialized in businesses within industrial parks. Figure 49 shows the location of the principal industrial parks of the Federal District and the Metropolitan Zone of the State of Mexico. The design and construction of engineered landfills, equipped with technology to capture and process landfill gas should consider the proximity of industries. Business and industrial parks represent a potential market for steam to drive heavy machinery; therefore, waste management facilities including landfills with combined heat and power generation can be located near such areas (Bates *et al.*, 2008).

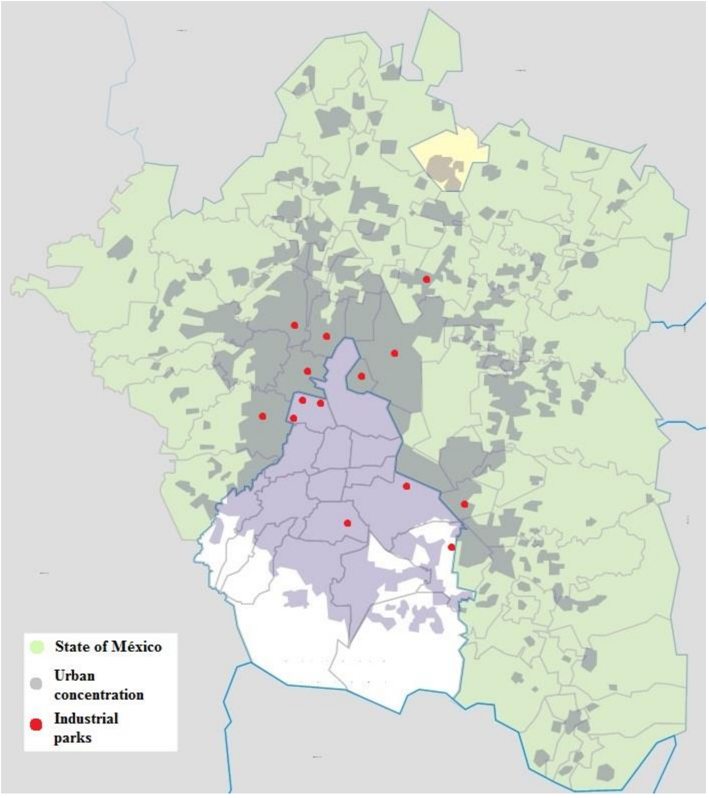


Figure 49 Industrial parks in the Metropolitan Zone of Mexico City

The main industrial areas should be considered as potential markets given the possible necessity of energy. Industries and companies in such areas can become consumers of the energy from landfills. Industrials parks can include:

- Industrial park Naucalpan – San Andres Atoto – La perla
- Industrial park Vallejo – Azcapotzalco
- Industrial park Lerma
- Industrial zone of Iztacalco – Iztapalapa
- Industrial park Los Reyes La Paz
- Industrial park Tlanepantla – FEMSA
- Industrial park of Ecatepec
- Industrial park of Tecamac

The electrical service in Mexico is provided by the CFE. The price of the electrical energy cannot be lower that the level fixed by the CFE. Therefore, in the first instance, the competition in the market with a low price policy is not feasible. However, due to industries are identified as potential markets, other benefits to encourage companies to use clean energy can be explored.

The Mexican Centre for Philanthropy (in Spanish CEMEFI) is aimed to certify companies which carry out best practices of corporate social responsibility by issuing certificates of "Corporate Social Responsibility" (in Spanish ESR). Therefore, obtaining the ESR certificate may become a motivator to use clean energy in order to achieve the environmental requirements to obtain the ESR certificate. The undertaking of best ecological practices is a fundamental part to be considered as an ESR. Such practices involve full responsibility for the environmental impact of production processes; products and the realization of specific actions to contribute to the preservation and improvement of common ecological heritage for the benefit of current and future humanity (Cajiga, 2013).

The search for potential clients should focus on pointing out the advantages of the use of clean energy. The ESR certificate involves significant benefits including that it: (1) increases possibilities to receive financial support, (2) enables access to capital, (3) increases the value of investments and long-term profitability, (4) improves financial performance, (5) reduces operating costs optimizing resources by focusing on sustainable development, (6) strengthens the corporate image and brands. In addition, the ESR certification can lead to a sustainable management of waste that is generated by certified companies and institutions, and thus to achieve significant economic savings by a proper waste management given sustainable handling processes (Tudor *et al*., 2008).

7.4.2.4 Price

The price is the monetary amount to buy or sell the product or service. The description of the price should include the strategy of policy and price fixing. Different policies can be applied according to local regulations. The fixing of prices should be carried out for each specific product or services and taking into consideration legal provision due to the price of some products or services can be controlled and regulated by the government (Levich, 2001).

For the purpose of the analysis, the price of the electrical energy is determined by the Secretariat of Energy and is charged by the CFE. The characteristic of the service and hence, the prices may vary according to the operation and the type of client. The accurate price depends on, first, the type of client; although the identified potential clients include industries and enterprises, a specific economic sector should be defined. Second, the transmission characteristics: low voltage, medium voltage, and high voltage (Detailed tables related to average prices and the determination of price for high voltage, are presented in appendix 7).

The monthly fee used in 2013 presented significant fluctuation in the price given the classification of prices according to periods of consumption in the central region of Mexico. It must be pointed out that the final price would depend on the characteristics of the service and the date when the service contract is signed, given a constant change in the price levels. The fluctuation of the prices and any disposition in matter of energy fees can be monitored in the official website of the CFE; however, the analysis will assume an average estimated fixed price of US$0.060 per kW, based on average prices in Mexico in 2015 The estimation of the price was based on average levels of energy prices according of type of consumption and region, for further details regarding price of energy in Mexico, see Appendix 7).

7.4.2.5 Conditions of the commercialization

The condition of the commercialization should include the marketing strategy. The commercialization must be given by the existing necessity of the product of service. The strategy should involve the different distribution channels according to the type of product or service. A distribution channel must consider the route to provide the product or service to the final user. The distribution can be carried out through channels for domestic or industrial consumption. The commercialization should consider the strategy for market launch with promotional activities, coverage of market, control of product, costs and prices (Coughlan *et al*., 2013).

For the purpose of the analysis, the commercialization of the energy should be based on the scheme of cooperation with the CFE. Therefore the Secretariat of Energy of Mexico (in Spanish SENER) defines the different applicable modalities and instruments of regulations for independent power producers. Figure 50 shows the different permitted modalities of generations, according to different cooperation agreements with the CFE.

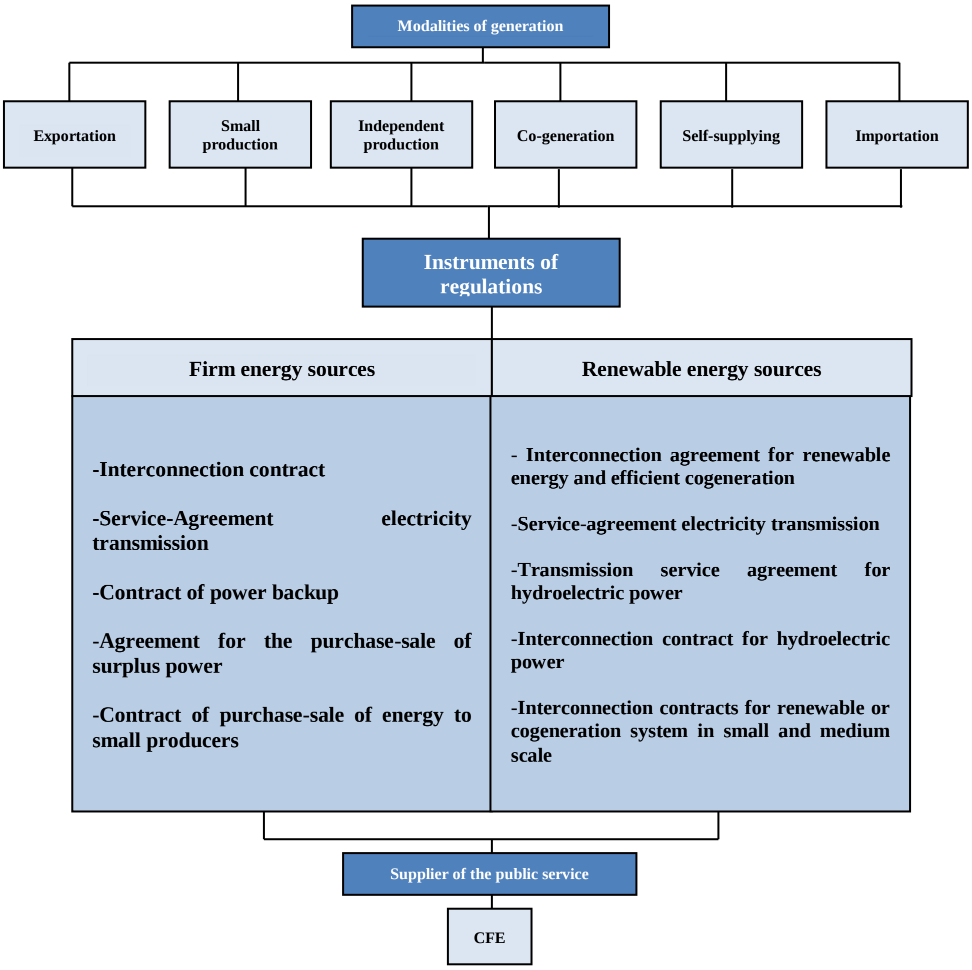


Figure 50 Permissions and instruments of cooperation
(Constructed with data from SENER, 2013)

As can be observed there are six different modalities of energy generation allowed by the CFE. The instrument of regulation is based on the type of energy sources. The modalities of generation can be combined, the case of the generation of energy is small landfills could be considered in different categories. However, the generation is estimated at 2.475 MW (according the capacity of the selected generator); therefore the SENER considers as small production schemes, the generation of energy lower than 30MW. The commercialization of electrical energy from landfill gas can be carried out through the interconnection agreement for renewable energy and efficient co-generation, which involves a contract of small generation and co-generation with the CFE since the CFE provides the interconnection between the national electricity system and the source of energy. The instruments of cooperation may vary according to different characteristics of the landfill and the generator, and then it is important the identification of the possible permissions listed in figure 50.

7.4.2.6 Legal conditions

The legal conditions refer to laws and legislations that rule the production, operation and commercialization of the product or service. Normally, there are local, federal or international laws to fulfil. The project should indicate all applicable legislations related to the proposal. The legal conditions may include: NOMs, security procedures, construction guidelines, environmental laws, fiscal conditions, among others (Witt & Hogan, 1993).

For the purpose of the analysis, the applicable legal framework for the installation of technology to capture and process landfill gas and its conversion into electrical energy can be categorized according to the main activities as follows:

- **Landfill operation and biogas generation:**

The landfill operations are regulated through the guidelines provided in the NOM-083-SEMARNAT-2003, which is the Official Mexican Standard from the Mexican Secretariat of Environment and Natural Resources (in Spanish SEMARNAT) related to the specifications for environmental protection in the selection, design, construction, operation, monitoring, closing and additional works of sites for final disposal of municipal solid waste and waste requiring special handling.

The sixth section of the norm establishes guidelines related to landfill gas generation. The norm specifies that the amount of expected biogas must be estimated through stoichiometric chemical analysis. The seventh section of the norm, related to the characteristics of the construction and operation of the final disposal site, mentions in the point 7.2 (Original text in Spanish translated by the author): *"The extraction, catchment, conduction and control of biogas must be guaranteed. Once, the level enables the generation. And if systems for the use of the biogas are not available, biogas must be burned through individual wells or through the establishment of a network with central burners"* (SEMARNAT, 2003). It is also mentioned that landfills must have specific programmes of quality control, maintenance and environmental monitoring of landfill gas in addition to controls for the generation and handling. Regarding to the monitoring of biogas the norm mentions that programmes aimed to determine the degree of stabilization must be elaborated in order to protect the integrity of the site and detect migration outside the site. Such programmes have to specify the parameters of composition, explosiveness and flow of the landfill gas.

In the same way, the Law of Municipal Solid Waste of the Federal District (LMSWFD) mentions in its article 51 of the Chapter IV related to the final disposition that (Original text in Spanish translated by the author): *"Disposal sites will have restricted access to reusable or recyclable materials and should receive a lower percentage of organic waste. Furthermore, they will use mechanisms to install biogas extraction systems and leachate treatment for its collection"* (LAFD, 2003). The type of procedure to treat and use landfill gas is not specified either in the NOM or in the LMSWFD. Therefore, there is not a legal limitation to use technology for electrical generation.

- **Generation of electrical energy:**

The political constitution of the United States of Mexico establishes in the article 27 (Original text in Spanish translated by the author):*"It is an exclusive power of the nation to generate, conduct, transform, distribute and supply electricity which aims at the provision of public service. In this matter no concessions will be granted to individuals, and the nation will use the assets and natural resources that are necessary for such purposes"* (HCU-CD, 1917). In order to regulate the electrical service in Mexico, the Law of the Public Service of Electrical Energy was enacted in 1975. Such a law mentions that all acts related to public service of electrical energy are public policies. However, the article 3 of the law specifies that the following activities are not considered public policies:

I. The generation of electrical energy to self-supplying, co-generation, or small production;
II. The generation of electrical energy carried out by independent power producers for selling to the CFE;
III. The generation of electrical energy for exportation, derived from co-generation, independent production, and small production;
IV. The importation of electrical energy by individuals or legal entities intended exclusively to supply own uses;
V. The generation of electrical energy for use in emergencies resulting from interruptions in electric power utility.

Although the generation of energy is an exclusive activity of the government; fractions I and II support the undertaking of projects to generate electrical energy. Independent power production has presented the most dynamic activity in terms of installed capacity given direct linkage with the CFE expansion plans. Schemes including self-supply and co-generation represent authorized production schemes in the law, and suitable to be exploited.

7.4.3 Economic study

The economic analysis aims to determine the resources needed to carry out the project. The determination of the total capital cost which includes costs of installation and operation and maintenance cost (O&M). In addition to the revenues and production budgets will provide information to determine the feasibility of the project (Molinos-Senante *et al*., 2013).

Although in some cases the unitary prices were only available in Mexican pesos ($), the analysis was carried out with economic values in US dollars. The exchange rate used for US dollars was 13.2050 Mexican pesos per 1 dollar (The data was provided by the Central Bank of Mexico - BANXICO on 10/10/2013).

The economic analysis was carried out following several assumptions. Therefore, important aspects must be clarified:

- The modelling was conducted using the LFGcost-WebV3.0 tool developed by the U.S. EPA for the EPA's Landfill Methane Outreach Programme (LMOP). The tool enables to estimate the costs of a landfill gas (LFG) energy projects using estimated parameters.
- The obtained results should be used for guidance only as they are preliminary results based on general estimations. A detailed final feasibility assessment should be conducted using accurate information related to specific data for a particular project.
- The calculation of all indicators and parameters was based on information from the U.S. Environmental Protection Agency. The average capital costs and the O&M costs are estimated based on typical project designs in landfills with similar characteristics operating in the U.S.A., therefore there may be variations when applying the analysis of a real case.
- The model includes all typical equipment for a landfill gas project. This includes: site work, permits, operating activities and maintenance. However, when applying the

model to a real case there may be modifications which would increase or decrease the final estimated costs.

7.4.3.1 Quantification of capital and O&M cost

The cost structure should be described in order to provide detailed information related to the different expected expenses. The total cost structure involves the identification of the main costs: Capital (purchase and installation of equipment) and O&M (operation and maintenance) (Jones & Mendelson, 2011). The capital cost may include: design and engineering, equipment, equipment housing, and installation, site preparation and installation of utilities, permits and fees, start-up costs and working capital. O&M cost may include: parts and materials, labour, utilities, financing costs, taxes (Gatti, 2012).

The first aspect to be considered in the capital costs in the installation of the gas collection and flare system. This equipment enables the capture of the gas to generate electricity or to burn the gas when the project is not being operated. The components of the system include: gas collection wells, gas piping, condensate knockout drum, blower, flare and instrumentation and control system. The project is based on a small-medium landfill site with specific characteristics defined for the purpose of the analysis, therefore, the installation of a gas collection and flare system is based on a smaller collection system which would be extended over time (EPA, 2014).

In terms of the energy generation, the most common technology available is related to internal combustion engines, gas turbines or micro turbines. Each technology is applied according to the project size given the energy generation, the capital cost and the O&M. For the purpose of the analysis, the technology selected is micro-turbines given the size of the project, the micro turbines are recommended for projects that could generate 1 MW or less. According to the U.S. EPA (2014) the average capital cost of micro turbines ranges in US$5,500 ($/kW) and the average O&M cost is estimated in US$380 ($/kW).

The analysis focuses on the acquisition and operation of only one set of micro-turbines since the investment cost is expected to be low (in comparison with similar technology used in LFG projects). It is important to mention that the possible inclusion of the private sector in waste management activities would be based on the expected economic profits. In order to promote participation of different entrepreneurs, the analysis is intended to prove that the profitability of the project is given with low investment levels. This approach would encourage development of similar projects due to the avoidance of risks of high investment. In addition, there are not previous experiences related to energy generation from landfill gas in Mexico City, therefore, the evaluation of profitability is a small scale would evidence whether the results can be extrapolated to conditions of higher capacity.

Therefore, considering the characteristics of the landfill, the modelling using the LFGcost-WebV3.0 tool resulted in the following capital and O&M costs [1]:

Installed Capital Costs:	
Gas Collection and Flaring System	$1,021,080
LFG Energy Project	$10,729,520
Total Capital Costs (for year of construction)	**$11,750,600**
Annual O&M Costs (for initial year of operation):	**$56,742**

Table Estimations of capital and O&M costs for the LFG project

7.4.3.2 Budget of estimated production

The budget of production refers to the estimation of production levels. This budget keeps a fundamental relation to the sales budget, desired inventory levels and the revenue estimations. The estimation of the production is given by the amount of products or the coverage of the expected service to provide. The budget aims to determine if the company can produce the amounts projected in the sales budget, in order to avoid an excessive cost in labour (Drury, 2007).

For the purpose of the analysis, the budget of production presents several particularities and it is based on the estimation of the landfill gas generation. The exact amount of LFG should be determined according to the specific type of wastes. When the waste is mixed and mainly come from households, the amount of biogas can reach levels from 150m^3 to 250m^3 per tonne of MSW (Scholz *et al.*, 2012). According to the U.S. EPA the values of the theoretical potential methane generated in cubic metres per tonne of MSW range in 6.2 to 270 m^3 (EPA,

[1] For detailed data related to capital costs of the collection and flaring system see appendix 8. For detailed data related to capital costs of the CHP micro-turbine-generator set see appendix 9.

1991). The variation depends on the factors such as: climate conditions, type of waste, microbial activity, dry matter content, and the composition nature of the waste (Morin *et al*., 2010).

However, for the purpose of the analysis, the model is based on information from the U.S EPA. The model utilises the EPA's Landfill Gas Emissions Model (LandGEM) which involves the First-Order Decay Equation to measure landfill gas generation. According to the EPA's LandGEM, the first order decay model assumes that methane generation in the landfills reaches peak levels shortly after initial waste placement. It also assumes that landfill methane will decrease exponentially as organic waste is degraded by bacteria. The LandGEM uses the following equation to estimate methane generation (EPA, 1991):

$$\mathbf{Q_{CH4}} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} \mathbf{k\,Lo\,(M_i/10)\,(e^{-kt_{ij}})}$$

Where:

Q_{CH4} = estimated methane generation flow rate (in cubic meters [m^3] per year or average cubic feet per minute [cfm])

i = 1-year time increment

n = (year of the calculation) – (initial year of waste acceptance)

j = 0.1-year time increment

k = methane generation rate (1/year)

L_o = potential methane generation capacity (m^3 per megagram [Mg] or cubic feet per ton)

M_i = mass of solid waste disposed in the i^{th} year (Mg or ton)

t_{ij} = age of the j^{th} section of waste mass disposed in the i^{th} year (decimal years)

Therefore, considering the amount of waste disposed in the landfill (this information can be seen table 20), the modelling using the LFGcost-WebV3.0 tool resulted in the following estimation of landfill gas including generation, collection, and utilization:

Modelling Parameters for First-Order Decay Equation:	
Methane Generation Rate, k (1/yr):	0.040
Methane Generation Capacity, L_o (ft^3/ton):	3,204
Methane Content of LFG:	50%
Generated During Project Lifetime (ft^3/min LFG):	
Minimum:	440
Annual Average:	2,949
Maximum:	5,061
Collected During Project Lifetime (ft^3/min LFG):	
Minimum:	374
Annual Average:	2,507
Maximum:	4,302
Project Size:	**Maximum**
Design Flow Rate for Project (ft^3/min LFG):	**4,302**
Utilized by Project (ft^3/min LFG):	
Annual Average:	2,331.55
LFG Collection Efficiency:	**85%**

Table 52 Estimation of landfill gas generation, collection, and utilization

7.4.3.3 Revenue budget

The revenue budget refers to the estimation of the expected economic profits through the sales of the product or service. The information on the revenue budget provides cash flows for each period of the analysis. The cash flows represent significant information for subsequent analysis related to financial feasibility. The budget is given by the production estimations and the unitary price in order to determine the total sales. The budget considers the deduction of production costs and initial investments to determine the net profit or loss. Therefore, a proper revenue budget is a key factor to predict whether a project would be profitable (Bragg, 2012).

For the purpose of the analysis, the modelling using the LFGcost-WebV3.0 tool resulted in the following data related to the revenues expected during the lifetime of the project.

Cash Flow Inputs:	Construction Year	Operating Years														
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Total installed capital cost ($)	11,750,600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total annual cost ($)	-	56,700	151,300	251,500	357,500	469,500	587,800	712,600	844,100	982,600	1,128,300	1,281,600	1,442,700	1,611,900	1,789,600	1,976,100
Net electricity produced (kWh)	-	5,481,700	10,748,500	15,808,700	20,670,600	25,341,800	29,829,800	34,141,900	38,284,900	42,265,400	46,089,900	49,764,400	53,294,800	56,686,800	59,945,700	63,076,900
CHP steam produced (million Btu)	-	31,800	62,300	91,700	119,900	147,000	173,000	198,000	222,100	245,100	267,300	288,600	309,100	328,800	347,700	365,800
Landfill gas utilized (ft^3)	-	182,732,300	358,299,500	526,982,700	689,051,700	844,765,800	994,374,400	1,138,116,700	1,276,222,700	1,408,913,600	1,536,401,600	1,658,890,700	1,776,576,900	1,889,648,600	1,998,286,700	2,102,665,000

Economic Analysis:		Year of Operation														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenue																
Electricity sales	-	$328,900	$651,400	$967,600	$1,277,800	$1,582,200	$1,881,100	$2,174,500	$2,462,800	$2,746,000	$3,024,500	$3,298,200	$3,567,600	$3,832,600	$4,093,400	$4,350,300
CHP steam sales	-	$143,100	$283,300	$420,900	$555,800	$688,300	$818,300	$945,900	$1,071,300	$1,194,500	$1,315,600	$1,434,700	$1,551,900	$1,667,200	$1,780,600	$1,892,400
Operating Costs	-	($56,700)	($151,300)	($251,500)	($357,500)	($469,500)	($587,800)	($712,600)	($844,100)	($982,600)	($1,128,300)	($1,281,600)	($1,442,700)	($1,611,900)	($1,789,600)	($1,976,100)
Capital Costs																
Down payment	$2,350,100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loan (principle)	$967,900	$967,900	$967,900	$967,900	$967,900	$967,900	$967,900	$967,900	$967,900	$967,900	$967,900	$967,900	$967,900	$967,900	$967,900	$0
Loan (interest)	$564,000	$539,800	$514,100	$486,900	$458,000	$427,400	$395,000	$360,600	$324,200	$285,600	$244,600	$201,200	$155,200	$106,500	$54,800	$0
Equity payment	$403,900	$428,100	$453,800	$481,000	$509,900	$540,500	$572,900	$607,300	$643,700	$682,300	$723,300	$766,700	$812,700	$861,400	$913,100	$0
Principle remaining	$9,400,500	$8,996,600	$8,568,500	$8,114,700	$7,633,700	$7,123,800	$6,583,400	$6,010,500	$5,403,200	$4,759,500	$4,077,200	$3,353,900	$2,587,200	$1,774,500	$913,100	$0
Taxes	-	$783,400	$783,400	$783,400	$783,400	$783,400	$783,400	$783,400	$783,400	$783,400	$783,400	$783,400	$783,400	$783,400	$783,400	$783,400
Tax liability	-	($794,500)	($211,500)	$369,700	$949,800	$1,529,300	$2,108,800	$2,689,000	$3,270,600	$3,854,200	$4,440,400	$5,030,000	$5,623,500	$6,221,800	$6,825,500	$7,435,400
Tax before credit	-	($278,100)	($74,000)	$129,400	$332,400	$535,200	$738,100	$941,200	$1,144,700	$1,349,000	$1,554,100	$1,760,500	$1,968,200	$2,177,600	$2,388,900	$2,602,400
Net tax	-	$0	$0	$129,400	$332,400	$535,200	$738,100	$941,200	$1,144,700	$1,349,000	$1,554,100	$1,760,500	$1,968,200	$2,177,600	$2,388,900	$2,602,400
Net income	**($564,000)**	**($794,500)**	**($211,500)**	**$240,300**	**$617,400**	**$994,000**	**$1,370,700**	**$1,747,900**	**$2,125,900**	**$2,505,200**	**$2,886,300**	**$3,269,500**	**$3,655,300**	**$4,044,200**	**$4,436,600**	**$4,833,000**
Cash flow	**($3,318,000)**	**($439,200)**	**$118,100**	**$542,700**	**$890,800**	**$1,236,900**	**$1,581,200**	**$1,924,000**	**$2,265,600**	**$2,606,300**	**$2,946,400**	**$3,286,200**	**$3,626,000**	**$3,966,100**	**$4,306,900**	**$5,616,400**

Table 53 Estimation of revenues and cash flows of the projects

As can be observed, the first part of the table 53 presents the required inputs to determine the cash flows. The total installed capital cost is $11,750,600, the cost is considered to be paid during the project with down payment of $2,350,100 and subsequent payments with an interest (it must be noted that this may vary according to the type of funding obtained to carry out the project). The cash flow inputs also consider to total estimations of O&M costs during the operating years and also show the estimation of the production of Net electricity (kWh), the steam (Combined Heat and Power) and the landfill gas utilized.

The second part of the table shows the economic analysis that estimates the economic values to be obtained from sales of energy and steam. Finally, it can be observed the estimated net incomes and cash flows of the project. It can be seen that, as the total installed capital cost is high; the three first years of the project present a loss. However, after the third year, the project generates only profits.

The cash flows evidenced a similar trend. The two first years of the project present a negative cash flow. The cash flows are used to carry out the estimated related to the financial indicators in order to determine the feasibility of the project.

7.4.3.4 Minimum acceptable rate of return

In order to carry out the financial analysis, the determination of a minimum acceptable rate of return (MARR) is required to provide a reference rate to accept or decline the profitability of the investment. The MARR serves as a comparative base for the calculation of economic evaluations, if at least this rate of return is not obtained; the investment would be rejected and shall be defined as economically unviable. The MARR is defined by the investor and should consider the levels of inflation plus a risk premium (Wilson & Gilligan, 2004).

For the purpose of the analysis, the risk premium was defined considering that the electricity demand is stable, it presents few fluctuations over time and it will increase in the following years. In addition, the market of clean energy in Mexico is new; therefore, there is no strong competition among producers. With the aforementioned, it can be inferred that the investment risk is relatively low and the risk premium can fluctuate between 2 and 5%.

In order to base the analysis on a context with strict conditions, the determination of such a rate considered the following aspects (The average inflation rates in Mexico can be observed in appendix 10):

MARR = Three times the inflation rate + risk premium

Average inflation rate: 4.24% * 3 = 12.72

Risk premium: 2.28%

MARR = 15%

7.4.3.5 Net present value

The net present value (NPV) implies bringing from the future into the present the monetary amounts to their equivalent value. To make the interpretation of the NPV, it is necessary to point up that this value does not represent the profit or loss that can be generated during the project. The NPV simply indicates whether, within the investment, an approximate percentage to the MARR is been earning. A negative NPV does not imply that there is a loss in the investment or throughout the period of analysis. It only involves that the investment project is not generating the expected profit by the investor (Baca, 2007). Therefore, the acceptance criteria for the NPV in investment projects are based on the value as: (1) NPV > 0 accepted; (2) NPV < 0 rejected. The formula used to determine the NPV is described as follows:

$$\mathbf{NPV = -}\boldsymbol{P}\mathbf{ + \frac{NCF_1}{(1+\boldsymbol{i})^1} + \frac{NCF_2}{(1+\boldsymbol{i})^2} + \ldots + \frac{NCF_n}{(1+\boldsymbol{i})^n}}$$

Where:

NCFn = Net cash flow effective in the year n

P = Initial investment in the year 0

i = Reference rate corresponding to the MARR

For the purpose of the analysis, the model resulted in:

NPV = $10,981,563

$10,981,563 > 0, therefore, investment should be accepted.

7.4.3.6 Internal rate of return

The annual profit in the project can be expressed as a yield rate, the Internal Rate of Return (IRR). The IRR is the interest rate, which equates the future value of the investment with the sum of the future values of the profits, by the comparison of the money at the end of the period of analysis (Lester, 2013). The IRR is the discount rate, which makes the NPV=0. The acceptance criteria are given by IRR > MARR = accepted, IRR < MARR = rejected.

For the purpose of the analysis, the model resulted in:
IRR = 27%

27% > 15%, therefore the investment project is accepted as feasible.

7.4.3.7 Payback period

The payback period refers to the exact period of time when the initial investment is recovered. The method for the calculation of the payback period may vary according to the type of project (Garret, 2013). However, a recurrent formula includes the following aspects:

$$\mathbf{PP = n + \frac{(I - CFA)}{CFI}}$$

Where:
n = Immediate previous period in which the investment is recovered
I = Initial investment
CFA = Cash flow accumulated from the immediate previous period in which the investment is recovered
CFI = Cash flow for the period in which the investment is recovered

For the purpose of the analysis, the model resulted in:

PP = 7 years

7.4.4 Main expected impacts

The description of the main impacts of the project enables a proper classification of the proposal. The categorization of the project in accordance with the expected impacts may vary in relation to the agency that is intended to evaluate the project and to provide funding. Classifications of the impacts include social, political, environmental, economic, cultural, and any other consequences of the project. The impacts can be categorized according to the degree of impact (high, medium, low). The proper description of the main impacts can provide supporting information to encourage investment, or to obtain funding. For the purpose of the analysis, two main impacts are expected: environmental impact and economic impact.

7.4.4.1 Environmental impact

The project is based on a disposal site with an average daily capacity of 2,500 tonnes of MSW. Therefore, the main environmental benefits are represented by the amount of methane collected and destroyed. In addition, as disposal sites are generally located far from electrical installations, the energy needed to perform the operational activities is obtained by burning fossil fuels such as diesel and petrol. Therefore, the production of energy from landfill gas, not only represents an alternative to cover the cost of fuels, but also helps to reduce the emission of pollutants to the atmosphere. The consumption of clean energy represents benefits in contrast with the use of energy coming from fossil fuels. In addition, the use of clean energy decreases the negative environmental impacts (Abbasi, 2012).

For the purpose of the analysis, the calculation of environmental benefits with LFGcost-WebV3.0 is based on the following assumptions and conversion factors:

Amount of methane in landfill gas (%) =	50%
Expected LFG energy project lifetime (years) =	15
Methane heat content (Btu/ft^3) =	1,012
Natural gas heat content (Btu/ft^3) =	1,050
Global warming potential (GWP) of methane =	25
Density of methane (lb/ft^3)	0.0423
Average 2014 U.S. power emissions (lb CO_2/kWh) =	1.18
Metric ton per short ton =	0.9072
Pounds per short ton =	2,000
Conversion efficiency of LFG methane to High Btu methane (%) =	90%
Carbon dioxide from natural gas combustion (lb CO_2/ft^3) =	0.12037
Conversion efficiency of LFG methane to CNG (%) =	65%
Carbon dioxide from diesel fuel combustion (lb CO_2/million Btu) =	161
Efficiency of displaced natural gas-fired hot water/steam boiler (%) =	80%

Table 54 Assumptions and conversion factors used in the model

It must be noted that the parameters of table 54 are based on information provided by the U.S. EPA according to general information on existing landfills in the U.S.A. Once clarified the aforementioned, the model resulted in the following indicators related to expected environmental benefits:

Project Lifetime Totals:	
Total Methane Collected & Destroyed (ft^3) =	9,882,757,447
Direct Methane Reduced (MMTCO*$_2$E) =	4.741
Total Methane Utilized by Project (MMTCO$_2$E) =	4.409
Total Carbon Dioxide Avoided (MMTCO$_2$E) =	0.503

* Total million metric tonnes of methane represented by carbon dioxide equivalents

Table 55 Benefits of collecting and destroying methane (during the life of the project)

It can be observed that the project is expected to collect and destroy 9,883 million cubic feet of methane (assuming 100% destruction efficiency), and that approximately 503,000 metric tonnes of methane (represented by carbon dioxide equivalents) are expected to be avoided. With this the project evidences important environmental benefits.

7.4.4.2 Economic impact

The main expected economic impacts refer to coverage of the operational costs of the disposal site. The sales of energy from landfill gas cannot represent direct economic benefits only, but also the costs of different activities on the site can be reduced. The reduction of operational costs of the landfills (costs of petrol, water, energy, salaries, etc) can raise the profits obtained by the main activity of the landfill.

- **Employment**

Expected direct jobs: 1 (Staff responsible for supervising the generator)
Expected indirect jobs: 3 (Temporary workers for maintenance)

- **Cost reduction**

A disposal site with an average reception capacity between 2,000 and 3,000 tonnes per day in Mexico, presents the following costs according to size and location:

Consumption of diesel for energy generators = 5,000 litres per week (715 per day)
Consumption of water = 20,000 litres per week (2,857 per day)
Salaries = $70,000 per month

Total expenditure of diesel per year[2] = US$ 241,700
Total expenditure of water per year[3] = US$ 4,700
Total expenditure on salaries = US$ 63,600

The total estimated operational cost of the disposal site is US $310,000. Therefore, the revenues obtained from the sales of energy are higher than the total operational cost. The profits (after the fourth year) can cover the total costs and still generate high revenues. It must be pointed out that this analysis only considers the revenue from sales of energy and steam; however, it must be taken into consideration that the main activity of the site would be the disposal of MSW, an activity which also represents economic incomes that can increase the total profits of the landfill.

[2] The price per litre of diesel on November 2013 in Mexico City was $12.27 (Mexican pesos)
[3] The price of a water truck of 20,000 litres on November 2013 in Mexico City was $1,200 (Mexican pesos)

7.4.5 Financing mechanisms

The financing mechanism may present different requirements and characteristics according to the source of funding. However, the business plan is a significant document that is required by institutions and governmental agencies which aim to promote technology transfer. In order to provide an integrated context of the different alternatives to finance the acquisition of technology; several options should be evaluated. The selection of a proper financing mechanism may vary according to the type of technology or service. For the purpose of the analysis, three mechanisms were evaluated.

7.4.5.1 Partnership

This mode implies a technology alliance between the supplier of the technology and the receiver. In such a case, the provider of the generator can disburse a percentage of the total cost of the technology transfer. The participation can go from a small percentage up to coverage of the total cost. The technology alliance represents different advantages for the receiver because the stages of acquisition, installation, adaptation and absorption exploitation are carried out by the supplier (Buckup, 2012).

The percentage of participation must be defined since the beginning of the project and the responsibilities and rights of both parts should be clarified. For the purpose of the analysis, such a scheme can be used as follows:

7.4.5.1.1 Participation of 50/50

In this case, the supplier covers the half of the total cost of the technology. The investment needed is $11,750,600, with a down payment of $2,350,100; therefore, the supplier and the receiver must invest at least $1,175,050 each. This financial strategy is described as follows:

Participants	Monetary contribution	Non-monetary contribution	Benefits	Risks
Supplier (National or International)	50% of the investment $1,175,050	-Technology - Patents - Licenses - Knowledge - Training - Advise	- Preferential price of the technology - Shared investment risk - Reduced investment of the receiver - Safe investment -Ensures the transfer and absorption of technology - The receiver draws on the experience of the supplier in the field of biogas exploitation and distribution of clean energy - No interest on investment	-Shared profits - Reliance on the supplier - Equality of rights, benefits and conditions
Receiver (Mexican waste management enterprise)	50% of the investment $1,175,050	- Facilities - Terrains - Feedstock (MSW) - Human resources - Knowledge of local markets		

Table 56 Strategy for financing with a 50/50 partnership

Table 56 presents the distribution of the investment between the supplier of the technology and the receiver (operators of the landfill site). It can be observed that the scheme of partnership involves also non-monetary contribution of both parts. For the supplier the main non-monetary contributions are completely related to the technology and infrastructure required for the project. This involves a proper knowledge related to installation, operation, maintenance of the technology. On the other hand, the receiver contributes with facilities, human resources and a significant knowledge of local markets. This scheme is advisable when there is not a proper understanding of the technology to be acquired and when the investment cost in significantly higher in relation with the average income of the receiver.

7.4.5.2 National governmental financing

The financing can be also obtained by institutions in Mexico aimed to support improvement of technology and processes. The main advantage includes the direct deal with the institutions due to their location.

7.4.5.2.1 National Bank of Works and Public Services

The National Bank of Works and Public Services (in Spanish BANOBRAS) aims to finance the creation of public services. Some of the activities supported include the final disposal sites for waste and the generation of energy. The financing loan is managed by the National Infrastructure Fund. The financing can be focused only on improving or building infrastructure. The maximum loan is $303,000 and the payment terms range from 10 to 15 years with variable and fixed rates between 8% and 10%. Therefore, as the amount required for the down payment in significantly higher that the maximum loan, the scheme of funding from BANOBRAS is not feasible.

7.4.5.2.2 Venture capital trusts

The Venture Capital Trusts (FIRCO-SAGARPA) from the Mexican Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food, supports programmes which are aimed at correcting missing funds in order to support the realization of investments, works or tasks necessary to achieve the increase in productivity of the land; support technology adoption and manage productive activities for the benefit of the environment, with a strong social impact. The financing structure is described as follows:

Concept supported	Maximum percentage of the total investment	Maximum funding provided (Mexican Pesos)	Estimated maximum funding provided in US dollars
Formulation of business plan; studies and designs; pre-operative expenditures	90%	$200,000	$US 15,000
Technical support and agro-industrial training	80%	$200,000	$US 15,000
Infrastructure and equipment	50%	$4,000,000	$US 303,000
Working capital	80%	$1,000,000	$US 76,000
Investment	70%	$2,500,000	$US 189,000

Table 57 Maximum amounts of support from FIRCO (SAGARPA, 2013)

The main advantage of this mechanism is that, although the venture resources are recoverable, they are provided without financial cost and they do not imply the right to participate in profits achieved. However, similar to case of BANOBRAS, the maximum funding is lower than the required investment.

7.4.5.3 Inter-American Development Bank

Although technology transfer can be funded by different international institutions, the Inter-American Development Bank (IADB) is analysed as a feasible institution due to its support to the technological development in countries of North and Latin America and the Caribbean. The Inter-American Investment Corporation (an agency of the IADB) is aimed to finance the following aspects:

1) Acquisition of machinery, tools and equipment of all kinds, which contain a considerable amount of information technology. The purchase implies a significant transfer of technology as the equipment involves a technological innovation.

2) Direct investment by foreign companies to partner with local firms, represent another instrument of technology transfer, especially when the investment enables the introduction of new advanced methods and helps to develop local industrial research activities.

Both options can be used to finance the purchase of the generator. In the first instance, all the financial resources to cover the initial investment can be obtained from a financial loan. Such a scheme presents the following characteristics:

- Loan amounts ranging from US$100,000 to US$40 million[4]
- Preference for projects aimed at environmental and social sustainability
- Payment terms from 1 to 15 years
- An option to obtain financial loans in Mexican currency
- Variable interest rates

Considering that the payback period of the project is 7 years, applying for a loan from the Inter-American Development Bank, is also a feasible option to carry out the purchase of technology. In addition, the maximum loan is higher than the required investment for the project; therefore the Inter-American Development Bank is presented as the most feasible option to obtain funding given that the loan can cover the totality of the investment.

[4] The financing can be from 30% up to 50% of the total investment

7.5 Summary of Chapter 7

The analysis enabled to determine the main aspects to be included in an investment project in the waste management sector. The variety of funding sources for the transfer and acquisition of technology in developing countries can be limited, therefore, the proper design and formulation of projects highlighting technical and economic feasibility is essential. The obtained results in this Chapter are aimed to encourage the diversification of waste management activities by the acquisition and application of new technologies. The integrated programme from Chapter 6 provides the basis to diversify such activities and services which, along with the results of Chapter 7, integrate the proposed development of the waste management system in Mexico City.

Chapter 8

Conclusions

8.1 An overview of work

The work that is reported in this thesis has focused on several areas of activity: (1) theoretical aspects of waste management (Chapter 2); (2) demographic and economic information for Mexico City (Chapter 3); the performance of the waste management system within Mexico City (Chapter 4); and operation and management of waste systems in selected international cities (Chapter 5). The evaluation leads to the development of an integrated waste management programme (Chapter 6) and the formulation of an investment project in waste management activities (Chapter 7).

The research addressed the waste management sector in Mexico City and significant issues identified included: (1) an inefficient and limited legal framework related to waste management; (2) increasing generation of waste resulting from high levels of population and business activity; (3) inadequate performance of the waste management system, produced by lack of proper public policies; (4) consistently ineffective procedures in the separation and recycling activities; (5) obsolescence of equipment and infrastructure contributing to a lack of proper technology available for waste management; (6) significant environmental impacts resulting from inefficient treatment methods for MSW; and (7) wastage of market opportunities in the waste management sector.

The author identified fundamental elements required to achieve efficiency in the waste management system of Mexico City taking into consideration the main problems that were identified in the initial analysis. In order to develop a programme of research focusing on the improvement of waste management, the formulation of the general aims and the specific objectives was carried out.

8.2 Overall discussion of the research

High population, population growth and business activity in Mexico City have contributed to extremely high and increasing levels of waste generation. Such a rapid increase in MSW generation demands a wide coverage of the public services; however the current capacity has been exceeded and the government has depleted resources to provide a proper waste management service. The current system was evidenced as inefficient and obsolete. There are no programmes to promote waste prevention thorough the proper implementation of the waste hierarchy.

The waste problem in Mexico City can be approached from the standpoint of lack of culture and education related to separation and recycling of waste at source; it is important to consider education and the dissemination of information as fundamental requirements to support the system. The problem can also be approached from the political and economic perspectives. The government has to develop public policies to address the problem as a whole; the formulation of strategies should consider all stakeholders involved in the system and must be supported by a comprehensive legal framework. The legal framework in Mexico City is significantly weak; this argument is supported by comparing the scheme with the legal frameworks applied in the countries of the European Union, which incorporate specific directives focusing on all actions related to waste management. Laws should be improved and include specific regulations for each part of the system, considering the waste hierarchy and waste minimisation as key factors.

The current administration cannot be blamed for a problem, which has existed for more than 25 years; however, new administrations should avoid careless attitudes and inefficient public policies, which lead to negative externalities on public finances, social stability and adverse environmental impacts. A new economic sector focusing on waste management can be created with supervision of governmental institutions related to environmental protection. The private sector inclusion in selected activities within the waste management system, in addition to the new integrated programmes from the government, can achieve effectiveness and efficiency in the waste management system of Mexico City.

8.3 Main conclusion

The research was conducted based on different analysis intended to achieve the general aims and specific objectives. The following conclusions are listed according to each analysis carried out.

The analysis of the economic and demographic context of Mexico City resulted in the following conclusions:

- The amount of MSW is expected to increase and closely correlates with the population growth.
- New plans and projects in the field of waste management should consider the population growth and the increasing demand for services.
- The future demand for waste management should integrate all stakeholders involved in the provision of public services in the Mexico City Metropolitan Zone according to demographic characteristics.
- The economy of Mexico City depends significantly on MSMEs which are focused on the economic sectors of trade and services.
- Mexico City has been ranked as an important emerging economy and it is expected to become a rich urban agglomeration.
- Private capital can be channelled into waste management initiatives in order to improve the system due to diversification of services, this is in the context of the competitiveness for public funding.

The comprehensive analysis of the generation, type of wastes, status of facilities and any other aspects related to the current Municipal Solid Waste Management system of Mexico City resulted in the following conclusions:

- The collection system was demonstrated to be inefficient based on the obsolescence of vehicles and the lack of separate collection according to the planning of routes.
- The recycling activity presents deficiencies which are caused by the significant number of unregulated stakeholders and lack of appropriate and updated equipment in waste management facilities.
- The government should instigate an extensive programme to regulate recycling markets and to increase efficiency in transfer stations and sorting facilities.

The analysis of waste management systems in selected cities resulted in the following conclusions:

- The case of London represented a system that is based on a comprehensive compendium of directives from the Commission of Environment of the European Union. The operation of the system is divided into local authorities with separation of actions for specific regions. The system demonstrates significant private sector involvement, and cooperation between public and private sectors has been a key aspect in developing new treatment facilities. The landfill tax was identified as a punitive device that has effectively led business and local government to decrease the use of landfills.
- The case of Berlin evidenced a system highly supported by recycling activities. Similar to the case of London, the system is also based on regulations from the European Union. The efficiency of a single company for collection and cleaning services in the city has led the government of Berlin to focus on recycling initiatives. The participation and high commitment of people in separation and recycling activities can be attributed to environmental awareness, but also to high fees to be paid where residual waste requires collection.
- The case of Tokyo represented a system that is highly supported by incineration technology. The high costs for waste management have led the government to encourage the participation of the private sector. The waste management sector can be regarded as an attractive market for private business due to expected profitability; this was demonstrated by the creation of an inclusive project in which nine private sector companies were created in only 3 years.
- The case of New York was a system with a high participation of the private sector; however the system lacks specific actions to prevent and recycle waste. The exportation of waste from, transfer stations to incinerators and landfills in other cities was evidenced. It is too early to evaluate the impact of implementation of the plan "beyond waste"; nevertheless, the creation of local units for waste management is presented as a strategy to improve the system. Similar to the case of London, the division of actions can help to manage waste system in large cities.
- As a general overview, the models analysed are supported by comprehensive legal frameworks. The participation of the private sector is significant in all systems and the

waste hierarchy is considered in the formulation of all programmes. Significant aspects of the models analysed provided useful information in the development of a new integrated programme to improve the waste management system in Mexico City.

The identification of the fundamental elements required in the development of a feasibility study of the generation of energy from landfill gas, including commercialization conditions, economic and financial aspects, and suitable funding sources; resulted in the following conclusions:

- An attractive market for clean energy was evidenced based on low projections of energy from alternative sources.
- Sales of energy from landfill gas can be focused on the industrial sector due to significant energy consumption of industrial parks in the vicinity of the city.
- Certification of best practices of Corporate Social Responsibility can be an attractive aspect to encourage companies to use clean energy.
- The commercialization of energy should be in accordance with the conditions of the Federal Electricity Commission through the interconnection agreement for renewable energy and efficient co-generation.
- The cost of installation shall vary considerably according to the needed interconnection lines and electrical transformers to connect the generator with suitable substations.
- As the financial indicators, including net present value (NPV = $10,981,563), internal rate of return (IRR = 27%), and payback period (PP = 7 years) proved the profitability of the investment; the project was evidenced as economically feasible.
- The analysis also indicated positive environmental impacts due to the decrease of methane released to the atmosphere in 9,883 million cubic feet (assuming 100% destruction efficiency).
- The energy can be substituted for that derived from diesel and petrol generators in the landfill.
- The revenues from the sale of generated energy can cover the operational costs of the disposal site.

8.4 Contribution to the body of knowledge

The nature of the problem, which was related to the inefficient waste management system in a City with high population density like Mexico City, required the application of different theoretical methods to generate an appropriate approach. Initially, the research was conducted under an inductive method since, a general assumption was formulated: "The waste management system of Mexico City could be improved by the adoption of new technology". In order to carry out the study, particular elements, including the evaluation of the current waste management system, were analysed. The evaluation suggested that the initial theoretical method used should be changed from deductive to an inductive approach (see section 1.2). The application of such methods enabled the development of a comprehensive bibliographic research, mainly related to municipal solid waste management and to a lesser extent technology transfer.

The complex issues that contribute to the inefficient Solid Waste Management (SWM) system in Mexico City were identified. The SWM systems operated in the four international cities were critically identified to determine the key factors of successful development. These analyses enabled the evolution of the guiding principles, which were used in the development of an integrated programme for SWM in Mexico City with detailed recommendations for policies, plans and actions over the diverse aspects of the system.

Once clarified the elements that constructed the research it must be mentioned that the research aimed to apply knowledge in the waste management field in an innovative form. The application and generation of new knowledge are based on the practical and on the theoretical contributions. The theoretical and practical contribution responds to the development of technical solutions in the field of waste management. Therefore, the main contributions can be described as follows:

- **Theoretical contribution**

The theoretical contribution represents the results that contribute to develop the research field related to MSW management. The theoretical contribution is represented by the new proposal and solutions formulated in the case of Mexico City, but that can generate new methods to approach similar problems in different context. The main theoretical contributions include:

- The identification of key elements to contribute to the sustainability of waste management programmes not only in Mexico, but in any aspects within the field of waste management worldwide.
- The approach in which the research was conducted can create new schemes to help and assist project managers and makers or public policies to design models aimed to develop new and innovative waste management systems.

- **Practical contribution**

The practical contribution represents the results that provide a practical solution to waste management problem in Mexico City. The contribution is a function of the general aims (see section 1.3) and directly impacts on the waste management activities carried out in Mexico City in order to transform the current context into an improved situation. The main practical contributions include:

- The diagnosis of the current status of the whole waste management system of Mexico City which was summarised in evaluations and recommendations.
- The modification suggested in the legal framework of selected areas of environmental protection and waste management in Mexico City.
- The foundation to enable the creation and modification of operational procedures in the facilities for waste management of Mexico City.
- The strategies to create an integrated system and which are based on key elements within a waste management process, including environmental education, improvement of infrastructure, appraisal and use of alternative technologies, and institutional coordination.
- The guiding principles to support all actions related to waste management and which were originated through the identification of key elements in selected systems of different cities.
- An integrated programme for MSW management in Mexico City. The programme details specific activities, responsible staff and tentative time scales, all intended to achieve the development of the system. The programme is expected to be extrapolated to other cities inside or outside Mexico.

- A detailed guide to obtain funding for technology transfer of waste management activities. The guide is expected also to be adapted to another context with similar characteristics.

It must be noted that no previous research has been conducted under the same working approach. The aspects aforementioned are new results to the body of knowledge in the research field of Municipal Solid Waste management.

8.5 Recommendations for further research

The proposals put forward by the author involve the participation of a wide number of stakeholder. The successful implementation of the programme requires full cooperation and coordination among government, society and private sector. The MSW problem should be approached in an integral form. Further research to improve programmes and initiatives in the waste management sector should consider the review of provided guidelines of this thesis. The integrated programme for waste management provide basis to undertake new projects which support specific actions. The twelve general strategies in the four categories: operation, information, technology and coordination, require constant monitoring to update the programme.

The section related to projects related to waste management can represent further evaluations to develop supporting documents for institutions and business which intend to undertake activities. Organisation manuals, credit manuals, accounting books, financial systems, environmental impact studies, can be developed to help businesses to remain on the market.

Altough the scope of the thesis was limited to Mexico City, the analysed aspects enable the adaptation of the research to different contexts. The applied working approach in the research may be applicable to similar cases with a federal, state or local scope. The author encourages wider evaluations and research which can strengthen a sustainability model for Mexico City and that can be also applied to different cities.

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Appendices

Appendix 1
Legislation on hazardous waste

Legislation of the European Union considers as hazardous waste:

1. Gaseous effluents
2. Radioactive elements
3. Decommissioned explosives
4. Faecal matter
5. Waste waters
6. Animal by-products
7. Carcasses of animals that have died other than by being slaughtered;
8. Elements resulting from mineral resources.

The obligations of Member States regarding hazardous wastes include:

1. It is prohibited to export or import hazardous wastes or other wastes to or from a non-party State;
2. No wastes may be exported if the State of import has not given its consent in writing to the specific import;
3. Information related to proposed transboundary movements must be communicated to the States concerned, by means of a notification form, so that they may evaluate the effects of the proposed movements on human health and the environment;
4. Transboundary movements of wastes must only be authorized where there is no danger attaching to their movement and disposal;
5. Wastes which are to be the subject of a transboundary movement must be packaged, labelled and transported according to international rules, and must be accompanied by a movement document from the point at which a movement commences to the point of disposal;
6. Any party may impose additional requirements that are consistent with the provisions of the Convention.

Properties of hazardous wastes include:

1. **Explosive:** Substances and preparations which may explode under the effect of flame or which are more sensitive to shocks or friction than dinitrobenzene.
2. **Oxidizing:** Substances and preparations which exhibit highly exothermic reactions when in contact with other substances, particularly flammable substances.
3. **Highly flammable:** Liquid substances and preparations having a flash point below 21 °C (including extremely flammable liquids), or substances and preparations which may become hot and finally catch fire in contact with air at ambient temperature without any application of energy, or solid substances and preparations which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition, or gaseous substances and preparations which are flammable in air at normal pressure, or - substances and

preparations which, in contact with water or damp air, evolve highly flammable gases in dangerous quantities.

4. **Flammable:** Liquid substances and preparations having a flash point equal to or greater than 21 °C and less than or equal to 55 °C.
5. **Irritant:** Non-corrosive substances and preparations which, through immediate, prolonged or repeated contact with the skin or mucous membrane, can cause inflammation.
6. **Harmful:** Substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may involve limited health risks.
7. **Toxic:** Substances and preparations (including very toxic substances and preparations) which, if they are inhaled or ingested or if they penetrate the skin, may involve serious, acute or chronic health risks and even death.
8. **Carcinogenic:** Substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence.
9. **Corrosive:** Substances and preparations which may destroy living tissue on contacts.
10. **Infectious:** Substances containing viable micro-organisms or their toxins which are known or reliably believed to cause disease in man or other living organisms.
11. **Teratogenic:** Substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce non-hereditary congenital malformations or increase their incidence.
12. **Mutagenic:** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce hereditary genetic defects or increase their incidence.
13. Substances and preparations which release toxic or very toxic gases in contact with water, air or an acid.
14. Substances and preparations capable by any means, after disposal, of yielding another substance, e.g. a leachate, which possesses any of the characteristics listed above.
15. **Ecotoxic:** substances and preparations which present or may present immediate or delayed risks for one or more sectors of the environment.

Legislation in Mexico City identifies the following products as wastes requiring special handling:

1. Wastes coming from health services, generated by establishments which supply medical-care to human or animal populations, research centres development and experimentation within the pharmacology and health field.
2. Cosmetics and food unfit for consumption generated by industrial or commercial establishments.
3. Wastes generated by agriculture, forestry and livestock, including the raw material used of those activities.
4. Wastes from transport services generated as a result of the activities performed in transportation terminals.
5. Wastes from demolition, maintenance and civil construction in general.
6. Technological wastes from industries of computer manufacturers, electronic goods and vehicles and other that after spending their life require special handling.
7. Dewatered sludge.
8. Used tires, furniture, household items used in high volume, plastics and other slowly degradable materials.
9. Wastes form industrial laboratories, chemical, biological, production or research.

Appendix 2
Interview guide

Date: _______________
Interviewee: ____
Position : ____
Department : ____

1. What would you consider to be a proper description of the current waste management system of Mexico City?

2. In general terms, how could be explained the main strategy of the Mexico City's government to deal with the MSW generation problem? (actions and times)

3. Within the MSW management process, Mexico City's government has focused on the final disposal alternative only (landfill). Now that the "Bordo poniente" is closing, what would be the new strategy?

4. How old are the vehicles used for the collection system? And are they equipped with separation system and are enough to cover the existing demand?

5. When was acquired the machinery used in the selection plans? And what are they used for?

6. Official reports show discouraging data, what could be the reason to explain those figures?

7. The numbers show that recycling has been very low, what could be considered the main reason for this situation?

8. Legislation in Mexico does not specify methods about recovery methods, there are ambiguities and lack of detailed information. Is there any short-term plan to improve these regulations? If there is, what aspects would be improved? What would be the priority?

9. Does Mexico City's government really have the technology to increase the recycling levels?

10. Is there any strategy which contemplates the informal economies within the new waste management systems? If there is, what is it?

11. The energy generated from waste is a priority in the short-term?

12. Is there any cooperation plan with any other entity (national or international) is MSW management matter?

13. From the government budget, how many resources are allocated for MSW management system?

14. What could the advantages and disadvantages of allowing the private sector to get into the MSW management system?

Appendix 3
Statistics of sorting per facility in Mexico City

Plant	Activity	January	February	March	April	May	June	July	August	September	October	November	December	Total (ton/year)
Bordo Poniente (PBP)	Input	40,082	39,046	53,300	5,0453	48,273	51,395	55,339	51,218	48,190	53,135	50,081	68,757	609,339
	Sorted	4,008	3,905	5,330	5,045	4,827	5,139	5,534	5,129	4,819	5,313	5,008	6,876	60,934
	Output	36,074	35,142	47,970	45,408	43,446	46,255	49,806	46,158	43,371	47,821	45,073	61,881	548,405
San Juan de Aragon (PSJA)	Input	38,304	36,534	40,813	38,380	37,424	39,298	41,915	38,213	37,421	36,948	39,041	60,210	484,500
	Sorted	3,830	3,653	4,081	3,838	3,742	3,930	4,191	3,821	3,742	3,695	3,904	6,021	48,450
	Output	34,473	32,881	36,732	34,542	33,681	35,368	37,723	34,391	33,678	33,253	35,137	54,189	436,050
Santa Catarina (PSC)	Input	50,402	48,014	57,619	53,536	53,628	57,520	59,247	58,320	53,471	49,226	46,659	48,991	636,635
	Sorted	5,040	4,801	5,762	5,354	5,363	5,752	5,925	5,832	5,347	4,923	4,666	4,899	63,663
	Output	45,362	43,213	51,857	48,183	48,265	51,768	53,323	52,488	48,124	44,304	41,993	44,092	572,971
Total	Input	128,787	123,595	151,732	142,369	139,325	148,212	156,501	147,820	139,081	139,309	135,781	177,958	1,730,473
	Sorted	12,879	12,360	151,73	14,237	13,933	14,821	15,650	14,782	13,908	13,931	13,578	17,796	173,047
	Output	115,909	111,236	136,559	128,132	125,393	13,391	140,851	133,038	125,173	125,378	122,203	160,162	1,557,426

Table A1 Inputs, sorting and outputs of MSW in sorting plants in 2011
(Constructed with data from SE-DF, 2012)

Plant	Activity	2005	2006	2007	2008	2009	2010
Bordo Poniente	Input	42,095	41,783	42,570	43,876	52,818	50,778
	Sorted	2,107	2,256	2,355	2,648	5,337	5,078
	Output	39,988	39,527	40,215	41,220	47,480	45,700
	% of sorting	5	5	6	6	10	10
San Juan de Aragón	Input	45,462	43,357	42,398	46,763	46,098	40,375
	Recovery	3,470	3,024	3,420	3,422	4,659	4,037
	Output	41,993	40,333	38,978	43,341	41,439	36,337
	% of sorting	8	7	8	7	10	10
Santa Catarina	Input	39,918	40,907	40,127	50,105	48,870	53,053
	Sorted	8,138	1,859	2,358	2,895	4,939	5,305
	Output	31,780	39,048	37,769	47,210	43,932	47,748
	% of sorting	20	5	6	6	10	10
Totals	Input	**127,475**	**126,047**	**125,095**	**140,744**	**147,786**	**144,206**
	Sorting	**13,715**	**7,139**	**8,133**	**8,965**	**14,935**	**14,421**
	Output	**113,761**	**118,908**	**116,962**	**131,771**	**132,851**	**129,785**
	% of sorting	**11**	**6**	**7**	**6**	**10**	**10**

Table A2 Percent of separation in sorting plants of the Federal District
(Constructed with data from SE-DF, 2012)

Appendix 4
Low-income communities and waste management in New York City

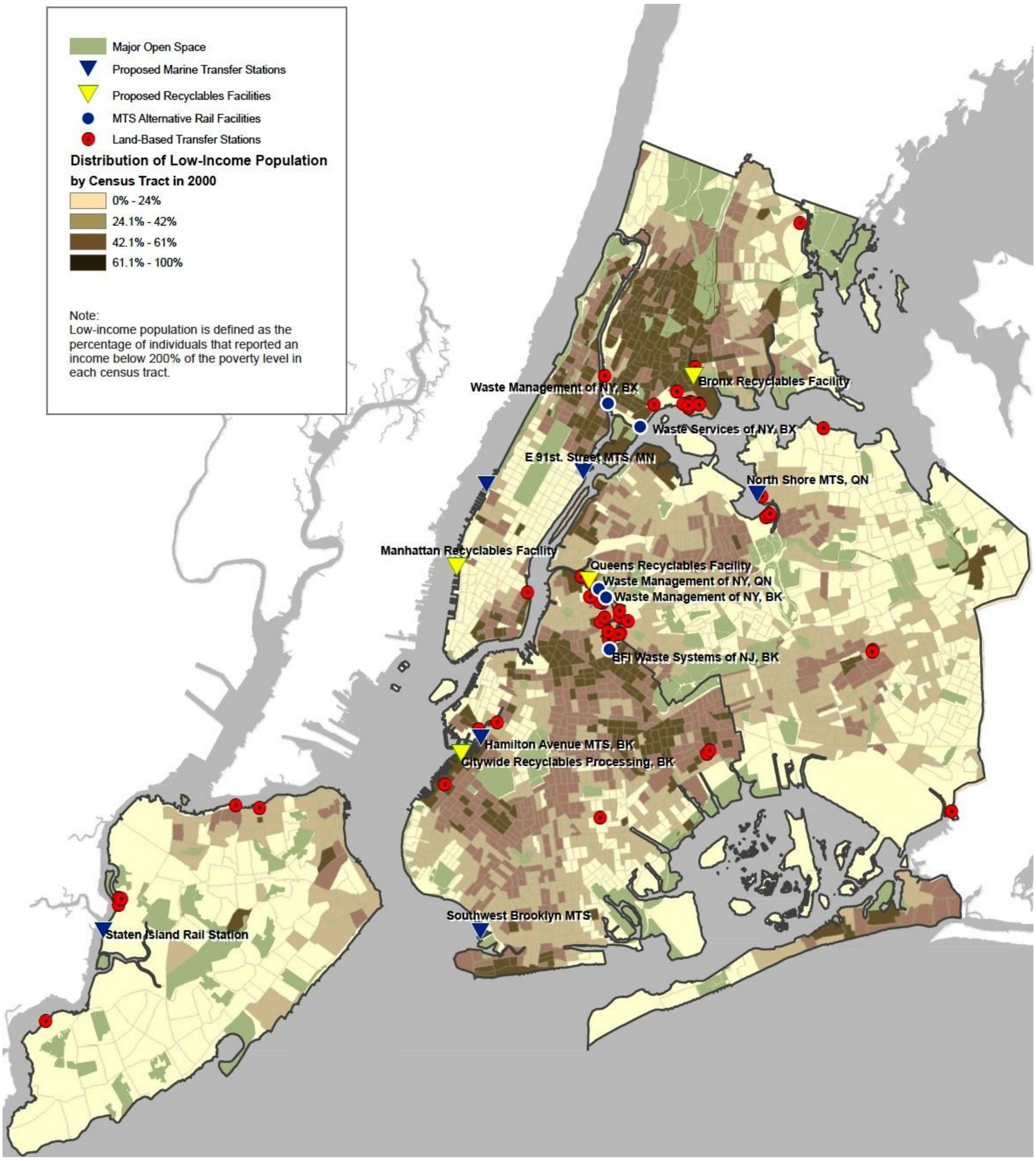

Figure A1 Location of waste management facilities in New York City and distribution of low-income population (Adapted from NYC-EJA, 2007)

Appendix 5
SWOT matrix

	Strengths: S	**Weaknesses: W**
	1. There are economic resources to undertake new initiatives. 2. Latent business opportunity for private companies. 3. Waste management systems have become a priority in the government agenda. 4. There are small organisations which have begun recycling and reuse activities. 5. People are aware of the rubbish problem in the City. 6. Any implemented system can be measured and analysed in function of the obtained results. 7. High costs can be afforded by public and private sectors. 8. Benefits of a new system are unquestionable. 9. The environmental cost is significantly reduced with a new system.	1. High initial set up costs. 2. Lack of credibility in the government. 3. The absence of similar initiatives and projects to compare results. 4. Marked diversity in the economic activities of each borough. 5. High disparity in the population concentrated in the 16 boroughs 6. Lack of motivation and commitment in the governmental workforce in charge of the waste management. 7. Lack of technology and procedure handbooks in transfer stations and selection plants. 8. Separation in the operational and planning dependencies. 9. Weak and incomplete legislation related to waste management.
Opportunities: O 1. The government is aware of the important need for an efficient waste management system. 2. The existing system has proved to be inefficient and harmful for the environment. 3. The participation of neighbourhoods in environmental activities has begun to increase. 4. Increasing in the funding for environmental projects in Mexico City 5. High business activity in Mexico City. 6. Unexploited market of waste management for private companies. 7. Absence of any feasible proposal for waste management.	1. To design a waste management system programme considering the participation of all involved parties. 2. To seek the participation of the private initiative in waste management activities by spreading the potential market of waste management.	1. To design the plan according to the characteristics of each borough showing a remarkable commitment of the government 2. To offer training courses and sensitivity programmes to alert stakeholder of the complexity of the problem and the important benefits.
Threats: T 1. Existence of a large number of intermediaries for recycling. 2. Social groups which live of the commercialization of waste. 3. The opening of a new small landfill in the State of Mexico. 4. Change of staff in the departments and agencies in the Federal District and in the government of the city. 5. Differences and conflicts between political parties in local boroughs and the parties in power. 6. The system cannot present solid results in the short term. 7. There is no market for all types of recycled products.	1. To design specific programmes of rewards and fines for the performance in the waste management activities undertaken either in business or in households. 2. To establish strategic linkages with local, state and federal governments and any other national or international institution in the matter to undertake joint projects.	1. To incorporate irregular groups and intermediaries into a regulated system for commercialization of recycled items. 2. Formulation of new supplementary laws for waste management and plant to improve technology and infrastructure for waste management.

Figure A2 Main results of a SWOT analysis for Mexico City

Appendix 6
Statistics of the energy market in Mexico

NON-RENEWABLE RESOURCES	RENEWABLE RESOURCES
Thermoelectric 81.24% (Hydrocarbons, Independent Power Producers (IPP) and coal-fired)	Hydroelectric 12.84%
Nuclear 3.58%	Geothermal 2.30%
	wind power 0.04%

Table A3 Electrical energy generation by source
(Constructed with data from SENER, 2013)

Year	Domestic	Commercial	Service	Agricultural	SME	Large Enterprise	Total
2005	42,531	13,007	6,431	8,067	61,921	37,799	**169,757**
2006	44,452	13,229	6,577	7,959	65,266	37,887	**175,371**
2007	45,835	13,408	6,789	7,804	67,799	38,833	**180,469**
2008	47,451	13,645	7,057	8,109	69,100	38,551	**183,913**
2009	48,540	13,417	7,787	9,299	67,630	34,794	**181,465**
2010	48,700	12,991	7,707	8,600	70,024	38,617	**186,639**
2011	51,771	13,591	8,068	10,973	73,431	43,112	**200,946**
2012	52,030	13,920	8,371	10,816	75,836	45,507	**206,480**

Table A4 Sales of electrical energy in Mexico in GigaWatts-Hour
(Constructed with data from SENER, 2013)

Year	Hydro-electric	Thermo-electric	Combined Cycle		Dual	Coal-fired	Nuclear	Geothermal	Wind power		Photovoltaic	Total
			CFE	IPP					CFE	IPP		
2004	10,530	16,954	4,776	7,265	2,100	2,600	1,365	960	2	0	0	**46,552**
2005	10,536	15,715	5,005	8,251	2,100	2,600	1,365	960	2	0	0	**46,531**
2006	10,566	15,586	5,203	10,387	2,100	2,600	1,365	960	85	0	0	**48,769**
2007	11,343	15,702	5,416	11,457	2,100	2,600	1,365	960	85	0	0	**51,029**
2008	11,343	15,734	5,456	11,457	2,100	2,600	1,365	965	85	0	0	**51,105**
2009	11,383	15,616	6,115	11,457	2,100	2,600	1,365	965	85	0	0	**51,686**
2010	11,503	15,627	6,115	11,907	2,778	2,600	1,365	965	85	0	0	**52,945**
2011	11,499	15,266	6,122	11,907	2,778	2,600	1,365	887	87	0	0	**52,512**
2012	11,544	15,142	6,122	11,907	2,778	2,600	1,610	812	87	511	1	**53.114**

Table A5 Effective capacity of energy generation in Mexico in Mega Watts
(Constructed with data from SENER, 2013)

Appendix 7
Prices of energy in Mexico

Year	Domestic	Commercial	Service	Agricultural	SME	Large enterprise
2008	106.18	254.98	172.15	50.97	152.69	118.30
2009	106.75	237.26	175.76	41.12	126.44	95.54
2010	111.97	257.00	186.28	49.24	143.17	109.99
2011	117.05	272.81	196.40	55.04	156.40	121.63
2012	116.94	291.15	208.05	58.27	164.66	127.36

Table A6 Average prices of low voltage electricity (Mexican cents per kWh)
(Constructed with data from SENER, 2013)

Voltage	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Low voltage	1-50	2.220	2.177	2.163	2.183	2.243	2.219	2.193	2.208	2.185
	51-100	2.682	2.630	2.613	2.637	2.710	2.681	2.649	2.667	2.639
	Additional	2.953	2.895	2.876	2.903	2.983	2.951	2.916	2.936	2.905
Medium voltage	Peak	2.0973	2.0457	2.0299	2.0543	2.1305	2.1060	2.0750	2.0864	2.0607
	Middle	1.2633	1.2004	1.1849	1.2151	1.3170	1.2976	1.2604	1.2601	1.2326
	Base	1.0560	1.0034	0.9905	1.0158	1.1010	1.0848	1.0537	1.0535	1.0305

Table A7 Monthly fees authorized of 2013 in Mexican Pesos $/kWh
(Constructed with data from CFE, 2013)

Day	Peak	Middle	Base
Monday to Friday	0:00 – 6:00	6:00 – 19:30 22:30 – 24:00	19:30 – 22:30
Saturday	0:00 – 7:00	7:00 – 24:00	
Sunday and Bank Holidays	0:00 – 19:00 23:00 – 24:00	19:00 – 23:00	

Table A8 Classification of periods by consumption in the central region
(Constructed with data from CFE, 2013)

The figure A12 shows local times when different fees are applicable, therefore, the payable fee for high voltage is calculated according to the use in the specific periods of figure 8 and following the methodology provided by the CFE. The billable demand (BD) is given by the following formula: $BD = PD + 0.100 \times \max(MD - PD, 0) + 0.050 \times \max(BD - MPD, 0)$

Where:

- PD is the is the maximum demand measured in the peak period
- MD is the maximum demand measured in the interim period
- DB is the maximum demand measured in the base period
- MPD is the maximum demand measured at the peak and middle periods
- max implies that when the difference in demands in brackets is negative, it will take the value zero.

Appendix 8
Detailed costs of the collection and flaring system

Project Component	Quantity
Average depth of landfill waste (ft)	65
Number of wells (1 well per acre)	10
Number of flares (1 flare per system)	1
Collected landfill gas design flow rate (ft^3/min)	4,302
Electricity usage by blowers (kWh/ft^3)	0.002

Table A9 Parameters used to estimate capital costs of the collection and flaring system

Cost Component	Cost (2013$'s)	Cost Unit
Drilling and pipe crew mobilization	$20,000	per system
Installed cost of vertical gas extraction wells	$4,675	per well
Installed cost of wellheads and pipe gathering system	$17,000	per well
Installed cost of knockout, blower, and flare system	$(x)^{0.61}$ * $4,600	$, x = ft^3/min
Engineering, permitting, and surveying	$700	per well
Annual O&M for collection (excluding energy)	$2,600	per well
Annual O&M for flare (excluding electricity)	$5,100	per flare
Electricity price (depends on type of project)	$0.060	per kWh with a 1.0% escalation rate

Table A10 Cost component of the collection and flaring system in estimated prices of 2013

Mobilization:	$20,400
Extraction Wells:	$47,685
Wellheads and Pipe Gathering System:	$173,400
Knockout, Blower, and Flare System:	$772,455
Engineering, Permitting, and Surveying:	$7,140
Total Capital Costs Including Cost Contingency	**$1,021,080**

Table A11 Installed capital costs of the collection and flaring system per type of equipment in estimated prices of 2014

Appendix 9
Detailed costs of the CHP micro-turbine-generator set

Project Component	Quantity
Gross capacity factor (%)	93%
System operating schedule (hours/year)	8,147
Fuel use rate (Btu/kWh generated)	14,000
Hot water production (Btu/kWh, net)	5,800
Parasitic loss efficiency (%)	83%
Landfill gas heat content (Btu/ft^3)	506
Micro-turbine capacity (kW)	9,328
Length of gas piping from compressor to micro-turbine (ft)	52,800
Length of water piping from micro-turbine to user (ft)	0

Table A12 Parameters used to estimate capital costs of the CHP micro-turbine-generator set

Cost Component	Cost (2008$'s)	Cost Unit
Installed cost of gas compression/treatment, micro-turbine/generator, site work, housings, and electrical interconnect equipment	$20,057 * $(x)^{0.6207}$	$, x = kW capacity
Installed cost of heat recovery exchangers	$20,057 * $(x)^{0.6207}$ * 0.06	$, x = kW capacity
Installed cost of gas pipeline	$63	per ft
Installed cost of water pipelines (assumes 2 lines for supply and return)	$106	per ft of trench
Installed cost of circulation pump	$12,000	per system
Annual O&M of compression/treatment, microturbine/generator, and exchangers (excluding energy)	0.0773 - 0.00987ln(x)	per kWh generated, x = kW capacity

Table A13 Cost component of the CHP micro-turbine-generator set in estimated prices of 2008

Gas Compression/Treatment, Micro-turbine/Generator, Site Work, Housings, and Electrical Interconnect Equipment:	$6,575,447
Heat Recovery Exchangers:	$394,527
Gas Pipeline:	$3,746,067
Water Pipelines and Circulation Pump:	$13,514
Total Capital Costs Including Cost Contingency	**$10,729,555**

Table A14 Installed capital costs the CHP micro-turbine-generator set per type of equipment in estimated prices of 2014

Appendix 10
Average inflation rates in Mexico

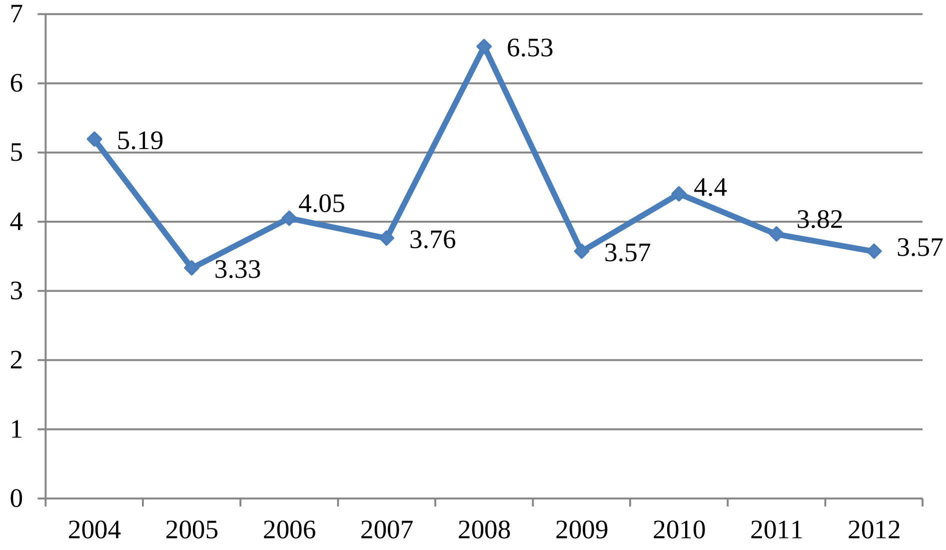

Figure A3 Inflation rates 2004-2012 (BANXICO, 2013)