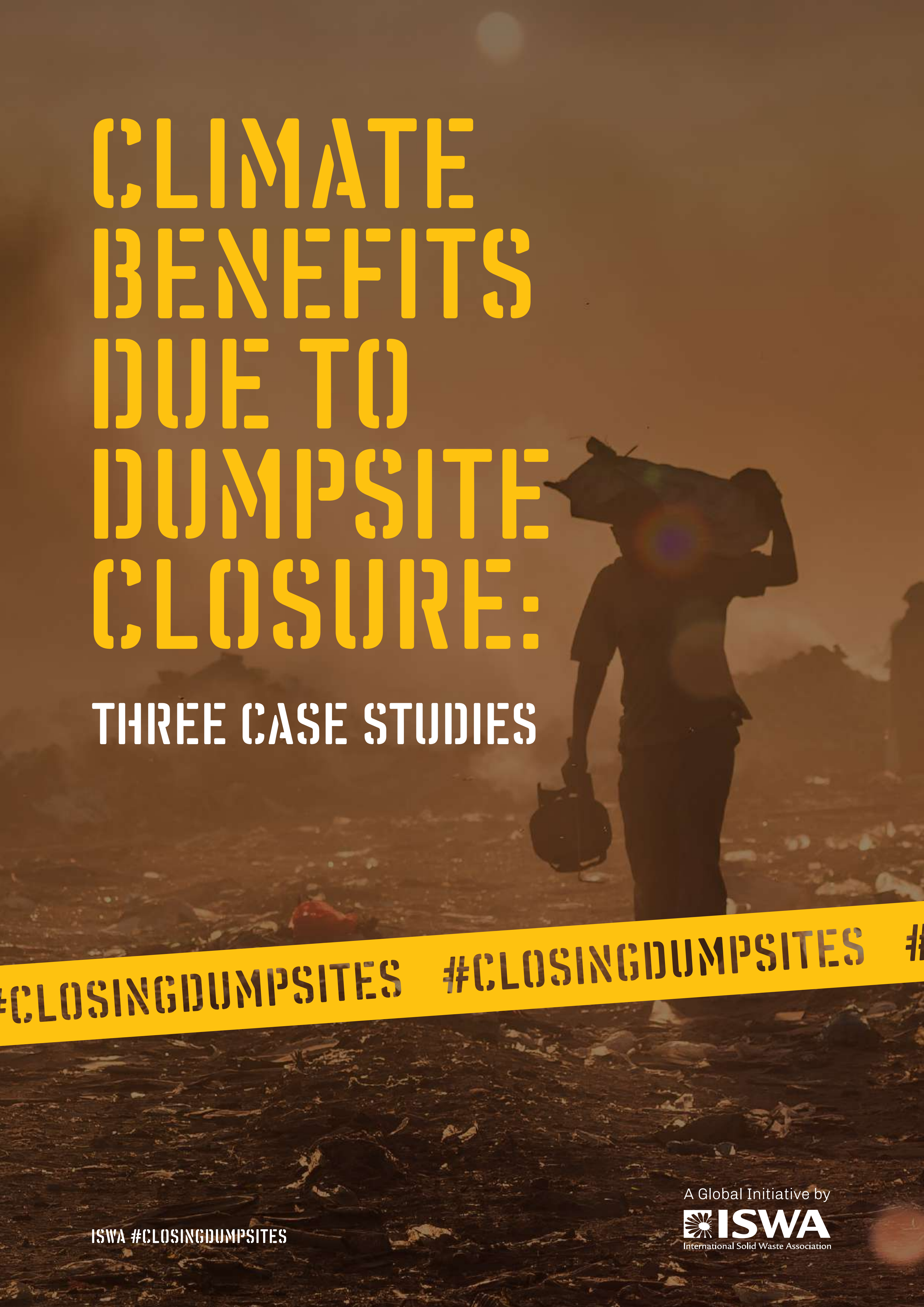


CLIMATE BENEFITS DUE TO DUMPSITE CLOSURE:

THREE CASE STUDIES

#CLOSINGDUMPSITES #CLOSINGDUMPSITES

A Global Initiative by ISWA International Solid Waste Association

ACKNOWLEDGEMENTS

The lead author of this document was Mr. Robert Bösiger. The main contributors included members of the ISWA Technical Cooperation Department including: Ms. Marianne Grant (ISWA Project Coordinator), Ms. Jennifer MacDonald (ISWA Project Manager), and Ms. Aditi Ramola (ISWA Technical Director).

A number of professionals from ISWA reviewed this document including: Mr. James Law (Working Group on Landfill Chair), Dr. Arne Ragossnig (ISWA Managing Director), Mr. René Møller Rosendal (Working Group on Landfill Vice-Chair) and the ISWA Scientific and Technical Committee.

Supporters of the document included: Cecília De Faria Sampaia from SLU, who kindly provided detailed data for the case study of the Estrutural site in Brasília, Brazil; Rainer Kronberger (MA48) and Werner Frühwirth, who provided detailed data for the case study of the Rautenweg site in Vienna, Austria, and Iftach Inbar from Hiriya Recycling Park, who provided detailed data for the case study of the Hiriya site in Tel Aviv, Israel.

Finally, the layout and design of the report was coordinated by Mr. Daniel Purchase, ISWA National Membership and Communications Manager.

CONTENTS

#CLOSINGDUMPSITES

ISWA
International Solid Waste Association

01

INTRODUCTION

According to the 2016 International Solid Waste Association's Roadmap Report, a dumpsite, or open dump, is an area that is characterized by having an "indiscriminate deposit of solid waste" where there are no or limited measures to control operations or protect the surrounding environment. A sanitary landfill, on the other hand, is a site that is carefully designed, constructed, operated, and monitored for purposes to protect the surrounding environment and public health.

Currently, dumpsites receive 40% of the world's waste, serving about 3-4 billion people. The globe's 50 biggest dumpsites affect the daily lives of 64 million people, a population of the size of France. From December 2015 to June 2016, ISWA has recorded more than 750 deaths related to poor waste management in dumpsites and several incidents with important health impacts, especially among communities of waste pickers working and living on these dumpsites (ISWA, 2016).

For the purposes of this report, 'tonnes' refers to 'metric tonnes'.

As urbanization and population growth continues, we can expect that hundreds of millions more people will depend on dumpsites as the only way to dispose of their waste, especially in the low- and middle-income countries. Studies conclude that dumpsites are the third largest source of global anthropogenic methane (CH4), a greenhouse gas 25-times more potent than CO_2, accounting for 11% of total methane emissions (Global Methane Initiative, 2018). If the situation doesn't change, dumpsites will cause 8-10% of the global anthropogenic greenhouse gas (GHG) emissions by 2025 (ISWA, 2016).

The operation of dumpsites damages the environment and affects the health of hundreds of millions of people that are living around or on these sites. Thus, closing the world's dumpsites becomes an important consideration for the progress of the Sustainable Development Goals (SDGs). Ensuring proper sanitation and solid waste management can be seen as a basic human need and as essential to society and to the economy as a whole, as with the provision of water, shelter, food, energy, transport and communications (ISWA, 2016).

Closing a dumpsite requires an alternative waste management system, which means adequate planning, institutional and administrative capacity, financial resources, social support, involvement of relevant stakeholders and political consensus. These conditions are sometimes impossible to meet in countries where dumpsites are the dominant method of waste disposal and the quality of governance is insufficient. However, the technical, financial and social elements for closing a dumpsite are proven and available, as shown in ISWA's "Roadmap for Closing Waste Dumpsites" (ISWA, 2016).

The case studies described in this document aim to showcase successful closures of dumpsites around the globe: The Estrutural Landfill in Brasília (Brazil), the Rautenweg Landfill in Vienna (Austria) and the Hiriya Landfill in Tel Aviv (Israel). These case studies focus on climate benefits resulting from moving away from uncontrolled dumping towards an integrated, sustainable waste management system. The results deliver a strong message: Compared to a "No Action" baseline scenario, these cities have already saved hundreds of thousand tonnes of carbon dioxide emissions (tCO_2-e). By 2050, Brasília will have saved about 1,000,000 tCO_2-e (70.6%), Vienna about 950,000 tCO_2-e (80%) and Tel Aviv about 2,300,000 tCO_2-e (75%). Beginning with the closure of the sites, the long-term mitigation effect is due to the constant decrease of emissions at the disposal sites, since no new organic waste has been or will be deposited and LFG systems have been deployed.

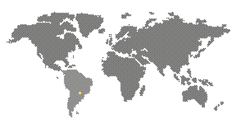
This study also considers lessons learned when closing a dumpsite. According to experts from the waste authorities, who contributed data to these case studies, the determining factors for the closure of a dumpsite were vigorous political will, significant subsidies, the involvement of multiple stakeholders and long-term planning. Furthermore, the lesson one can learn from the case studies is that, regional waste management systems face unique challenges and need unique regional solutions.

The case studies deliver proof that closing dumpsites and setting up a sustainable waste management system is a difficult task – but it is feasible. The earlier we take action, the more harm to our planet can be avoided - because the untreated waste of today produces the emissions of tomorrow.

The study was conducted for ISWA, as a part of **ISWA's Closing Dumpsite Campaign.**

closingdumpsites.iswa.org/

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES



[40% OF THE WORLD'S WASTE GOES TO DUMPSITES, SERVING ABOUT 3-4 BILLION PEOPLE.]

02

BACKGROUND

2.1 Municipal Solid Waste (MSW) Management

Municipal solid waste (MSW) is a by-product of human activities. Urbanization, economic growth and population increase the generation of waste. MSW is unique compared to other waste types, because it involves the public, where the generator frequently meets the waste management representative. As such, MSW management is highly influenced by the socio-economic and political factors in society (Agamuthu, 2011).

Definitions of MSW differ from country to country and between individuals, authors and researchers. In general, municipal solid waste refers to all waste generated, collected, transported, and disposed of within the jurisdiction of a municipal authority. The EU Waste Framework Directive does not give a definition for MSW either, although the term "municipal waste" can be found several times in the directive's text. However, the term "waste" is defined in Article 3(1) as "any substance or object which the holder discards or intends or is required to discard" (European Parliament and Council, 2008). The authors of the Guidance on Municipal Waste Data Collection, postulate that the most comprehensive definition of MSW is provided in the OECD/Eurostat joint questionnaire, used to collect waste statistics, as waste that, "covers household waste and waste similar in nature and composition to household waste" (Eurostat 2016).

The Waste Management Hierarchy

MSW management incorporates several interrelated aspects. It comprises aspects of waste generation, waste composition, collection, recycling, pretreatment and treatment, and finally disposal. These management aspects thus require input from legal, economic, governmental, political, administrative, and environmental players. These stakeholders need to interact and cooperate for the management system to achieve its target (Agamuthu, 2011).

A concept which gives guidance to countries prioritizing their resources and efforts for environmentally sound waste management and climate change mitigation, is the internationally recognized **waste management hierarchy.** The hierarchy establishes priorities based on sustainability. To be sustainable, waste management cannot be solved only with technical end-of-pipe solutions and thus an integrated approach is necessary. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste. It helps prevent emissions of greenhouse gases, reduces pollutants, saves energy, conserves resources, creates jobs and stimulates the development of green technologies. In the waste management hierarchy, waste prevention receives the highest priority, to optimize the co-benefits for climate change mitigation, see Figure 2.1. (UNEP, 2012, p. 5).

The Waste Management Hierarchy establishes the priorities of waste management; waste prevention, re-use, recycling, waste-to-energy, and finally landfill. Within the limitations of available financial resources, a country or city's action should be implemented in line with the waste management hierarchy, e.g. actions pertaining to waste prevention and reduction should be implemented first (UNEP, 2012, p. 50). In the EU, the waste management hierarchy is defined in Article 4 of the Waste Framework Directive (European Parliament and Council, 2008).

Hence, the challenge of MSW management, which is even more pressing in low- and middle-income countries, is often associated with the following issues (Agamuthu, 2011):

- Inadequate waste collection system
- Low recycling rate
- Poor treatment or no treatment
- Uncontrolled disposal
- Inadequate technology
- Low awareness of health risks

Generation and Composition

The generation of MSW is influenced by several factors such as income level, education, season, type of residence, waste collection system and frequency, consumption pattern, and socio-economic strata. Income levels directly influence the waste generation per capita, and higher economic status results in an increase in MSW volume. With few exceptions, there is a strong correlation between gross national income (GNI) and waste generation per capita. (Agamuthu, 2011)

Composition of MSW is dynamic, and changes with factors such as income level, changing lifestyle, season, residence type and location. Generally, the organic component is predominant, especially in low- and middle-income countries (Agamuthu, 2011).

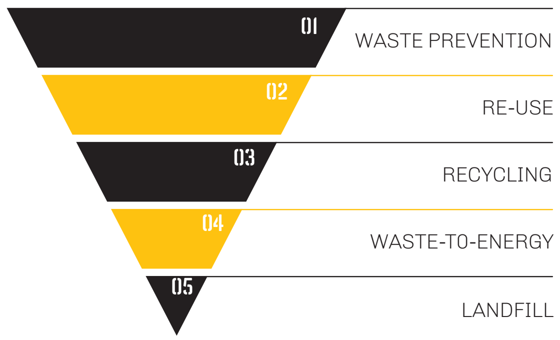


Figure 2.1
Waste hierarchy (UNEP, 2012, p. 5)

#CLOSINGDUMPSITES

[11% OF THE WORLD'S TOTAL ANTHROPROGENIC METHANE IS GENERATED BY DUMPSITES]

Collection

The initial steps in ensuring sound MSW management are providing a collection service to all citizens and eliminating uncontrolled dumping and open burning. Providing a regular waste collection service to 100% of the urban population has been a public health objective since at least the mid-19th century (UNEP & ISWA, 2015, p. 62).

According to data compiled by UNEP & ISWA (2015), the average collection coverage in low-income countries is at 36%, in lower-middle income countries at 64% and in upper-middle income countries at 82%. In higher income countries collection coverage approaches 100%. Figure 2.2 shows collection coverage data on 39 cities. At lower income levels, collection coverage appears to increase with income. Above a certain threshold, indicated by the blue vertical bar, collection reaches 100%. The four horizontal lines show the median collection coverage for each income group.

Treatment and Disposal

MSW treatment and disposal depend on waste quantity, composition, and available funding schemes to pay for it. Rich nations can afford high-end technology such as incineration, whereas most low- and middle-income countries still depend on landfill or dumpsite disposal (Agamuthu, 2011).

Uncontrolled disposal through open dumping and open burning was the norm around the globe until the 1960s, it is still the norm in most low- and middle-income countries. This practice however comes with substantial public health and environmental risks. Figure 2.3 shows progress around the world in closing uncontrolled dumps and achieving controlled disposal. "Controlled disposal" involves adequate treatment of waste and operation of facilities which meet defined compliance requirements. It is estimated, that at least 3 billion people worldwide lack access to controlled waste disposal facilities (UNEP & ISWA, 2015, p. 65).

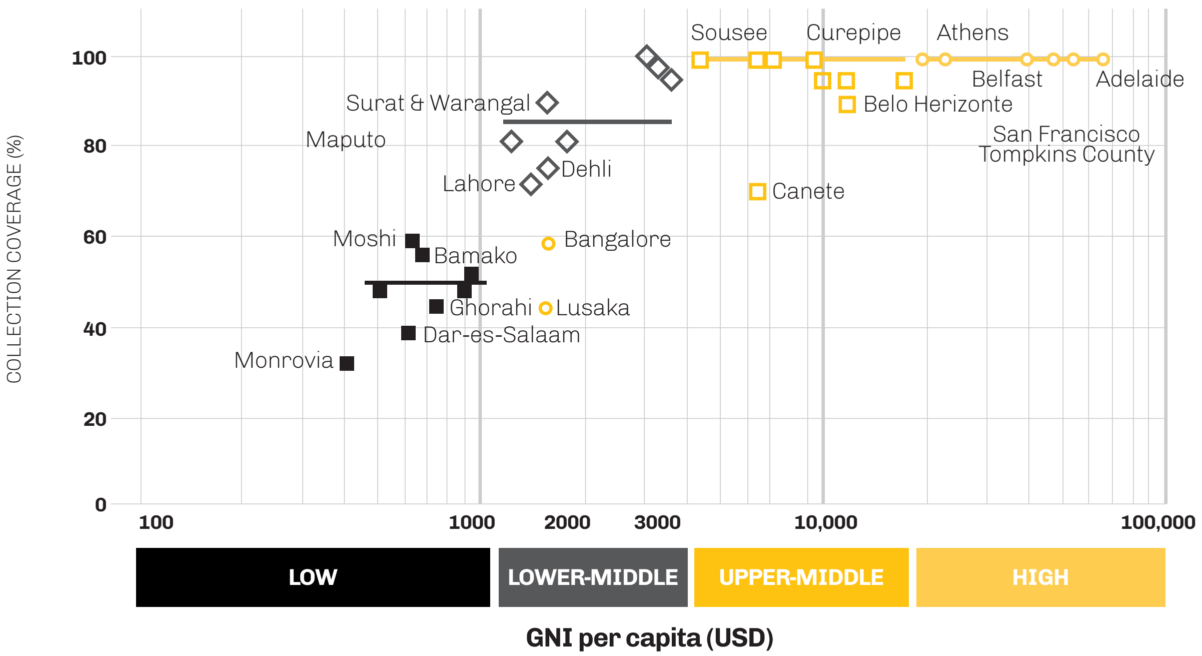


Figure 2.2
Collection coverage for selected cities by income level (UNEP & ISWA, 2015)

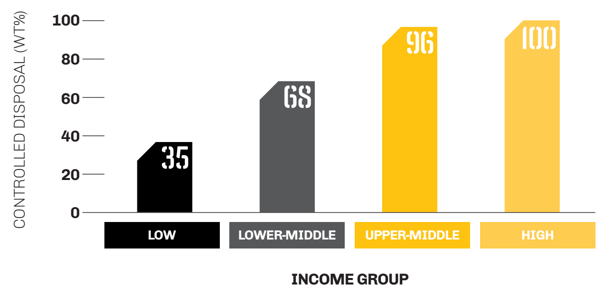


Figure 2.3
Controlled disposal for selected cities by income level (UNEP & ISWA, 2015, p. 65)

A number of technologies are used for the processing and recovery of resources from waste, and the selection of technologies for a particular local situation is as much of a governance issue as a technical matter (UNEP & ISWA, 2015, p. 72). Alternative technologies for resource recovery from waste are summarized in the following (UNEP & ISWA, 2015, p. 74):

Material Recovery and Sorting Facilities:

- Material recovery facilities (MRFs)
- Waste sorting centers
- Mechanical biological treatment facilities (MBTs)

Organics Recycling/Recovery:

- Composting
- Anaerobic Digestion
- Animal Feeding

Fuel and Energy Recovery from Waste Streams:

- Combustion with energy recovery as electricity and/or heat
- Co-Combustion in an industrial facility
- Gasification
- Pyrolysis
- Landfill gas utilization

It is important to note that both gasification and pyrolysis are not recommended to be used on mixed waste streams. Typically, for optimal efficiency, these technologies require very homogenous fractions of waste in large scale quantities (i.e. greater than 100.000 tonnes/year). Furthermore, according to the European Commission's science and knowledge service, the Joint Research Center (JRC), have concluded that gasification and pyrolysis of MSW and other mixed wastes have not been commercially proven to-date; there have been costly failures with these technologies in the past decades, some companies failing to make the transition to commercial efficacy in small-scale demonstration plants. Even when waste has been pretreated, the technology has been unable to achieve higher overall electrical efficiencies compared to other, conventional plants (Saveyn et al., 2016).

Waste Management and Climate Change

Regarding emissions due to MSW management practices, landfills and dumpsites are often the most significant source of greenhouse gas emissions. Emissions from landfills including leachate and landfill gas (LFG) require appropriate treatment technologies. While this issue can easily be tackled in a sanitary landfill, many non-sanitary disposal sites around the world release greenhouse gases directly into the environment (Agamuthu, 2011).

The waste industry holds an unique position as a potential reducer of greenhouse gas (GHG) emissions. As industries and countries worldwide struggle to address their carbon footprint, waste sector activities represent an opportunity for carbon reduction which has yet to be fully exploited (ISWA, 2009, p. 4).

According to the World Bank, an estimated 1.6 billion tonnes of CO_2e of global GHG emissions were generated from solid waste management in 2016: five percent of global emissions (Kaza, et al., 2018).

2.2 Solid Waste Disposal Sites

For the majority of countries around the world, dumping of untreated MSW is still the primary disposal method. Methane emissions from solid waste disposal sites (SWDS) – dumpsites and landfills – represent the largest source of GHG emissions from the waste sector, contributing around 795 Mt CO_2e (estimate for 2015).

The difference between a dumpsite and a landfill is simply that in a dumpsite there is no attempt to isolate the waste from the underlying soil. Where the bottom of the dump extends to below the groundwater level, waste is dumped directly into the groundwater. There is also no attempt to cover the waste daily to prevent odors or prevent the attraction of insects, vermin or scavengers, or to seal the surface of the dump against surface infiltration of rain water. In contrast, a sanitary landfill is constructed on an impermeable base that is covered with a drainage system designed to collect leachate and LFG (Blight, 2011).

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES

[795 MT CO_2E DUMPSITES AND LANDFILLS REPRESENT THE LARGEST SOURCE OF GHG EMISSIONS]

02 BACKGROUND

Once MSW has been deposited in a dumpsite or on a sanitary landfill, the organic matter continues to decompose. The products of decomposition are mainly gas (LFG) and leachate. The amount of LFG emitted from the disposal site depends greatly on the technical configuration of the site, amongst other factors like waste composition, bacteria and climatic conditions.

For this study, the terms "dumpsite", "controlled dumpsite" and "sanitary landfill" are used in order to divide disposal sites with similar technical configuration and equipment into three categories. These categories correspond to the input requirements of the Solid Waste Emission Estimation Tool (SWEET), an LFG emission quantification model used in this study. In SWEET model, the user has to select one of three types of disposal sites. Table 2.1 corresponds well with Table 1 in the SWEET user manual (CCAC MSW Initiative, 2018).

2.3 Landfill Gas (LFG) and Short-lived Climate Pollutants (SLCPs)

2.3.1 LFG Generation

Landfill gas (LFG) is a natural by-product of the decomposition of organic material in anaerobic conditions. LFG contains roughly 50 to 55% methane (CH_4) and 45 to 50% carbon dioxide (CO_2), with 2-5% non-methane organic compounds (such as N_2O) and trace amounts of inorganic compounds, such as perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF6). Methane is a potent GHG more effective than carbon dioxide at trapping heat in the atmosphere over a 100-year period (EPA USA, 2017, p. 1). In this study, a methane global warming potential (GWP) of 25 is assumed (CCAC MSW Initiative, 2017; Forster et al., 2007). Global warming potential is the measure of the amount of heat that is trapped by a compound relative to a carbon dioxide molecule.

The CH_4 in LFG is flammable, and this can be in danger of exploding if, the waste is ignited by spontaneous combustion and the presence of CH_4 is within the lower and upper explosive ranges. LFG can be extracted from the waste with vertical gas collector wells or horizontal collector trenches and then be used to power internal combustion gas engines to generate electricity (Blight, 2011). LFG is a good source of useful fuel to generate energy, normally through the operation of engines or turbines.

Many landfills collect and use LFG voluntarily to take advantage of this renewable energy resource while also reducing GHG emissions. However, it is more common to burn off the collected CH_4 in a flare, as both a safety and environmental protection measure. If the GWP of CO_2 is taken as 1 and that of CH_4 has been determined as 25, then when CH_4 is burned its GWP is reduced from 25 to 1.

2.3.2 LFG Emissions Quantification

Numerous LFG emissions quantification models exist that seek to quantify methane generation from MSW disposal sites. These models apply several different parameters to project methane generation from a specific mass of disposed waste over a given time period, taking account of factors like waste composition, climatic conditions and cover type at a specific disposal site. LFG emissions quantification models are used for different purposes, e.g. for better estimating the size of required LFG collection systems, for monitoring objectives, assessments and forecasts.

In this study, the SWEET version 2.1 is used to estimate emission mitigation (CCAC MSW Initiative, 2017). The tool applies EPA's Landfill Gas Emissions Model (LandGEM) version 3.02.

2.3.3 Short-lived Climate Pollutants (SLCPs)

Short-lived climate pollutants (SLCPs) are agents that have a relatively short lifetime in the atmosphere – a few days to a few decades – and they contribute to global warming. The main short-lived climate pollutants are black carbon, methane and tropospheric ozone, which are the most important contributors to the human enhancement of the global greenhouse effect after CO_2. These short-lived climate pollutants have various harmful effects on human health and the environment. Other short-lived climate pollutants include hydrofluorocarbons (HFCs); organic compounds containing fluorine and hydrogen atoms that are frequently used in air conditioning and refrigeration units. While HFCs are currently present in small quantity in the atmosphere, their contribution to climate change is projected to climb to as much as 19% of global CO_2 emissions by 2050 (CCAC, 2018).

Methane

CH_4 is a greenhouse gas that is a climate pollutant and atmospheric pollutant with a high ability to cause warming potential. It has an atmospheric lifetime of about 12 years.

It is produced through natural processes (e.g. the decomposition of plant and animal waste), but is also emitted from many man-made sources, including coal mines, natural gas, oil systems, and landfills. Methane directly influences the climate system and also has indirect effects on human health and ecosystems, as well as through its role as a precursor to the formation of tropospheric ozone in the lower atmosphere (CCAC, 2018).

Approximately 60% of methane in the atmosphere is emitted from human activities. In 2005, agriculture (livestock farming and rice production), fossil fuel production and distribution, and municipal waste and wastewater management accounted for 93% of global anthropogenic methane emissions. According to projections, without further mitigation efforts, anthropogenic methane emissions are expected to increase by about 25% by 2030 (CCAC, 2018).

Criteria	Open Dump	Controlled Dump	Sanitary Landfill
Siting of facility	Unplanned and often improperly sited	Hudro geologic conditions considered	Site chosen is based on environmental, community and cost factors
Capacity	Site capacity is not known	Planned capacity	Planned capacity
Cell planning	There is no cell planning The waste is indiscriminately dumped The working face/area is not controlled	There is no cell planning, but the working face/area is minimized Disposal is only at designated areas	Designed cell by cell development The working face/area is confirmed to the smallest area practical Disposal is only at designated cell
Site preparation	Little of no site preparation	Grading of bottom of the disposal site Drainage of surface water control along the periphery of the site	Extensive site preparation
Leachate management	No leachate management	Partial leachate management	Full leachate management
Gas management	No gas management	Partial or no gas management	Full gas management
Application of cover soil	Occasional or no covering of waste	Covering of waste implemented regularly but not necessarily daily	Daily, intermediate and final soil cover applied
Compaction of waste	No compaction of waste	Compaction in some cases	Waste compaction
Access road maintenance	No proper maintenance of access road	Limited maintenance of access road	Full development and maintenance of access road
Fencing	No fence	With fencing	Secure fencing with gate
Waste inputs	No control over quantity and/or composition of incoming waste	Partial or no control of waste quantity, but waste accepted for disposal is limited to MSW	Full control over quality and composition of incoming waste Special provisions for special types of waste
Record keeping	No record keeping	Basic record keeping	Complete record of waste volumes, types sources and site activities/events
Waste picking	Waste picking by scavengers	Controlled waste picking and trading	No site waste picking and trading
Closure	No proper closure of site after cease of operations	Closure activities limited to covering with loose or partially compacted soil and replanting of vegetation	Full closure and post-closured management
Cost	Little initial cost, high long term cost	Low to moderate initial cost, high long term cost	Increased initial, operational and maintenance costs, moderate long term cost
Environmental and health impacts	High potential for fires and adverse environmental and health impacts	Less risk of adverse environmental and health impacts compared to an open dumpsite	Minimum risks of adverse environmental and health impacts

Table 2.1
Characteristics of solid waste disposal site types (ISWA, 2015, p. 10)

In this study, the GWP potential is 25 for methane according to the assumptions used in the SWEET emissions quantification tool (CCAC MSW Initiative, 2017).

Pollutant	Black Carbon	Organic Carbon	Methane	Nitrogen Oxides
GWP in	900	-69	25	-31

Table 2.2
provides an overview of GWP of each pollutant, which is accounted for in SWEET.

CH4 IN LFG IS HIGHLY FLAMMABLE AND THIS CAN BE A DANGER

03

METHOD

The main objective of the case studies is to estimate emission mitigation resulting from closing dumpsites. As well as making an estimation of mitigation, we will depict the evolution of the MSW management system of the municipality and the main aspects of the country's MSW policy and legislation. In addition, lessons learned from introducing new MSW management practices are discussed.

In each case study, four different scenarios are modelled for the time period 1965 to 2050. These scenarios are: (1) No Action (baseline), (2) LFG Collection Only, (3) Dumpsite Closure, Composting and Recycling, and (4) Increased Composting and Recycling by 2030. Starting from a baseline scenario, which assumes that all MSW is deposited at an uncontrolled dumpsite, the other three scenarios include different improvements to the waste management system.

Comparison of the different scenarios shows how emissions can be mitigated due to the implementation measures like the installation of an LFG collection system or the increase of composting and recycling rates.

However, comparing different scenarios within the same system boundaries, by applying a constant set of assumptions, as is done in this study, can provide valuable conclusions regarding emissions, and can thus provide the reader with valuable insights into emission mitigation resulting from sound waste management practices.

The study focuses on emissions released into the air and LFG management. The effects of uncontrolled dumping on soil i.e. leachate, is not considered. Also not considered are emissions from transportation vehicles and waste handling equipment, which occur prior to final disposal. Due to a lack of data, uncontrolled waste burning is not considered either. Health risks of affected people living in the dumpsite's surroundings or even in the dumpsites are not assessed.

3.1 Emissions Quantification Tool: SWEET

The Solid Waste Emission Estimation Tool (SWEET) was developed by Abt Associates and SCS Engineers on behalf of the U.S. Environmental Protection Agency (EPA) and the Climate and Clean Air Coalition Municipal Solid Waste Initiative (CCAC MSW Initiative). It is available on CCAC's website (CCAC MSW Initiative, 2017).

SWEET assists users in determining city-level estimates of annual emissions of methane, black carbon, and other pollutants (e.g. carbon dioxide) from various sources in the waste sector. The tool was designed with a particular focus on methane and black carbon (CCAC MSW Initiative, 2018).

According to its manual, SWEET provides emissions and emissions reduction estimates at the project, source, and municipality-level. Cities can use this information for multiple purposes, including establishing a baseline scenario, comparing a baseline scenario to as many as four alternative scenarios, analyzing specific projects for potential emissions reductions, and tracking progress over time, among other things (CCAC MSW Initiative, 2017).

As with any other LFG emissions quantification model, SWEET works with assumptions and limitations. Therefore, the reader must be careful when comparing the results of the study with other studies that do not have the same scope, or do not use the same tool or estimation model, because absolute numbers of GHG emissions can differ between models (Majdinasab, Zhang, & Yuan, 2017). Assumptions and limitations are discussed in SWEET's manual as well as in the SWEET model itself.

A brief reflection on the experience of using SWEET while conducting the study, and a discussion on the applicability of the tool for the study's purpose, can be found in chapter 5.1.

3.1.1 Assumptions and Limitations

According to its manual, SWEET is designed to provide estimates of waste sector emissions for cities throughout the world, and to evaluate the effects of alternative waste management strategies on those emissions. Although SWEET uses state-of-the-industry assumptions and calculation methods, the emissions estimates should be considered as approximate and not a substitute for detailed technical analyses and feasibility assessments (CCAC MSW Initiative, 2018).

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES

[CO_2 SWEET ASSISTS USERS IN DETERMINING CITY-LEVEL ESTIMATES OF ANNUAL EMISSIONS]

03 METHOD

The SWEET tool is an Excel file, where the user can input data, and results of the estimations are directly produced in tables and figures. SWEET makes assumptions for each step of the waste management process. The majority of these assumptions are outlined in the tool itself and in its manual (CCAC MSW Initiative, 2018).

The first assumption the user will notice is that SWEET holds waste composition and growth rates constant over time. Consequently, the values the user enters will apply to all years during the period of analysis. This is a strong assumption, if the aim is to estimate emission over several decades.

However, to consider changing waste composition, the user can create more spreadsheets for successive time periods with different compositions and extract the emission data manually from the tool. This study uses this approach to account for different waste compositions and different statuses of the disposal sites at certain periods of time.

According to SWEET's manual, sources of model inaccuracies and uncertainties include the following: (CCAC MSW Initiative, 2018)

- Uncertain emissions factors, particularly for landfill methane
- Uncertain estimates of waste decay rates and methane generation, collection, and oxidation rates at disposal sites
- Limits on the complexity of user inputs, which were made to allow the model to be user-friendly and to limit model sensitivity to lack of data or data error
- Limits on detailed accounting of site-specific factors influencing emissions

Since this study focuses on emissions from solid waste disposal sites (SWDS) and from different treatment scenarios, SWEET's manual describes how the tool calculates methane emissions from these sites and the limitations associated with these calculations (CCAC MSW Initiative, 2018). The underlying assumptions regarding emission factors, waste decay rates, oxidation rates at disposal sites, etc. are described in the Excel file, see spreadsheets "Default Values", Assumptions" and "Caveats and Notes".

Furthermore, in the SWEET emissions quantification tool, the GWP potential is 25 for methane. It is important to note, however, that the GWP of a gas depends on the time at which it is calculated. GHG are usually expressed with a 100 year GWP, giving more importance to persistent gases rather than to those with a shorter lifetime (Kaza et al., 2018).

Moreover, methane has a higher short-term GWP than CO_2. In other words, over a 100-year time frame, methane has a 25 times higher GWP, but in a shorter time frame of 20 years, methane has 72 times higher global warming potential than CO_2 (IPCC 2007b).

Therefore the 20 year GWP has, potentially, an even more alarming impact over this time frame not taken into account in the SWEET emissions quantification tool.

3.2 Data Collection

In order to do the emissions estimation as accurately as possible, historical data on collection and treatment of waste is necessary. This includes the total amount of waste collected, as well as the amounts of waste which are diverted to different treatment facilities for composting, anaerobic digestion, incineration and recycling. In addition to that, the estimation of waste generation allows projections for emissions in the future.

Most of the data was provided directly from experts at the local waste authorities: SLU (Serviço de Limpeza Urbana do Distrito Federal) in Brasília, Brazil; MA48 (Municipality Department 48) in Vienna, Austria; and Hiriya Recycling Park of the DAN Region, Israel.

In order to fill data gaps and to interpret data correctly, several conversations on the phone with local experts were necessary. The sources of data are often internal reports, which are in some cases not accessible to the public.

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES

[SWEET IS DESIGNED TO PROVIDE ESTIMATES OF WASTE SECTOR EMISSIONS FOR CITIES]

04

CASE STUDY:1

ESTRUTURAL DISPOSAL SITE
IN BRASÍLIA, BRAZIL

The necessary data for the estimation of emissions on mass balances and MSW facilities were provided by experts from the local waste authority of the Federal District SLU, Serviço de Limpeza Urbana do Distrito Federal, Brasília, Brazil.

4.1 Results and Findings

Brazil, as the largest country in Latin America, faces major challenges regarding the management of MSW. Population growth associated with technological development has caused an increase in the generation of MSW, which creates significant environmental and public health risks. However, only 58.7% of the MSW collected in 2015 was properly disposed of in sanitary landfills, while 41.3% was inappropriately disposed of in controlled landfills or open dumps (ABRELPE, 2016; Alfaia, Costa, & Campos, 2017). In addition to that, the collection of recyclable material covers less than half of the national territory. Consequently, the country loses around 2.5 billion dollars annually because recyclable waste is inappropriately disposed of in landfills (Alfaia, Costa, & Campos, 2017; Instituto de Políticas Economicas Aplicada, 2010).

In 2015, Brazil's generation of MSW was around 1.071 kg/person/day. There was an increase of about 31% in the generation of MSW compared to the early years of this century, while the population growth rate in the country during the same period was about 7% (ABRELPE, 2016; Alfaia, Costa, & Campos, 2017).

Brasília, the federal capital of Brazil, is located in the "Federal District" (Distrito Federal), see Figure 4.1. The Federal District, with a population of around 3 million people, is one of 27 federative units of Brazil and is divided into 31 administrative regions (RA – região administrativo).

Figure 4.1
Location of Federal District in Brazil (Wikipedia, 2018)

The Estrutural dumpsite and the sanitary landfill ASB (Aterro Sanitário de Brasilia) receive all the MSW which is collected in the 31 administrative regions of the Federal District. The public waste authority of Brasília SLU (Serviço de Limpeza Urbana do Distrito Federal) is responsible for the waste management in the region. For the following analysis and for the estimation of emissions, experts of SLU kindly provided quantitative and qualitative data as well as recent reports (SLU, 2017, 2018a, 2018b).

In 2017, SLU and the District Government of Brasília started an ambitious project that includes the closing of the former controlled dumpsite (Lixão da Estrutural), which was used for 60 years, serving up to 5 million people. Today, it has been given a new use as a Construction and Demolition (C&D) recovery facility (URE – Unidade de Recebimento de Entulhos). At 201 hectares (2.01 km2), the equivalent of about 280 football fields, the Estrutural dumpsite was the largest in Latin America. In 2017, with the closing of the old dumpsite, the new sanitary landfill ASB (Aterro Sanitário de Brasília) was opened and new sorting facilities started operating in 2018.

Figure 4.2
Brasília used the huge dump "Estrutural" for more than 60 years. About 2,000 people were living in and around the dumpsite. (ISWA, 2017)

In addition, a strong cooperation with the informal sector was established in order to reallocate waste pickers into the formal sorting facilities by promoting their informal organisational structures into cooperatives. Before closing Estrutural dumpsite, around 2,000 people were living in and around the dumpsite.

Brasília proves that a dumpsite can be closed in a relatively short amount of time, leading to a more environmentally sound MSW management system. The example of Brasília also shows the feasibility of steering a change in the habits of the informal sector, improving working conditions and transforming it into a formal system (ABRELPE & ISWA, 2018; ABRELPE, 2017)

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES

[IN 2015, BRAZIL'S GENERATION OF MSW WAS AROUND 1.071KG PER PERSON PER DAY]

4.1.1 MSW Policy and Legislation

The National Policy on Solid Waste (NPSW), established in 2010 by Federal Law n. 12.305 (Ministério do Meio Ambiente, 2010) is considered to be a milestone for waste management in Brazil. The NPSW provides principles, objectives, instruments and guidelines related to the integrated management of solid waste, as well as guidelines on the responsibilities of the generators and public authorities, and on the associated economic tools to achieve these changes (Alfaia, Costa, & Campos, 2017).

The goal of this law is to promote an integrated waste management system by the reduction, reutilization, recycling, treatment and appropriate disposal of MSW, including energy recovery systems. Furthermore, this law prohibits the open dumping of MSW and it is stipulated that all states and cities must have closed their open dumps by 2014. Since then, all MSW should have been disposed of in an environmentally acceptable manner (Alfaia, Costa, & Campos, 2017).

Nevertheless, the situation has changed very little since the introduction of the NPSW and much of the MSW still goes to inappropriate disposal. Between 2010 and 2015 the final disposal of MSW in Brazil was distributed as follows:

Sanitary Landfill **57.6–58.7%**
Controlled Landfill **24.3–24.1%**
Open Dump **17.2%-18.1**

(ABRELPE, 2016; Alfaia, Costa, & Campos, 2017)

Given that many cities and metropolitan regions have not met their goal of closing all open dumps by 2014, extending the deadline is often discussed. With this in mind, successful cases like the closure of the Estrutural dumpsite show the path is heading in the right direction.

In accordance with NPSW, municipalities in Brazil shall draw up a municipal solid waste management plan (MSWMP) for the next 20 years, in order to request and receive funding from the federal government (Alfaia, Costa, & Campos, 2017). However, there is no obligation to submit and get approval for the plan and there is no agency or governmental body assigned to receive, evaluate and approve such plans.

The law neither sets diversion targets nor recycling goals. The legal determination is that only "refuse" must be disposed of in landfills. What the law defines as "solid waste" (discharged materials with economic value and technically feasible for recovery and recycling) must have all its potential used before being sent to landfills (Ministério do Meio Ambiente, 2010). Diversion targets and goals are supposed to be set by the National Solid Waste Master Plan, which is still under development by the Federal Government, as the first proposal from 2012 has not been formally approved. (Alfaia, Costa, & Campos, 2017).

Waste type	2008 (%)	2015 (%)	2016 (%)
Food waste	42	31.15	46.27
Green	0	0.00	0.00
Wood	0	0.00	0.00
Paper/Cardboard	15	9.79	12.71
Textiles	0	0.00	0.00
Plastic	17	12.27	14.13
Metal	3	3.42	1.7
Glass	2	6.25	2.21
Tires	0	0.00	0.00
Rejected	21	6.03	5.75
Other	0	23.95	17.28
TOTAL	**100**	**100**	**100**

Table 4.1
MSW composition in the Federal District according to different surveys from 2018 (Governo Do Distrito Federal, 2008), 2015 (SLU, 2016) and 2016 (Governo Do Distrito Federal, 2018)

4.1.2 MSW Generation and Composition

In 2017, 98% of the population of the Federal District (total: 3,039,444) was serviced by a formal collection service. The per capita waste generation is 0.88 kg/capita/day, with a projected annual growth rate of collected waste of 2.22%. Basic facts about MSW generation and growth rate in 2017 are summarized in the following (Governo Do Distrito Federal, 2018):

- Population inside collection zones: 2,978,655
- Waste generation inside formal collection zones: 0.88 kg/capita/day
- Average annual growth rate in quantity of waste collected – projected: 2.22%
- Total waste collected annually inside collection zones: 829,229 tonnes

Waste Composition

Not only the amount of waste, but its composition, determines the amount of degradable carbon it produces. However, waste composition surveys are not conducted often, as they are resource-intensive and therefore costly. In recent years, several surveys have been conducted on waste composition in the Federal District by different institutions.

Table 4.1 compares the results of these studies. For the estimation of emissions with SWEET, regional default values are applied, based on recommendations made in the IPCC (Intergovernmental Panel on Climate Change) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

This classification of waste types is based on the classification made by IPCC (IPCC, 2006). For the waste types "Green", "Wood" and "Textiles" however, there is no percentage given in Table 4.1. In the cited surveys, green waste is considered as "organic waste" (resíduos orgânicos), together with food waste. Wood and textiles are not accounted for separately either, they are part of the "Other" fraction. Information about the composition of the "Other" fraction is not available.

4.1.3 Collection and Treatment

Collection

After starting to implement a selective collection scheme in 2015, the public waste authority SLU performs both a conventional and a selective collection. In the selective collection scheme, the consumer separates the organic waste from the recyclable waste, which is picked up and transported directly to waste picker cooperatives. These cooperatives, consisting of previously informal waste pickers, sort and sell the recyclables. The organic fraction and the waste that is not separated by the customers, are both collected by the conventional collection. The conventional collection trucks go to transfer stations where, in 4 out of 5 transfer stations, the unseparated waste is sorted by waste pickers.

All of the 31 Administrative Regions (RA – região administrativo) are serviced by a conventional collection service which collects a total of approx. 2,700 tonnes/day. In addition, 25 of the 31 Administrative Regions receive a selective collection service, accounting for about 6% of the total waste collected.

Table 4.2 shows the most recent data on MSW collection and diversion to treatment (composting, recycling, disposal at dumpsite and landfill). The Estrutural dumpsite stopped receiving MSW after 2017, and in 2018, all of the refuse, which was not composted or recycled, went to the new sanitary landfill. Only C&D waste is still deposited on the former Estrutural dumpsite.

MSW collected and diverted to treatment	Metric tonnes	Percent
Total MSW collected annually inside formal collection zones	829,229	100.0%
Composting	60,119	7.2%
Recycling	29,970	3.6%
Dumpsite ESTRUTURAL (last year of receiving MSW)	486,436	58.7%
Sanitary landfill ASB	252,704	30.5%

Table 4.2
Federal District: MSW collection and treatment in 2017 in tonnes/year (SLU, 2017)

ES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPS

COMPOSITION DETERMINES THE AMOUNT OF DEGRADABLE CARBON IT PRODUCES

Federal District: MSW Treatment and Disposal from 1965 to 2050

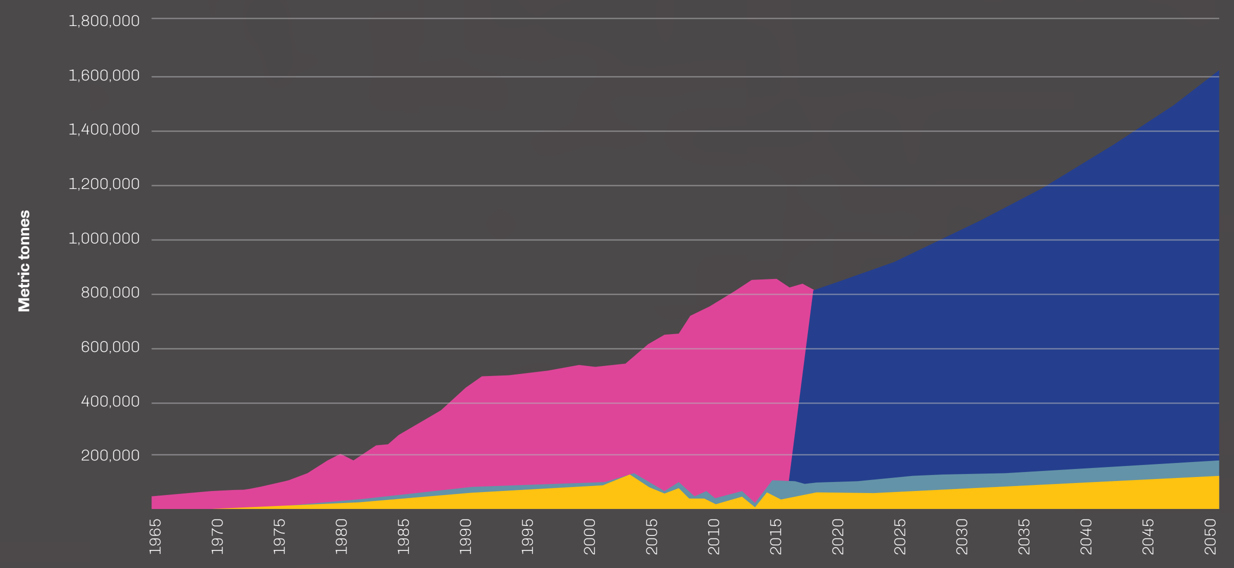


Figure 4.3
MSW collection and treatment in the Federal District from 1965 to 2050. Data from 2002 to 2018 is based on empirical data from the waste authority SLU. Data from 1965 to 2001 and from 2019 to 2050 are projections.

Based on the data provided by the local waste authority SLU and assumptions, Figure 4.3 gives an historical overview of MSW collection and treatment (composting, recycling, dumping and landfilling) in the Federal District.

As shown in Figure 4.2, the major share of MSW in 2018 is already disposed of at the sanitary landfill. The data for the years 1965 to 2001 are the mean annual growth ratesand the projection from 2019 to 2050 assumes that the waste growth rate stays constant at 2.22% and that the share of composting and recycling stays constant as well. However, the city of Brasília plans to undertake efforts to improve this performance. For instance, there are more sorting facilities in planning in order to raise rates of recycling and composting. Furthermore, an AD facility (anaerobic digestion) is scheduled to start operating in 2022. These measures are not considered here and will further reduce the amount of MSW which is landfilled. From the conventional collection, the solid waste is either directed into one of two mechanical biological treatment plants, to one of 5 transfer station units, or directly to the landfill.

The two mechanical biological treatment plants (UTMB – Usina de Tratamento Mecânico Biológico) receive 22% of the total waste which is collected conventionally. 100% of the material from the selective collection is treated in the Residues Recovery Facilities (IRR – Instalações de Recuperação de Resíduos) by former waste pickers.

Waste, which is not recovered in the IRRs, is buried in the landfill. In 2018, the public waste authority SLU have the following facilities in operation (SLU, 2018b):

a. Five Transfer Stations (Unidades de Transbordo) Capacity: 1,200 t/day

b. Mechanical Biological Treatment Plants
Capacity: Ceilândia 600 t/day, South Wing 150 t/day

c. One Residue Recovery Facility (IRR – Instalações de Recuperação de Resíduos). Capacity: 29,970 t in 2017

The first IRR was built next to the UTMB in Ceilândia and started to operate in July 2018. Before that, the sorting was done in 5 sheds by waste pickers who were reallocated from the informal sector. These sheds are equipped with conveyor belts and containers to dispose the tailings from the selection process of the recyclable materials. In 2018, one more IRR was being built and another three were planned.

d. Seven Debris Collectors (Papa Enthulo) and Debris Inbound Unit (URE – Unidade de Recebimento de Entulhos), former dumpsite of Estrutural (lixão antigo). Capacity: 5,300 t/day (projection for 2018)

e. One Sanitary Landfill Brasilia (ASB – Aterro Sanitário de Brasília). Capacity: 2,700 t/day (projection for 2018)

4.1.4 Dumping and Landfilling

The Estrutural dumpsite was closed in January 2018 and the sanitary landfill of Brasilia (ASB – Aterro Sanitário de Brasília) began operating in 2017. In the following, the status quo and the historical development of both the Estrutural dumpsite and the sanitary landfill ASB are described.

Estrutural Dumpsite

The dumpsite in Brasilia was opened in 1965 and had a size of about 2,000,000 m^2 with an average waste depth of 60 m. Table 4.3 shows basic facts about the dumpsite.

Dumpsite opening year	1965
Annual disposal, most recent year data: (metric tonnes)	2016: 830,055 t 017: 557,635 t
Size: (m2)	2,000,000
Average waste depth: (m)	60
Dumpsite closing year:	January 2018
Active LFG extraction and flaring start-up year:	2007

Table 4.3
Estrutural dumpsite: Basic facts (SLU, 2017)

Before the closure in January 2018, the dumpsite's technical configuration was as following (SLU, 2018b):

- Site planning and disposal on designated areas
- Compaction of waste
- Access road maintenance
- Record of waste inputs
- Planned dumping
- Waste picking: About 1,200 waste pickers
- LFG management: Collection and flaring, 159 vertical wells
- Leachate management: Collection and Circulation
- Debris reception for dumping: about 5,000 t/day
- Access control
- Environmental monitoring: Water and ground water

In order to close the dumpsite, a first major step was done in 2007, when the operators decided to apply soil cover and to install an LFG collection and flaring system. The next step towards an environmentally sound operation of the site was done in 2015, with the installation of fences and trenches, the prohibition of receiving food waste and the improvement of living conditions for the waste pickers. Table 4.4 shows the organizational and engineering measures that have been applied on the site by the Urban Cleaning Service SLU since 2007.

Measure	When?
Soil Cover	2007
LFG extraction and flaring: Installation of 159 gas drains, every 50-100 m	2007
Installation of Fences and trenches: 6,000 m	2015
Prohibition of receiving food waste	Since 2015
Installation and maintenance of 3 new road balances	Since 2015
Installation of a software for balance registers	Since 2015
Living area and restrooms for waste pickers	Since 2015
Health diagnosis for 1,100 waste pickers	Since 2015
Reallocation of waste pickers	Since January 2018
The dumpsite is used mainly for disposing C&D waste	2018

Table 4.4
Organizational and engineering measures applied at Estrutural dumpsite over time (SLU, 2018b)

Today, in 2018, the Estrutural dumpsite is completely covered with soil and is mainly used for dumping C&D waste. By May 2018, no waste pickers were active on the site anymore.

Sanitary Landfill ASB (Aterro Sanitário de Brasília)

The sanitary landfill ASB opened in 2017, and in itsfirst year of operation it received 252,704 t of MSW. The site has a perimetric fence surrounding an area of 760,000 m^2.

There is a protocol for accessing the site including identification of persons and vehicles. Table 4.5 shows basic facts about the landfill.

Landfill opening year	2017
Annual disposal, most recent year data: (metric tonnes)	2017: 252,704 t
Size: (m^2)	760,000
Average waste depth: (m)	55 (projected)
Dumpsite closing year:	2047 (projected)
Active LFG extaraction and flaring start-up year:	2017
Gas-to-energy project:	In planning

Table 4.5
Landfill Aterro Sanitário de Brasília (ASB): Basic facts (SLU, 2017)

#CLOSINGDUMPSITES

TODAY, IN 2018, THE ESTRUTURAL DUMPSITE IS COVERED WITH SOIL

04 CASE STUDY: I

In 2018, the MSW in the 1st sector is covered daily with soil and the 2nd sector is currently being excavated in preparing for the next landfilling area. Already filled sub-sectors of the landfill are equipped with LFG wells installed about every 50-100 m and a flare station is also installed. The LFG collected is currently flared. The landfill's current technical configuration in 2018 is as follows (SLU, 2018b):

- Site preparation: Grading and drainage
- Site planning and disposal on designated areas
- Compaction of waste
- Access road maintenance
- Access control and record of waste input
- LFG management: collection and flaring, every 50-100 m
- Leachate management: collection and circulation

4.1.5 Dealing with the Informal Sector

Many thousands of people in cities in low and middle-income countries depend on recycling materials from waste for their daily living. With the focus on poverty reduction and waste strategies to improve recycling rates, one of the major challenges in solid waste management in low and middle-income countries is how best to work with this informal sector to improve their livelihoods and working conditions (Wilson, Velis & Cheeseman, 2006).

Despite the health and social problems associated with informal recycling, informal waste picking provides significant economic benefits for the waste pickers, which need to be retained. Experience shows that it can be highly counter-productive to establish new formal waste recycling systems without considering informal systems that already exist. According to Wilson, Velis & Cheeseman (2006), the preferred option is to integrate the informal sector into waste management planning, building on their practices and experience, while working to improve efficiency and the living and working conditions of those involved.

In order to integrate the informal sector into the new recycling system, the Urban Cleaning Service SLU signed contracts with cooperatives of waste pickers that previously operated inside the dumpsite. After the closure of the dumpsite in January 2018, the waste pickers sort waste after the conventional collection and they also carry out the sorting of the material resulting from the selective collection.

In addition, the eight cooperatives originating from the dump officially received five rented sheds. These sheds are used for handling the recyclable materials until the construction work of the new recycling facilities is completed (IRR – Instalações de Recuperação de Resíduos). These sheds are equipped with conveyor belts and containers to receive the tailings from the separation. The waste pickers can work in this environment in an ergonomic position and individual safety protection equipment is also available.

According to the contracts signed in January 2018, cooperatives and associations started to receive a certain amount of money per tonne of material sorted. For each tonne, the SLU pays an average of R$ 300, ranging between R$ 240 and R$ 310, depending on the average amount of sold recyclables.

Another seven cooperatives were hired to provide the selective collection service in the other ten administrative regions (RA – região administrativo). These services are paid based on the length of the route of the selective collection, ranging from R$ 625 to R$ 735. Another four cooperatives/associations already held contracts to provide selective collection in different RAs since 2016, so they received an additive to their contracts.

In 2018, there are, in total, 28 contracts with 22 cooperatives/associations that originated from the previous informal waste picking sector.

4.1.6 Future Outlook

According to the "District Plan of Integrated Management of Solid Waste (PDGIRS)" (Governo Do Distrito Federal, 2018) efforts will be made to further increase treatment of the organic fraction and to increase the rate for dry recyclables. The following treatment facilities are already in planning:

Anaerobic Digestion: An Anaerobic Digestion facility is planned for 2022. The aim is to generate energy by anaerobic digestion in the Mechanical Biological Treatment Plants after they are renovated. Even though it was planned for in the Federal District plan of integrated solid waste management, an investment is still needed to realize such a facility (Governo Do Distrito Federal, 2018).

Recycling: More IRRs are being projected (Waste Recovery Facilities – Instalações de Recuperação de Resíduos). One is already being built and another three are planned to be constructed in 2019.

4.1.7 Lessons Learned

According to experts from the local waste authority SLU, the determining factor for the closure of Estrutural dumpsite was a vigorous political will. The current Governor of the Federal District was a strong supporter of the case and defined the following four challenges in 2015, which were considered as main tasks and as a priority of the government:

1. Construction of the first sanitary landfill in the Federal District
2. Ending illegal waste picking activities at the Estrutural dumpsite
3. Implementation of a selective collection scheme with the inclusion of the informal waste pickers
4. Modernization and restructuring the waste authority

These tasks were coordinated directly by the Governor's office with the involvement of a total of 17 governmental bodies.

Relating to items 2 and 3, the major challenge was to find an agreement between the government and the cooperatives formed by waste pickers who were previously living and working on the dumpsite. In order to stop illegal activities on the site and to implement a new business model for the cooperatives, in which cooperatives are paid to carry out the sorting of recyclables in new facilities, **a strong collective effort of respective stakeholders** was indispensable. Only by incorporating conditions and commitments from both parties, a peaceful and just solution could be found. Therefore, this agreement, signed on 30th October 2017 by the waste pickers' cooperatives, National Collectors Movement and the government, was a major milestone.

Today, former waste pickers do the sorting in different facilities and they provide collection services in the selective collection scheme. The legal basis for these services is set in **contracts**, signed by cooperatives and the waste authority SLU. The first four contracts were signed in 2016, as test cases for both SLU and the cooperatives. There were many challenges to overcome, e.g. securing the quality of the service and meeting the bureaucratic demands of public contracts. In 2018, 11 contracts were signed to provide selective collection and another 17 contracts to provide the sorting of the recyclables, totalling 28 contracts with different waste pickers' cooperatives.

These contracts are the first of their kind in the Federal District; there has never been a contract between a cooperative and a public authority before 2016.

Again, the political will of the Governor was essential to guarantee the success of these contracts, not only because considerable efforts were made during the negotiations with the waste pickers, but also because these projects demand financial investments and ongoing maintenance.

4.1.8 Estimation of GHG Emissions and Short-Lived Climate Pollutant Mitigation

In order to estimate the GHG mitigation due to closing the Estrutural dumpsite, four scenarios are compared. Each scenario below starts in the dumpsite's opening year (1965) and ends in 2050. The projected closing year 2050 is an assumption which allows for estimating emission mitigation in the long term.

Scenario "No Action": This scenario estimates the emissions of the MSW management in the Federal District, as if no measures would be applied at all in order to improve the dumpsite's technical configuration or to move towards an integrated waste management. In this scenario, the dumpsite's technical configuration stays as it was in 1965. Neither the new sanitary landfill nor composting and recycling are considered. Comparing the emissions of the "No Action" baseline scenario with the current status allows for quantifying the climate benefits of the actual steps taken.

Scenario "LFG Collection only": This scenario depicts the upgrade of the Estrutural dumpsite to a "controlled dumpsite" with the application of cover soil and the installation of an LFG collection system. This scenario does not consider the new sanitary landfill and waste treatment in composting and recycling facilities. This scenario thus sheds a light on the potential emission mitigation only due to the installation of LFG collection.

Scenario "Dumpsite Closure, Composting, Recycling (current status)" depicts the actual state of the Estrutural dumpsite and the actual facilities which are in operation in 2018, including the new sanitary landfill. Hence, it calculates the emissions of the waste management in the Federal District as it is described in chapter 4.1.1 to 4.1.4. Future measures, which are not yet in operation in 2018, are not considered.

Scenario "Increased Composting & Recycling 2030": This scenario points out additional potential future benefits that could be realized by further improvements in waste management. It is assumed that additional steps regarding the increase of recycling and composting are implemented such that the recycling and composting rates meet the current EU-average (2016) by the year 2030: 29.4% Recycling and 16,5% Composting (Eurostat, 2018).

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES

[THE AIM IS TO GENERATE ENERGY BY ANAEROBIC DIGESTION IN THE MECHANICAL BIOLOGICAL TREATMENT PLANTS]

Characteristics	Scenario			
	No Action	LFG Collection only	Dumpsite Closure, Composting, Recycling	Increased Composting & Recycling 2030
Closing Dumpsite Estrutural in January 2018	✘	✘	✓	✓
Application of cover soil and installation of LFG collection in 2017	✘	✓	✓	✓
Opening new sanitary landfill ASB in 2017	✘	✘	✓	✓
Treatment 2018: Composting (7.7%) and Recycling (3.5%)	✘	✘	✓	✓
Treatment 2030: Increased Composting (16,2%) &Recycling (29.1%)	✘	✘	✘	✓

Scenario	Characteristics				
	Closing Dumpsite Estrutural in January 2018	Application of cover soil and installation of LFG collection in 2007	Opening new sanitary landfill ASB in 2017	Treatment 2018: Composting (7.7%) and Recycling (3.5%)	Treatment 2030: Increased Composting (16.2%) & Recycling (29.1%)
No Action	No	No	No	No	No
LFG Collection only	No	Yes	No	No	No
Dumpsite Closure, Composting, Recycling	Yes	Yes	Yes	Yes	No
Increased Composting & Recycling	Yes	Yes	Yes	Yes	Yes

Table 4.6
Estimation of GHG emissions: 4 scenarios and their characteristics

Table 4.6 gives an overview of these 4 scenarios and their characteristics.

The four scenarios were modelled with SWEET. Figure 4.4 shows total emissions of MSW management in the District Federal by scenarios. The total emissions are summarized as global warming potential (GWP in tonnes CO_2e (equivalents) and include CO_2, NOx, black carbon, CH4 and organic carbon.

In 2007, the year of the dumpsite upgrade (installation of LFG collection), the emissions produced by the different scenarios start to differ. Hence, the scenarios begin to diverge causing a vast difference in GWP by 2050 between scenario "No Action" and "Current Status". The Estrutural dumpsite closure in 2018 marks another major change in the waste management system. In the "Current Status" scenario, all MSW, which is not treated (recycling and composting), is disposed of at the new sanitary landfill, thus causing emission mitigation in comparison to the "LFG Collection" scenario, in which Estrutural is still in operation as a controlled dumpsite. The scenario "Increased Composting & Recycling 2030" points out potential benefits that could be realized by further improvements in the waste management system by raising for composting rates (16.1% improvement in comparison to Current Status) and recycling rates (29.1% improvement in comparison to Current Status) to the EU-average from 2016.

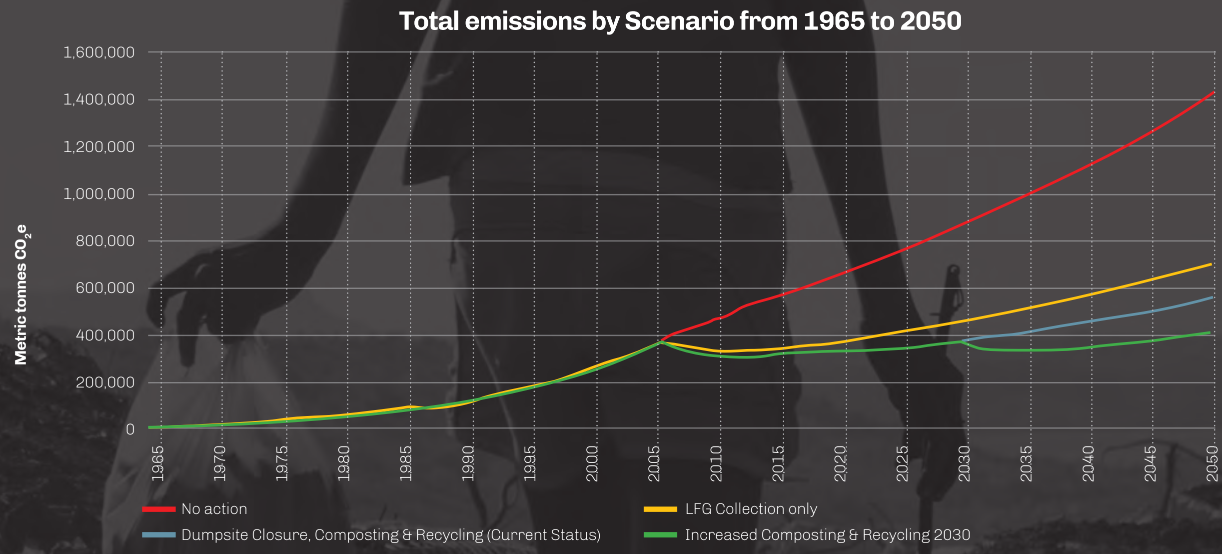


Figure 4.4
Total GWP of MSW management in the Federal District by scenario from 1965 to 2050

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPS

[16.1% RAISING COMPOSTING RATES BY 16.1% CAN REALISE FURTHER BENEFITS]

04 CASE STUDY: I

Comparing the scenarios "No Action", "Current Status" and "Increased Composting & Recycling 2030" more closely, Figure 4.5 shows the total mitigation of emissions in time steps of ten years, beginning in 2010, three years after the LFG collection was installed.

As can be seen in Figure 4.5, mitigation rises significantly with every decade up to 60.6% (current status) and 70.6% (Increased Composting & Recycling 2030) by 2050. This underlines again the urgency for immediate action in regions where there is neither treatment nor environmentally sound final disposal. The sooner a municipality is capable to act, the better.

Emission Mitigation due to Dumpsite Closure by Scenarios

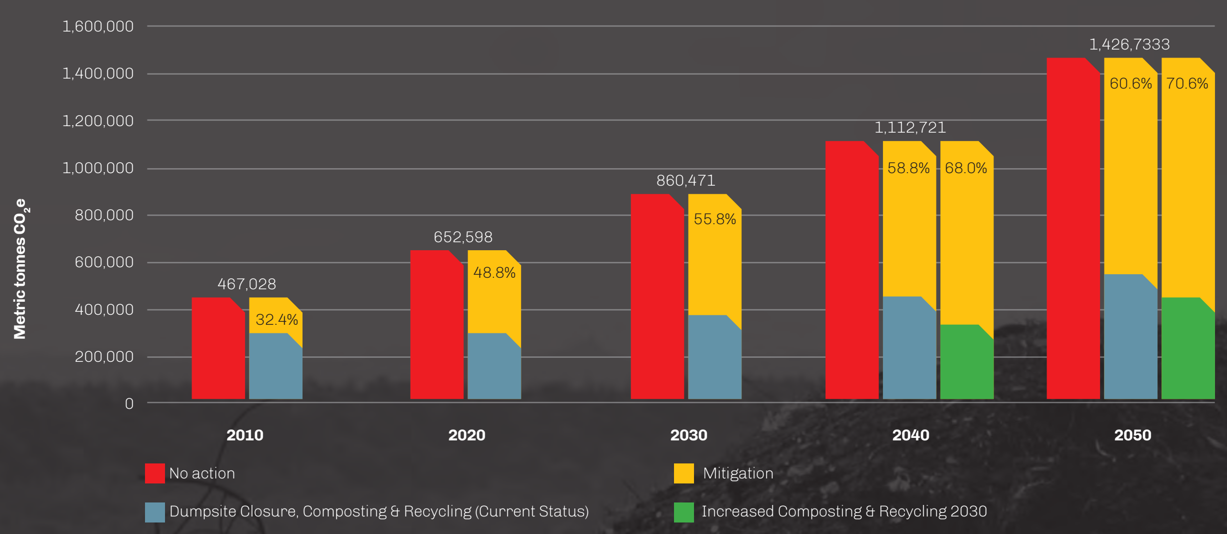


Figure 4.5
Emission mitigation resulting from closing the Estrutural dumpsite (current status) and potential mitigation due to raising composting and recycling rates to EU-average by 2030 (Increased Composting & Recycling 2030)

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES

[16.1% RAISING COMPOSTING RATES BY 16.1% CAN REALISE FURTHER BENEFITS]

05

CASE STUDY:2

RAUTENWEG DISPOSAL SITE
IN VIENNA, AUSTRIA

The necessary data for the estimation of emissions was kindly provided by experts from Vienna's waste authority MA48 (Municipal Department 48).

5.1 Results and Findings

Since the late 1950s, when the authorities began monitoring and recording the city's waste streams, Vienna's MSW management had come a long way. Since 2009, final disposal of MSW without prior treatment is forbidden in Austria. Today, the major challenges in the Viennese waste management system are waste prevention and the implementation of concepts of resource management in a circular economy, such as improving waste collection and recycling rates.

One might ask, what is the benefit of analysing a dumpsite closure in western Europe in 2018, when a city like Vienna faces totally different challenges in waste management compared to less developed countries with wide-spread open dumping. However, to have an historical look at waste management practices that proved successful can show that closing a dumpsite cannot be a single event, but it is rather one step in implementing an integrated sustainable waste management system. This means to set up alternative waste management practices along with the waste management hierarchy – including waste prevention strategies, improving waste collection and rates for recycling and composting. Not only is long-term planning needed to ensure a smoothly functioning sustainable waste management system, but also environmental awareness training is needed for children and adults.

Vienna is the capital of Austria and the country's biggest city, with a population of about 1,9 million. The "MA48" (Municipal Department 48) is the waste authority responsible for waste management in Vienna. In 2017, MA48 provided waste management services for 164,745 residential buildings and 888,462 households (residences) (MA48, 2018c).

Vienna's only landfill site "Rautenweg" is the largest landfill in Austria, having an authorized depositing volume of more than 14 million m3. Rautenweg is located north of the city, about 10 kilometers from the city centre. The trapezoid-shaped landfill covers an area of 58 hectares (143,21 acres) and exists as a disposal site since the 1960s. Originally, the location was used as a gravel pit. On 14 March 1966, the authorities approved the use of the area for depositing residual waste. Since 2008, no untreated waste has been deposited in the landfill.

Rautenweg only receives combustion residues from the waste-to-energy facilities and C&D waste. (MA48, 2007)

5.1.1 MSW Policy and Legislation

The legal basis for waste management in Austria is the Waste Framework Directive of the European Union (Council Directive 2008/98/EC). On the basis of this directive, the national environmental policy targets in the field of waste management are outlined in the Austrian Waste Management Act from 2002 which states, "the purpose of this Act is to hinder harmful effects on human beings, animals, plants and their natural environment through the principles of waste prevention, waste processing and waste disposal." The Act includes regulations regarding prevention of waste and processing of waste, general obligations for waste plants, waste collectors and treatment of waste, waste collection and processing systems and waste disposal treatment plants.

This law is implemented by different ordinances which set specific environmental targets. For instance, the Packaging Ordinance 2014 obliges producers of packaging material to either take back and recycle/reuse packaging, make use of deposit return schemes in retail stores (e.g. supermarkets), or to take part in a collection and recovery system.

Regarding Austria's landfills, the following legal regulations were essential, because these laws facilitated the transition from controlled dumping to sanitary landfilling and further improvements towards sustainable waste management. (Lamport, 2000)

Landfill Regulation 1996

The landfill regulation is the most important instrument to implement the overall targets of the Waste Management Act 1990. Its leading principles are:

- Reduction of total organic compounds and minimization of total volume of landfills as a direct consequence
- Classification of landfills (e.g. demolition waste, residual waste etc.)
- No final deposition without prior treatment after 2008, which reduces reactivity of waste (mechanical-biological treatment)
- High technical standards for landfills to minimize impact on environment

Figure 5.1
The Rautenweg site is the largest landfill in Austria. Since 2008, no untreated waste has been deposited in the landfill. (MA48, 2007)

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES

[SINCE 2008, NO UNTREATED WASTE HAS BEEN DEPOSITED IN THE RAUTENWEG LANDFILL]

05 CASE STUDY: 2

Landfill Charge Act 1989

(Contaminated Sanitation Act)

Leading principles:

- Disposal of waste on landfills is subject to a charge
- Rate of charge depends on type of waste
- Charge raised step by step between 1997 and 2001
- Supplemental charges for disposal on landfills without gas recovery
- Revenue of charge earmarked for clean-up of contaminated land

The combination of the landfill ban and the financial "incentive" of the landfill charge act forced the landfill operators to take action. It had become too expensive not to comply. Hence, these regulations made it possible that after 2008 no waste without prior treatment was sent to Austria's landfills.

5.1.2 MSW Generation and Composition

In 2017, about 1 million tonnes of MSW were generated and collected. The waste authority MA48 provided services for about 1.9 million residents. The annual growth rate of waste collected in Vienna is about 0.6% and the per capita waste generation in Vienna is 1.5 kg/capita/day. Basic facts about MSW generation and growth rate in 2017 are summarized in the following (MA48, 2018c):

- Population: 1,867,582
- Waste generation inside formal collection zones: 1.5 kg/capita/day
- Average annual growth rate in quantity of waste collected – projected: 0.6%
- Total waste collected annually inside collection zones: 1,024,000 tonnes

Composition

Vienna's waste authority conducts waste composition surveys on a regular basis. The relevant surveys, which were used as input data in SWEET are shown in Table 5.1. This classification of waste types is based on the classification made by IPCC (IPCC, 2006). Therefore, the composition data of the conventional collection and the separate collection is combined.

Waste type	1993 (%)	1997 (%)	2003 (%)	2019 (%)	2016 (%)
Food waste	28.37	32.56	24.34	32.50	30.90
Green	5.61	5.01	10.34	5.95	6.49
Wood	4.26	4.27	1.15	2.31	1.89
Paper/Cardboard	18.79	15.88	27.73	28.14	25.24
Textiles	4.20	3.01	2.46	2.07	2.26
Plastic	10.60	8.53	7.75	8.10	9.57
Metal	5.31	2.99	2.91	3.04	2.62
Glass	5.20	4.86	6.83	6.47	7.10
Tires	0.00	0.00	0.25	0.00	0.00
Other	17.66	22.92	16.03	11.61	14.55
TOTAL	**100**	**100**	**100**	**100**	**100**

Table 5.1
MSW composition in Vienna according to different surveys from 2015 (MA48, 2018d), 2009 (MA48, 2018d), 2004 (MA48, 2004), 1997 (Ma48, 1998) and 1993 (Ma48, 1994)

Collection

The city of Vienna started the separate collection of recyclables in 1977 (separate collection of glass).

Today there are different collection schemes for different types of waste. Vienna's municipal territory offers approximately 430,000 waste containers, 19 waste collection centres and 112 sites for the collection of hazardous waste from households. Each of the containers is emptied 65 times per year on an average, which equals a total of roughly 27 million emptying operations. Table 5.2 gives an overview of the collection schemes in Vienna . (MA48, 2013a)

Residual waste is collected in containers with a capacity ranging from 120 to 4,400 litres, which are mostly used by households. If their waste composition corresponds to that of household residual waste, commercial enterprises may also use these containers. These containers are located either in the basement of older buildings or in specially provided waste storage rooms in newer buildings. Inside the collection vehicle, the waste is compacted. The majority of these vehicles are able to empty bins with a capacity of 120 to 1,100 litres; special vehicles are used for the large 2,200-litre bins. (MA48, 2013a)

Separate collection of recyclables. Vienna's collection system offers a combination of waste pick-up (from households by MA48) and waste delivery (by citizens and businesses) systems. The waste delivery system consists of containers which are publicly installed in parking lanes or on sidewalks (delivery by users at approx. 4,300 sites across the city) and of containers at 19 waste collection centres. There are containers for each type of recyclable: waste paper, clear and coloured glass, organic waste, metal and plastic bottles. Additional containers for plastic foils and kitchen scraps are available for commercial enterprises. (MA48, 2013a)

Paper and Cardboard. Containers for waste paper collection are installed, if possible, close to the front door of a building. In less densely inhabited areas, they are set up in decentralized locations, e.g. at street corners; they can also be found at the waste collection centres. Every year, 125,000 to 130,000 tonnes of waste paper are recovered in Vienna. (MA48, 2013a)

Waste category	Collection Schemes			
	Backyard Collection (pick up at household)	Kerbside Collection (bring collection)	Recycling Centre (bring collection)	Mobile Collection Hazardous Waste (bring collection)
Residual Waste	•			
Organics	•	•	•	
Paper	•	•	•	
Glass		•	•	
Metal		•	•	
Plastics		•	•	
Other Recyclables			•	
WEEE			•	•<50 cm
Hazardous Waste			•	• & kitchen oil
Reusables			•	

Table 5.2
Waste collection schemes in Vienna (MA48, 2013a)

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES

[VIENNA'S WASTE AUTHORITY CONDUCTS WASTE COMPOSITION SURVEYS ON A REGULAR BASIS.]

05 CASE STUDY: 2

Organic waste. About 80,000 "green bins" with their brown lids and labels are installed across Vienna's less densely inhabited zones, having high levels of vegetation. Usually these bins are found directly on residential properties. Only plant matter is collected: tree and shrub cuttings, leaves, lawn clippings, windfall fruit and plants. Waste of animal origin such as meat products, eggs and bones or food scraps are disposed of as residual waste (in the case of households) or in specially designated kitchen waste bins (catering industry). Every year, a total of 65,000-70,000 tonnes of biogenic material is collected from green bins. This is complemented by 30,000 tonnes of garden waste originating from skips at the 19 waste collection centres. (MA48, 2013a)

The major portion of the kitchen scraps collected by MA48 originates from restaurants and cafés, canteen kitchens or commercial enterprises. In addition to food scraps, other types of fermentable waste, such as used cooking fat, are likewise collected. Four special collection vehicles as well as 2,200 hermetically sealable kitchen containers are available to store this sort of wet and pulpy waste. 9,000 tonnes of household kitchen scraps as well as 12,000 tonnes from commercial enterprises are collected annually and transported to the biogas plant for energy generation. (MA48, 2013a)

Glass. The separate collection of glass started 1977 and by 1990, the glass collection scheme covered all of Vienna. Clear and coloured glass is collected separately.

The containers are picked up by special vehicles that have two separate chambers for clear and coloured glass, which allows for the collection of both fractions in one go. The waste glass containers are set up in public locations such as sidewalks or parking lanes as well as at waste collection centres. Every year, between 25,000 and 30,000 tonnes of waste glass are recovered in Vienna. (MA48, 2013a).

Metals. The collection of scrap metal and cans began in 1985. Today, the containers with blue lids can be found across the entire municipal territory at recyclable collection points and waste collection centres. Scrap metal collected includes beverage cans, other metal packaging and small metal objects. Metals are divided into different fractions and recycled at specialized facilities. Every year, approx. 4,000 tonnes of scrap metal are collected from the containers set up in public spots, e.g. on sidewalks or in parking lanes. Metals discarded in residual waste containers despite the separate collection scheme are either separated from the slag after incineration or, in case of mechanical separation, directly removed from the residual waste by means of separators for ferrous and non-ferrous metals, and subsequently recycled.

Every year, over 10,000 tonnes of ferrous and nonferrous metals are separated from residual waste and then recycled. (MA48, 2013a).

Plastic bottles. The collection of plastic items began in 1989. Previously, foils, yoghurt cups and hollow items were collected in separate containers however, from autumn 2004 to spring 2005, the system was switched over to a new collection scheme for hollow plastic items (plastic bottles). Containers for plastic bottles are installed all over the municipal territory in public locations and at waste collection centres. About 5,000 tonnes of plastic bottles are collected in this way every year. Since 2013, two municipal districts of Vienna also offer pick-up collection of plastic bottles by means of "yellow bags" (this is available for areas mainly characterised by single-family homes). The switch made it possible to double the collection rate in these test areas. (MA48, 2013a)

Collection of hazardous wastes from households. Hazardous waste, cooking oils and electrical appliances can be dropped off at 19 waste collection centres, four stationary collection points and at 89 mobile collection vehicles throughout the city, always free of charge. Big household appliances like washing machines (with an edge length > 50 centimetres) are only accepted at waste collection centres. It is also possible to dispose of some types of hazardous waste, such as device batteries, fluorescent tubes or electrical appliances, free of charge at some supermarkets. Expired medical drugs can be left at many pharmacies free of charge. Every year, MA48 disposes of approximately 7,000 tonnes of hazardous waste, which mostly originates from households. (MA48, 2013a)

Separate collection at waste collection centres. Since 1988, Vienna's population can take advantage of waste collection centres as their one-stop contact points for bulky waste, electrical appliances, recyclables and problematic household waste, as well as objects that are still functioning and thus need not yet be discarded. This service is free of charge. Every year, the 19 waste collection centres are use by 2.4 million people, who drop off about 160,000 tonnes of waste. Of this, approx. 70,000 tonnes are construction waste; 20,000 tonnes, bulky waste; and 15,000 tonnes, organic waste. The waste collection centres not only provide a place to leave all sorts of special waste but also offer other services for Vienna's citizens, high-grade compost from green waste can be picked up free of charge, and peat-free soil with compost is for sale as well. (MA48, 2013a)

5.1.3 Waste prevention and public relations

Waste prevention is also given attention in Vienna's waste management. With numerous projects like the initiative "Natürlich weniger Mist" ("Naturally Less Waste"), the City of Vienna sends a signal to encourage the Viennese population to use products in an ecologically responsible manner (MA22, 2018). Projects for eco-compatible event organizations or for the prioritization of repair services over simple discarding have been implemented (MA48, 2018b). Moreover, MA48 recovers attractive discarded items from its waste collection centres and sells these at the "MA48 bazaar", see Figure 5.2. In addition, raising awareness is a key focus of the activities pursued by the Vienna City Administration.

Figure 5.2
Vienna's waste authority MA48 also operates the "MA48 Bazaar", where reusables are repaired and sold (MA48, 2018a)

While Vienna is ranked highly among other large cities when it comes to separate collection, there is still a need to stimulate greater **awareness for waste avoidance** among the population and to enhance **civic participation in separate collection** in order to increase the recycling quota and attain a higher volume of separately collected hazardous waste. This calls for massive efforts in the field of municipal services and communication with all age groups.

Hence, the **importance of public relations** activities cannot be underestimated. MA48 regularly targets different groups through a great variety of measures in order to encourage eco-conscious behaviour to promote sound waste management, e.g. direct contact via the waste hotline, information stands at various events, the joint Spring Cleaning push, "waste championships" (a competition for primary schools), lessons and workshops at schools, a special program for kindergartens, or the dissemination of information via campaigns, pamphlets, websites, Facebook and a special waste disposal app.

Figure 5.3
Where waste and energy meet art: The waste-to-energy plant "Spittelau" was designed by Friedensreich Hundertwasser. The appearance contributes to the high acceptance of the incineration plant in the city.

5.1.4 Collection and Treatment

The City of Vienna is responsible for the entire chain of waste management from collection to treatment and disposal. By operating its own waste treatment plants, it is possible to have short distances between the customer and the facilities. (MA48, 2013b)

a. Composting Plant "Lobau"
Capacity: 100,000 t/yr. In Lobau, about 100,000 t/yr of biogenic waste (in particular garden trimmings and similar waste) is transformed into high-grade compost.

b. Anaerobic Digestion Facility "Biogas Wien"
Capacity: 22,000 t/yr. Kitchen scraps are converted into biogas at the "Biogas Wien" plant and then fed as energy into the city's district-heating system.

c. Four Waste Incineration Plants
Capacity 600,000 t/yr. About 60% of all waste annually produced in Vienna – are subjected to thermal treatment at one of four waste incineration plants ("MVA Flötzersteig", "MVA Spittelau", "MVA Pfaffenau", "WS04" (fluidized bed incinerator 4) in Pfaffenau, which cogenerate energy for district heating, district cooling and electricity.

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES

[2.4 MILLION — 2.4 MILLION PEOPLE, WILL DROP OFF ABOUT 160,000 TONNES OF WASTE]

05 CASE STUDY: 2

Vienna's waste-to-energy plants, which are operated by the city's energy provider "Wien Energie", produce a total of more than 1.5 million MWh of heat, approximately 81,000 MWh of electricity and 38,000 district cooling. This accounts for approximately 20% of Vienna's total energy demand for district heating. (MA48, 2013; Wien Energie, 2018)

Plant	Commissioned in	Capacity
MVA Flötzersteig	1963	200,000 t/a
MVA Spittelau	1971	250,000 t/a
MVA Pfaffenau	2008	250,000 t/a
WS04	2003	80,000 t/a

Table 5.3
Waste-to-energy plants in Vienna (MA48, 2013)

d. Waste Treatment and Logistics Centre "Pfaffenau"

Capacity 250,000 t/yr. The pre-treatment and interim storage of residual waste began in 2013. In addition to dealing with recyclables, electrical appliances and hazardous waste, the facility's treatment unit for incineration residues compacts slag and ash from Vienna's waste incineration plants into slag-ash concrete. The stabilized incineration residues are then disposed of at the Rautenweg landfill.

Treatment

Table 5.4 shows the most recent data (2017) on MSW collection and diversion to treatment facilities. On the landfill Rautenweg, only C&D waste is still deposited.

Based on the data provided by the local waste authority MA48, Figure 5.4 gives an historical overview of MSW treatment and disposal in Vienna from 1960 to 2017.

MSW Collection and Treatment	Metric tons	Percent
Total MSW collected annually inside formal collection zones	1,024,000	100.0%
Composting	105,898	10.3%
Anaerobic Digestion	19,722	1.9%
Recycling	206,271	20.1%
Incineration	692,109	67.6%
Sanitary Landfilling	0	0%

Table 5.4
Vienna: MSW collection and treatment in 2017 (MA48, 2018c)

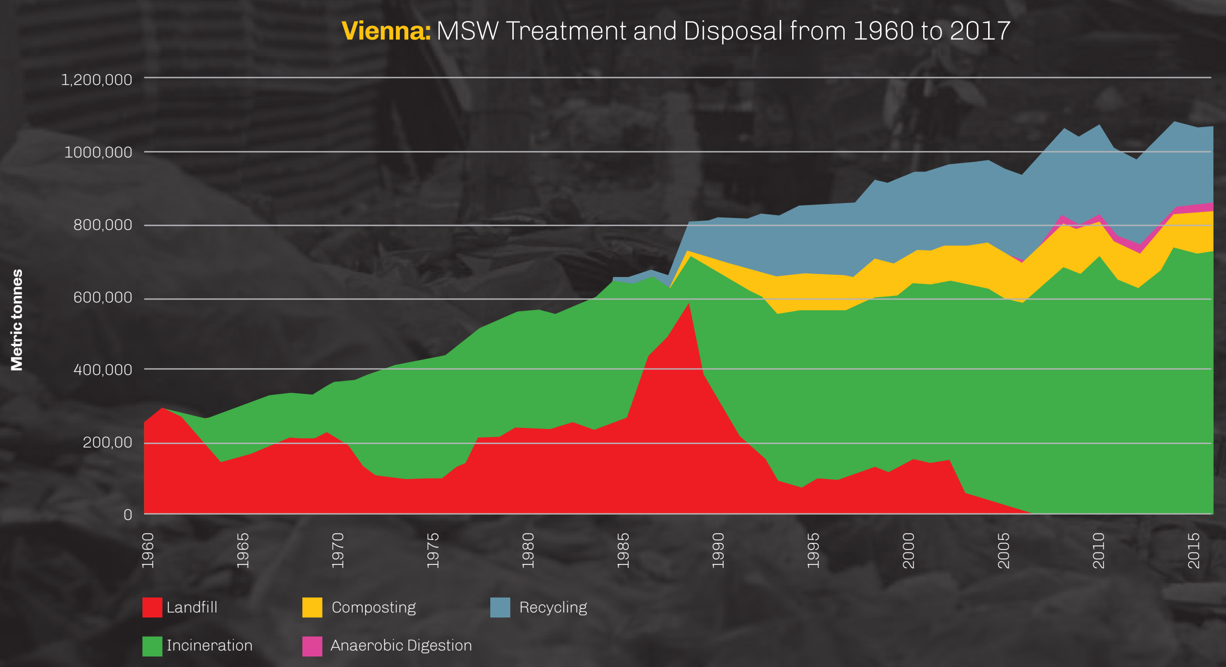


Figure 5.4
MSW treatment and disposal in Vienna from 1960 to 2017.
Data is based on empiric data from the waste authority MA48. (MA48, 2018c)

As depicted in Figure 5.4, the main share of MSW treatment in 2017 is incineration (67.6%). After 2008, no untreated MSW is discarded at the site. The amount of landfilled MSW skyrocketed in 1987 due to a fire at the waste incinerator "Spittelau" in May 1987. Today, the facility is still operating after being rebuilt. It serves as a modern waste-to-energy plant which provides energy for district heating, district cooling and electricity.

Figure 5.4 also shows that Vienna started the separate collection and treatment of recyclables in the 1980s. Despite the numerous successful measures undertaken to date, Vienna has the potential to mitigate potential emissions by raising rates for composting and recycling.

5.1.5 Dumping and Landfilling

The Rautenweg landfill has existed as a managed site since 1961. Since 2008, there is no landfilling without prior treatment; only C&D waste for slopes stabilization and slag/ash from incineration are deposited of at the site. Table 5.5 shows basic facts about the dumpsite.

Dumpsite opening year	1961
Annual disposal, data from the last years: (metric tonnes)	2007: 16,000
Size: (m²)	600,000
Height: (m)	60
Commissioned Capacity:	23 Mio m³
LFG extraction start-up year:	1991
Dumpsite closing year:	2008

Table 5.5
Rautenweg landfill in Vienna: Basic facts

Before 2008, the dumpsite's technical configuration was following: (Hiriya Recycling Park, 2018b)

- Site planning and disposal on designated areas
- Compaction of waste
- Access road maintenance
- Record of waste inputs

Table 5.6 shows the main organizational and engineering measures that have been applied on the site by the operators since the closure in 1998.

The landfill has also become home to many animals. The most prominent example is the Pinzgau mountain goat, which is a highly endangered species in Austria. More than 10 years ago, the goats were released on the landfill site by a veterinary surgeon. Today, 120 young goats have been successfully integrated into this habitat.

Furthermore, Rautenweg has become home to the crested lark (Galerida Cristata), a bird which is protected under Vienna's Nature Conservation Act. (MA48, 2007)

Measure	When?
Site and cell planning	1961
Application of soil cover	1961
Leachate Management: Construction of "Viennese chamber system" (MA48, 2007)	1986-1988
LFG extraction and flaring: 194 wells	1991
LFG extraction and electricity production: Electricity is fed into Vienna's grid. The LFG generation had its peak in 1996 and has decreased naturally since then. In 2017, less than 5 Mio. m3 were collected. In 2006, 4,000 households could be supplied with electricity.	1994

Table 5.6
Organizational and engineering measures applied at Rautenweg landfill over time (MA48, 2007, 2018c)

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPS

[SINCE 2008, THERE IS NO LANDFILLING WITHOUT PRIOR TREATMENT]

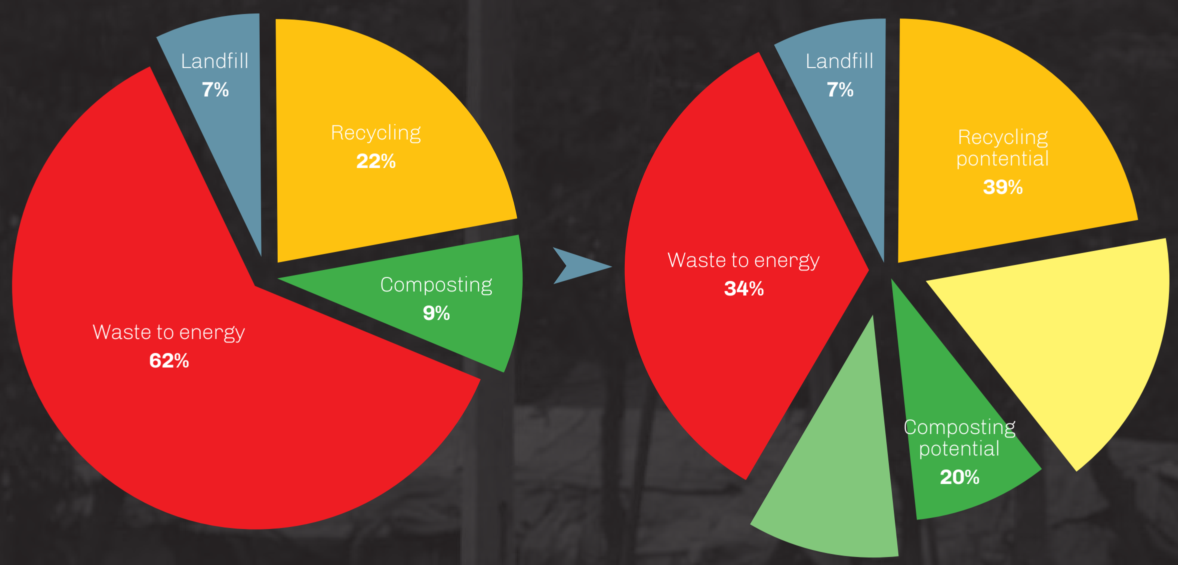


Figure 5.5
Waste Management in Vienna: Potential for improvement from raising rates for recycling and composting (MA48, 2018c)

5.1.6 Future Outlook

The major challenges of Vienna's sustainable waste management in 2018 are waste prevention strategies, as well as improving collection and rates for recycling and composting. This includes environmental awareness training for children and adults, as well as long-term planning.

According to experts from the MA48, there is potential for improvement, in particular regarding composting and recycling. Figure 5.5 depicts the potential improvement from raising rates for recycling and composting. (MA48, 2018c)

5.1.7 Lessons Learned

A determining factor for the closure of the Rautenweg landfill was the growing awareness of environmental issues in society and amongst policy makers. **The formation of a political will** lead to legal regulations which facilitated the transition from controlled dumping to sanitary landfilling. The combination of the landfill ban and the **financial incentive** of the landfill charge act forced the landfill operators to take action. Hence, these regulations made it possible that after 2008 no waste without prior treatment was sent to Austria's landfills.

A sustainable and smoothly functioning waste management scheme **needs long-term planning** and ongoing improvement. It has to involve multiple stakeholders and should consist of waste prevention strategies, an attractive collection scheme, eco-friendly waste treatment, but also environmental awareness training for children and adults.

Furthermore, effective **public relation strategies** are another major factor. Highlighting the importance of sustainable waste management for society and facilitating a positive perception of authorities or companies who are implementing it. This is of great help, for instance, when inventing new collection schemes or building new facilities.

5.1.8 Estimation of GHG Emissions and Short-Lived Climate Pollutant Mitigation

In order to estimate the GHG mitigation due to closing the Rautenweg dumpsite in Vienna, four scenarios are compared. Each scenario starts in the year 1965 and ends in 2050. The projected closing year 2050 is an assumption which allows for estimating emission mitigation in a long term.

Scenario "No Action": This scenario estimates the emissions of the MSW management in Vienna as if no measures had been applied in order to improve the dumpsite's technical configuration or to move towards an integrated waste management. In this scenario, the dumpsite's technical configuration stays as it was in 1965, which means that 100% of MSW is dumped without prior treatment.

Comparing the emissions of the "No Action" scenario with the "Real" scenario allows for quantifying the climate benefits of the actual steps taken since the 1960's.

Scenario "LFG Collection": This scenario depicts the closing of the Vienna dumpsite and its transformation to a sanitary landfill. It is assumed, that all MSW is diverted to sanitary landfilling and that the LFG collection was installed in 1991.

Scenario "Real Scenario" depicts the actual state of the waste management in Vienna in year 2017. It therefore considers the facilities which are in operation since the 1960's, as described in chapter 5.1.4 and 5.1.5. There is no MSW diverted to landfilling without prior treatment.

Regarding waste-to-energy, only direct emissions are considered. Net benefits from the avoided energy generation are not accounted for.

Scenario "Net Real Scenario": Like the "Real Scenario", this scenario depicts the actual state of the waste management in Vienna in year 2017. It also takes into account the facilities which are in operation since the 1960ies, as described in chapter 5.1.4 and 5.1.5. However, this scenario considers the avoided emissions due to the substitution of energy at the waste-to-energy plants.

Table 5.7 gives an overview of these four scenarios and their characteristics.

Charateristics	Scenario			
	No Action	LFG Collection	Real Scenario	Net real Scenario
LFG Collection	No	Yes	Yes	Yes
No Dumping without prior treatment 2008	No	Yes	Yes	Yes
Composting (10.3%) Anaerobic Digestion (1.9%) Incineration (67.6%) Recycling (20.1%) Only direct emissions considered	No	No	Yes	No
Composting (10.3%) Anaerobic Digestion (1.9%) Incineration (67.6%) Recycling (20.1%) Avoided emissions due to energy substitution considered	No	No	No	Yes

Table 5.7
Estimation of GHG emissions: 4 scenarios and their characteristics

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPS

[A SUSTAINABLE AND SMOOTHLY FUNCTIONING WASTE MANAGEMENT SCHEME NEEDS LONG-TERM PLANNING]

Scenario	Characteristics			
	LFG Collection	No Dumping without prior treatment 2008	Composting (10.3%) Anaerobic Digestion (1.9%) Incineration (67.6%) Recycling (20.1%) Only direct emissions considered	Composting (10.3%) Anaerobic Digestion (1.9%) Incineration (67.6%) Recycling (20.1%) Avoided emissions due to energy substitution considered
No Action	No	No	No	No
LFG Collection	Yes	Yes	No	No
Real Scenario	Yes	Yes	Yes	No
Net Real Scenario	Yes	Yes	No	Yes

The four scenarios were modelled with SWEET. The assumptions and limitations of the method are described in chapter 3. Figure 5.6 shows total emissions of MSW management in Vienna by scenario. The total emissions are summarized as GWP in metric tonnes CO_2 equivalents and include CO_2, NOx, black carbon, CH4 and organic carbon.

The emissions of the scenarios "No Action" with "LFG Collection" start to differ when the LFG collection was installed in 1991. The comparison of these two scenarios shows a mitigation of 38% by 2050, due to moving from dumping to sanitary landfilling including LFG management.

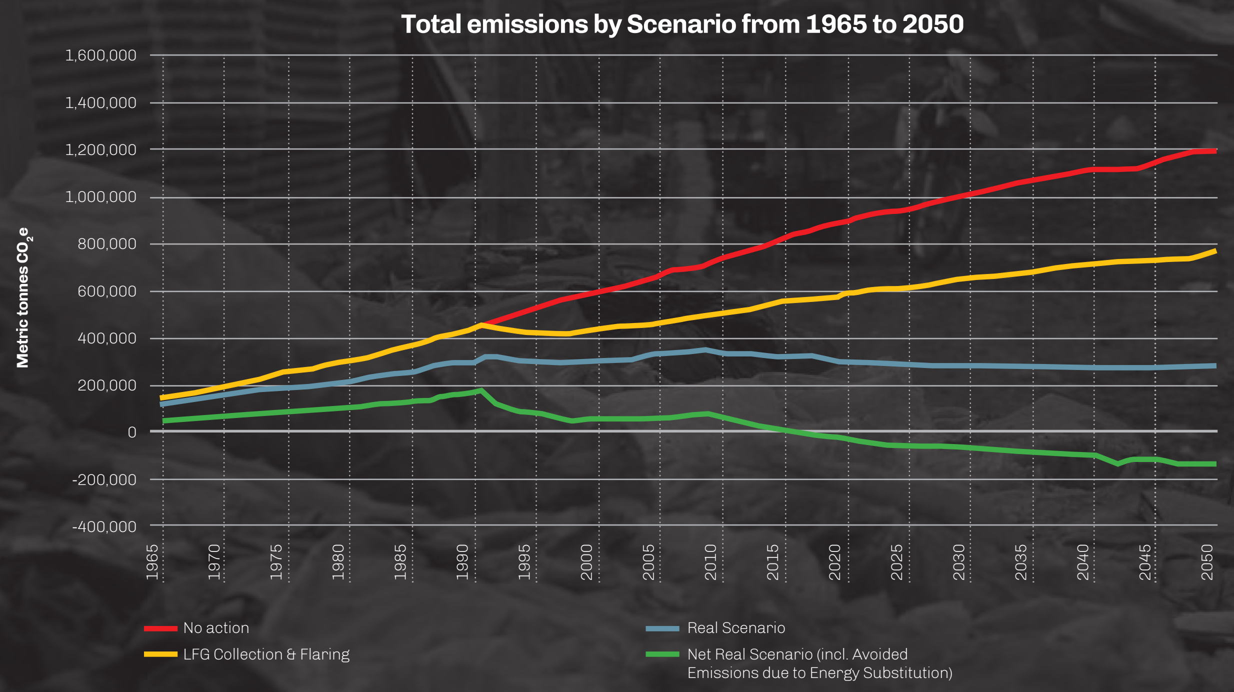


Figure 5.6
Total GWP of MSW management in Vienna by scenario from 1965 to 2050

In the "No Action" scenario, the dumpsite's technical configuration stays as it was in 1965, which means that 100% of MSW is dumped without prior treatment.

Comparing the emissions of the "No Action" scenario with the "Real Scenario" scenario, the calculation shows a vast reduction of emissions of 80% by 2050. These are the actual climate benefits of the Viennese waste management system, in which 100% of the collected waste is treated in an environmentally sound manner and no waste has been landfilled without prior treatment since 2008. The mitigation effect is also due to the constant decrease of emissions at the landfill Rautenweg, since no organic waste has been deposited there since 2008.

In addition to the "Real Scenario", the "Net Real Scenario" considers the avoided emissions due to the substitution of energy at the waste-to-energy plants. This results in net GWP credits of -73,000 tCO_2-ecquivalents by 2020 and -180,285 tCO_2-equivalents by 2050, which equals a mitigation compared to the "No Action" scenario of -108.4% by 2020 and -115.2% by 2050, see Figure 5.7.

Comparing the scenarios "No Action", "Real Scenario" and "Net Real Scenario" more closely, Figure 5.7 shows the total mitigation of emissions in time steps of ten years, beginning in 2010, two years after ceasing the deposition of untreated waste at the Rautenweg landfill. As can be seen in Figure 5.7, emission mitigation rises significantly with every decade, mostly due to the constant decrease of emissions at the landfill Rautenweg.

The actual emission mitigation shown in Figure 5.7 highlights again the urgency for immediate action in regions where there is neither treatment nor environmentally sound final disposal. In order to avoid lock-in effects, the sooner a municipality is able to act, the better.

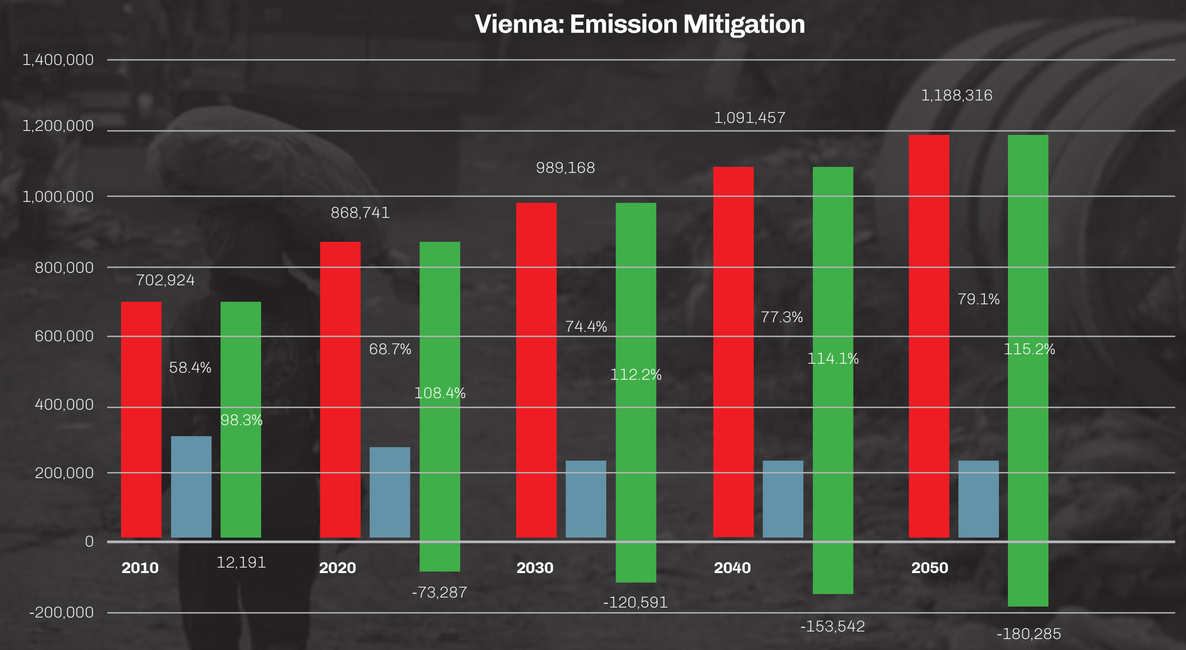


Figure 5.7
Emission mitigation due to closing the Rautenweg dumpsite in Vienna.

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPS

06

CASE STUDY:3

HIRIYA DISPOSAL SITE
IN TEL AVIV, ISRAEL

The necessary data for the estimation of emissions was kindly provided by experts from Hiriya Recycling Park.

Figure 6.1
Hiriya Recycling Park in 2018: The former dumpsite in the background, sorting and treatment facilities, education centre. (Hiriya Recycling Park, 2018b)

6.1 Results and Findings

The Hiriya landfill is located in Israel's capital, Tel Aviv. Today, the former dumpsite is part of the Hiriya Recycling Park, which is operated by the "Dan Region Association of Towns for Sanitation and Waste Disposal". This cooperation of towns was founded in 1966 by six municipalities: Tel Aviv Jaffa, Holon, Ramat Gan, Bat Yam, Bnei Brak and Givatayim. The association serves about 1.5 million people and receives 3,000 tonnes of municipal waste per day from these six municipalities. In addition to that, it serves 20-25 smaller municipalities, as well as private contractors. Therefore, Hiriya Recycling Park is Israel's most elaborate endeavour in the field of waste management. (Hiriya Recycling Park, 2018a)

In 1952, the city of Tel Aviv started dumping waste at Hiriya. After 46 years in operation, the site was closed down in 1998. One year later, there was no untreated waste being dumped at the dumpsite anymore and a new era of creative problem-solving and integrated solutions began. The first step was to turn the former dump into a transfer station of waste, most of which is transported to sanitary landfill sites in southern Israel.

This resulted in a broad transformation process of Hiriya, turning a disposal site into a constantly evolving waste management hub. By 2018, Hiriya Recycling Park consisted of a transfer station, a mechanical-biological treatment facility, a composting facility, a C&D recycling facility, an RDF (refuse-derived fuel) plant and an environmental education centre. Furthermore, the former dumpsite ("Mount Hiriya") was turned into a public park.

6.1.1 MSW Policy and Legislation

The closure of the Hiriya dumpsite was a direct consequence of the government's decision in 1993 to close all un-regulated dumpsites in Israel. Like the case of Estrutural dumpsite in Brasília, the political will to tackle environmental problems related to waste was of major importance for the closure of the Hiriya dumpsite in Tel Aviv, and the development of a sound waste management system as a whole.

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES

[THE ASSOCIATION SERVES ABOUT 1.5 MILLION PEOPLE AND RECEIVES 3,000 TONNES OF MUNICIPAL WASTE PER DAY]

06 CASE STUDY: 3

Since the 1970s, when landfilling was considered the only solution for dealing with waste, Israel's waste management policy has come a long way. Today, most of Israel's waste still ends up in sanitary landfills, but new policies are changing that. In addition, the regulation of landfills has changed, such that the method of burying waste is now environmentally safer than ever before. The historic evolution of landfilling policies in Israel is depicted in the following overview: (Ministry of Environmental Protection Israel, 2014)

- **1970s and 1980s:** Illegal and unregulated waste disposal was common
- **1984:** Fines for dumping waste in public domain were introduced, as part of the "Maintenance of Cleanliness Law". In the years 1986 and 1987, the "Cleanliness Maintenance Fund" was established. Fees and fines were applied under various environmental laws for strengthening waste disposal and treatment.
- **1989:** The "National Outline Plan for Solid Waste (NOPSW)" was Israel's first comprehensive attempt to regulate the locations and operational criteria for waste treatment and disposal sites, in particular for municipal waste. However, no timetable was set for shutting down unauthorized landfills or for establishing new ones that would meet appropriate sanitary and environmental standards.
- **1993:** The Government decided the closure of all uncontrolled dumpsites, which numbered some 500 at the time, including about 75 large landfills. Amendments to the NOPSW determined the location of central sanitary landfills, which were subject to environmental impact assessment procedures. Local authorities were granted financial aid for the transport of waste to regulated sites.
- **2003:** All uncontrolled dumpsites were shut down by 2003, including the Hiriya dumpsite, which was closed in 1998. At the same time, state-of-the-art landfills began to operate. Today most of the country's waste is concentrated in 14 sanitary landfills.
- **2006:** Because landfilling remained the principal option for disposing MSW in Israel, the government approved a new Sustainable Solid Waste Management Master Plan (SSWMMP), which introduced integrated waste management policies similar to those in other OECD countries. The SSWMMP set new goals for national and local governments, including reducing the total quantity of waste in general, and reaching a 50% recycling rate by 2015. That goal was eventually pushed back to 2020.
- **2007**: A landfill levy went into effect in Israel (Amendment 9 of the Maintenance of Cleanliness Law). The levy is aimed at reducing the amount of waste sent to landfills by internalizing the external costs of landfilling in order to reflect the true price of burying waste. The funds collected from the landfill levy are deposited into a Maintenance of Cleanliness Fund and are used for the development and establishment of alternative waste treatment methods, such as recycling and energy recovery.
- **2010:** The Ministry of Environmental Protection began to lead a so called "Recycling Revolution", which includes a separation of waste at source program, funding of recycling and recovery facilities, and an awareness-raising campaign. The goal is to increase recycling rates and to significantly reduce the amount of waste sent to landfills for burial.
- **2011:** A Packaging Law was passed, which imposes direct responsibility on manufacturers and importers for collecting and recycling the packaging waste of their products. In parallel, it obligates local authorities to make arrangements for the separation, collection and removal of packaging waste and prohibits the disposal of packaging waste in any other way.

6.1.2 MSW Generation and Composition

In 2018, Hiriya Recycling Park received about 1.1 million tonnes of waste, serving a population of around 1.5 million. The annual growth rate of collected waste at Hiriya is about 3%. The per capita waste generation in Israel is 1.7 kg/capita/day (Israel Ministry of Environmental Protection, 2018). Basic facts about MSW generation and growth rate in 2018 are summarized in the following (Hiriya Recycling Park, 2018b):

- Ppopulation: 1,500,000
- Waste generation inside formal collection zones: 1.7 kg/capita/day
- Average annual growth rate in quantity of waste collected – projected: 3%
- Total waste collected annually inside collection zones: 1,100,000 metric tonnes

Waste type	1975 (%)	1983 (%)	1986 (%)	1995 (%)	2005 (%)	2013 (%)
Organics	65	60	49	41	40	37
Paper & Cardboard	17	17	21	24	25	24
Plastics	8	10	15	15	13	18
Metals	3	3	4	3	4	2
Textiles	4	4	4	4	4	4
Glass	2	2	3	4	3	3
Other	3	3	3	9	13	11
TOTAL	**102**	**99**	**99**	**100**	**102**	**99**

Table 6.1
MSW composition in Tel Aviv (Israel Ministry of Environmental Protection, 2014)

Composition

The Israel Ministry of Environmental Protection has conducted waste composition surveys since 1975 (Israel Ministry of Environmental Protection, 2014), as shown in Table 6.1. This composition data is used for the calculation in SWEET.

6.1.3 Collection and Treatment

Collection

Each municipality of Dan Region Association of Towns (DRAT) is responsible for the collection of their own waste and they have their own collection schemes. Some municipalities implemented a separation process and are operating selective collection schemes, for instance separate collection of organic waste or separate collection of market/restaurant waste.

Hiriya Recycling Park takes over the process once the municipal trucks have entered the site (about 1,200 compactor trucks per day). The weight and data control system keep track of the weight and content of each truck load. The trucks are weighed when entering and leaving Hiriya. The payment for waste processing is by tonnage per truck. Depending on the type of waste, it is sent to one of four facilities operating at Hiriya.

Table 6.2 shows the most recent data on MSW collection and diversion to treatment facilities. On the former dumpsite, only C&D waste is still deposited.

MSW Collection and Treatment	Metric tons	Percent
Total MSW collected annually inside formal collection zones	1,124,734	100.0%
Composting	240,038	21.3%
Anaerobic Digestion	19,374	1.7%
Recycling	10,200	0.9%
Incineration	66,710	5.9
Sanitary Landfilling	788,412	70.1%

Table 6.2
Hiriya Recycling Park: **MSW collection** and treatment in 2018 (Hiriya Recycling Park, 2018b)

Based on historical data from Hiriya and assumptions, Figure 6.2 gives an historical overview of MSW collection and treatment. Data from 1985 to 2018 is based on empirical data. Before 1985, an annual growth rate of 6% is assumed.

ES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPS

[1970S AND 1980S: ILLEGAL AND UNREGULATED WASTE DISPOSAL WAS COMMON]

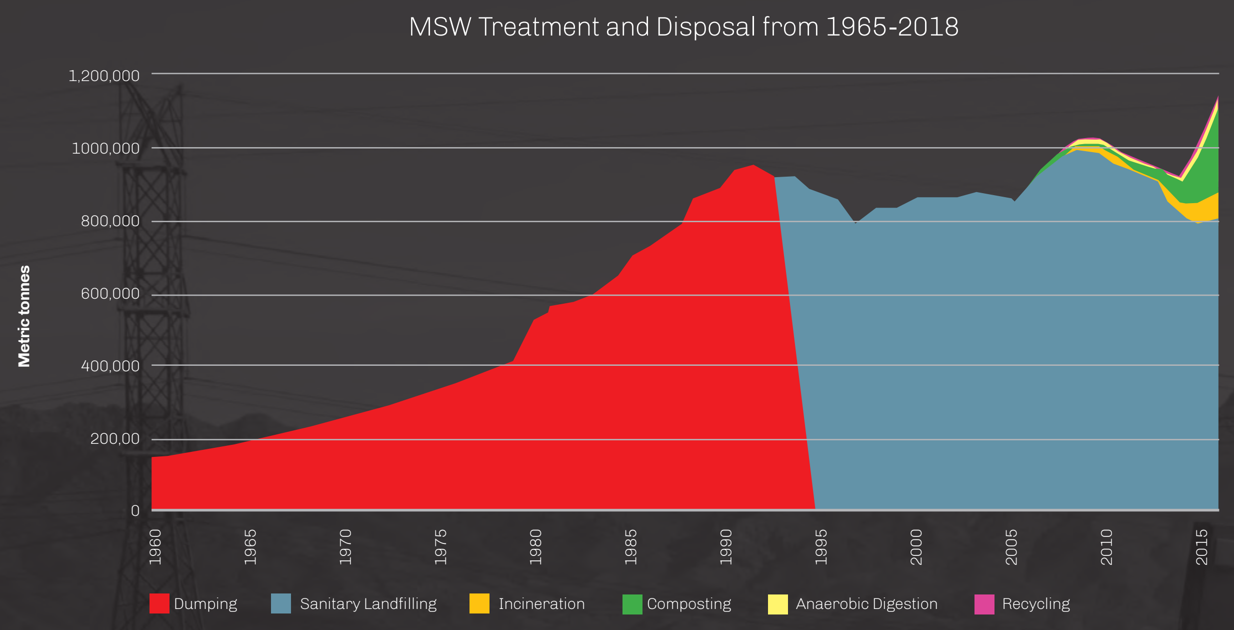


Figure 6.2
MSW collection and treatment at Hiriya Recycling Park from 1965 to 2018. (Hiriya Recycling Park, 2018b)

As shown in *Figure 6.2*, the major share of MSW in 2018 is disposed of at the sanitary landfill. By 2018, the share of MSW sent to composting could be raised to 21.3% due increasing capacity of the facilities.

According to Hiriya's vision, the goal is to further reduce landfilling and promote sorting and alternative treatment. A more detailed outlook on Hiriya's strategic plan is given in chapter 6.1.6.

Since 2003, Hiriya Recycling Park has been evolving constantly. New facilities are in planning and existing facilities are being upgraded in order to have better treatment for a larger amount of waste each year. In 2018, the following facilities are in operation: (Hiriya Recycling Park, 2017a, 2017b)

a. Transfer Station
Capacity: 1000-2000 t/d. Operating since 2000, the transfer station was opened after the closure of the old dumpsite. It is the largest facility of its kind in Israel. It operates around the clock, 364 days a year.

The transfer station condenses the waste before it is sent to sanitary landfills. With its maximum capacity of 8,000 tonnes, it is also used as a buffer when other facilities are under maintenance. The transfer station might be replaced by a new C&D facility as well as a new materials recovery facility (MRF), which are already in planning.

b. Mechanical Biological Treatment (MBT) Facility "ArrowBio"
Capacity: 400 t/d. In a first stage, the waste undergoes a sorting procedure while recyclables like cardboard, paper, metals, glass and plastics are extracted. In the second stage the organic fraction enters the anaerobic digestion facility.

c. Green Waste Facility
Capacity: 400 t/d. The green waste comes from private gardens, yards, and from pruning and culling of woods and street trees by the local authority. It produces compost and the green matter is also sold as a substitution for petroleum-based fuels to Galam factory in Maanit, which manufactures starch and corn flour.

d. RDF Plant
Capacity 1,500 t/d. The refuse derived fuel (RDF) plant began operating in 2016. After sorting and separating recyclables the facility produces 500 tonnes RDF per day, which provide energy for Israel's cement industry.

6.1.4 Dumping and Landfilling

The Hiriya dumpsite has existed since 1952 and was closed during 1998. In 1999, no waste was deposited at the site without prior treatment. It has a size of about 450,000 m² with a height of 60m. Table 6.3 shows basic facts about the dumpsite.

Dumpsite opening year	1952
Annual disposal, data from the last years: (metric tonnes)	1997: 954,785 1998: 600,000
Size: (m²)	450,000
Height: (m)	60
Dumpsite closing year:	1998
Active LFG extraction and flaring start-up year:	2005

Table 6.3
Hiriya dumpsite: Basic facts (Hiriya Recycling Park, 2018b)

Before the closure in 1998, the dumpsite's technical configuration was as follows: (Hiriya Recycling Park, 2018b)

- Site planning and disposal on designated areas
- Compaction of waste
- Access road maintenance
- Record of waste inputs since 1984
- A lot of waste picking
- A lot of open burning

Measure	When?
Soil Cover	1998
Leachate Management	2000
Slopes stabilization, preventing collapse into the river nearby	2000-2014
LFG extraction: 100 wells, providing energy for textile factory 3km away	2005
Transition from dumpsite to public park	2004-present

Table 6.4
Organizational and engineering measures applied at Hiriya disposal site over time (Hiriya Recycling Park, 2018b)

Table 6.4 shows the main organizational and engineering measures that have been applied on the site by the operators since the closure in 1998.

Sanitary Landfills

In 2018, about 50% of all incoming waste to Hiriya goes directly, without sorting and separation, to the sanitary landfills Ef-eh and Ganey Hadas. Both landfills are operated in compliance with the country's environmental standards. Following Hiriya's vision to maximize the amount of waste treated in Hiriya and to minimize the amount of waste transferred to landfilling, there is an ongoing process to raise the capacity of existing facilities as well as plan new facilities, see chapter 6.1.6.

6.1.5 Education Centre

About 125,000 visitors arrive at the environmental education centre every year, which began operating in 2007. Today, the education centre is an integral part of the recycling park and visitors can learn about the work being done at the site. They can take part in activities for various ages, including tours, seminars, waste prevention workshops etc. (Hiriya Recycling Park, 2017b)

Figure 6.3
In Hiriya's education centre, visitors can take part in activities for various ages, including tours, seminars, and waste prevention workshops (Hiriya Recycling Park, 2017b)

One of the main objectives of the education centre is to foster personal responsibility and community commitment to social-environmental change, which is necessary when trying to alter habits and to introduce new waste management practices. In addition, the education centre promotes positive public perception regarding waste management issues.

6.1.6 Future Outlook

The Hiriya Recycling Park is not intended to be the only main solid waste treatment site for the Tel Aviv Metropolitan Area. With its public park and educational centre it aims to become a unique educational, environmental and visual experience. Eventually, the development of the park will be instrumental in promoting the concepts of recycling and re-use in Israel, as well as promoting the reduction of the amount of waste sent for landfill. (Hiriya Recycling Park, 2017a)

ES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPS

ABOUT 125,000 VISITORS ARRIVE AT THE ENVIRONMENTAL EDUCATION CENTRE EVERY YEAR

Besides the educational activities and the development of the recreational area on the former dumpsite, there is a constant development of the waste treatment facilities. Hiriya's vision is to maximize the amount of waste treated on the site and to minimize the amount of waste transferred to sanitary landfills. According to an official at Hiriya, the next steps in the development of waste treatment in Hiriya are as follows:

- A new Material Recovery Facility (MRF) is planned. The opening of the new facility with a capacity of 1,200 t/day is expected in 2021 or 2022
- There is also a C&D facility with a capacity of 2,000 t/day in planning, which is supposed to start operating in 2020
- In addition, Hiriya takes part in a project to construct Israel's first waste-to-energy facility. The project is still in its early stages of planning. The optimistically estimated opening will be 2026 or 2027

6.1.7 Lessons Learned

According to the waste management experts from Hiriya Recycling Park, a strong political will, legal regulations, as well as significant subsidies were the most important factors for the closure of uncontrolled dumping in Israel.

As a consequence of the government's decision in 1993 to close all uncontrolled dumpsites, the closure of the Hiriya dumpsite was achieved in 1998. Similar to the other case studies of Brasília and Vienna, a strong political will and legal regulations were crucial in taking initial action.

The cheapest – albeit the most environmentally harmful – way to deal with waste is dumping. Therefore, the main barrier during the process was the increase in costs of new facilities at Hiriya, like transfer stations combined with the transportation of waste to sanitary landfills. Furthermore, it was necessary to prepare the numerous municipalities for the new tipping fees. This process was subsidized by the state of Israel for the first 5 years after closing the dumpsite in a decreasing portion, in order to give the municipalities time to prepare new budgets for the collection and treatment of MSW.

Consequently, the public hand did not only provide legal regulations, it also provided significant subsidies in order to facilitate alternative, environmentally sound waste management practices. Partially, these subsidies were funded by the "Maintenance of Cleanliness Fund", into which fines and the landfill levy are deposited since 2007 (Ministry of Environmental Protection Israel, 2017). By supporting the municipalities financially in their process, national policy targets could be met.

As any other metropolis, the Hiriya site is a unique and complicated case both at the national level and globally for two main reasons: the huge amount of waste handled daily (about 3,000 tonnes) and the operational complexity. The amount of waste is large, even by world standards, there are not many sites around the world that handle such a large amount of mixed household garbage. The reason for the operational complexity lies in the fact that Hiriya Recycling Park serves a wide variety of local authorities. Each authority has its own way of managing its affairs, its unique needs and character, and therefore each one of them requires a unique solution suitable for its specific needs (Hiriya Recycling Park, 2018c). Therefore, the lesson one can learn from the Hiriya case study is that each regional waste management faces unique challenges and needs unique solutions on a regional level.

Hiriya Recycling Park aims for such a regional-level solution. The setting-up of the Park, with its waste sorting and separation facilities and the production of energy from the waste are only the beginning of a comprehensive solution for treating the Tel Aviv Metropolitan Area's waste. A critical building block in the solution is involvement of the people. The way individuals conduct themselves, each in their own households and throughout the urban area as a whole, have a major impact on the area's waste management. By promoting waste awareness, for instance with the education centre, people's behaviour has been taken into consideration in the planning, building, and operation of the Hiriya Recycling Park.

6.1.8 Estimation of GHG Emissions and Short-Lived Climate Pollutant Mitigation

In order to estimate the GHG mitigation resulting from closing the Hiriya dumpsite, four scenarios are compared. Each scenario starts in the year 1965 and ends in 2050. The projected closing year 2050 is an assumption which allows for estimating emission mitigation in the long term.

Scenario "No Action": This scenario estimates the emissions of the MSW management in Tel Aviv metropolitan area, as if no measures had been applied in order to improve the dumpsite's technical configuration or to move towards an integrated waste management. In this scenario, the dumpsite's technical configuration stays as it was in 1952, which means that 100% of MSW is dumped without prior treatment. Neither the new sanitary landfill nor composting and recycling are considered. Comparing the emissions of the "No Action" scenario with the current status allows for quantifying the climate benefits of the actual steps taken since 1998.

Characteristics	Scenario			
	No Action	Dumpsite Closure & LFG Collection	Current Status 2018	Strategic Plan 2025
Closing Hiriya Dumpsite 2018	No	Yes	Yes	Yes
Application of cover soil and installation of LFG collection in 2005	No	Yes	Yes	Yes
Treatment 2018: Composting (16.4%) Anaerobic Digestion (2.1%) Incineration (5.9%) Recycling (1.2%)	No	No	Yes	Yes
Treatment 2030: Increased Composting (16.2%) & Recycling (29.1%) Anaerobic Digestion (2.1%) Incineration (5.9%)	No	No	No	Yes

Characteristics	Scenario			
	Closing Hiriya Dumpsite 2018	Application of cover soil and installation of LFG collection in 2005	Treatment 2018: Composting (16.4%) Anaerobic Digestion (2.1%) Incineration (5.9%) Recycling (1.2%)	Treatment 2030: Increased Composting (16.2%) & Recycling (29.1%) Anaerobic Digestion (2.1%) Incineration (5.9%)
No Action	No	No	No	No
Dumpsite Closure & LFG Collection	Yes	Yes	No	No
Current Status 2018	Yes	Yes	Yes	No
Strategic Plan 2025	Yes	Yes	Yes	Yes

Table 6.5
Estimation of GHG emissions: 4 scenarios and their characteristics

#CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES

[THE EDUCATION CENTRE IS TO FOSTER PERSONAL RESPONSIBILITY AND COMMUNITY COMMITMENT TO SOCIAL-ENVIRONMENTAL CHANGE]

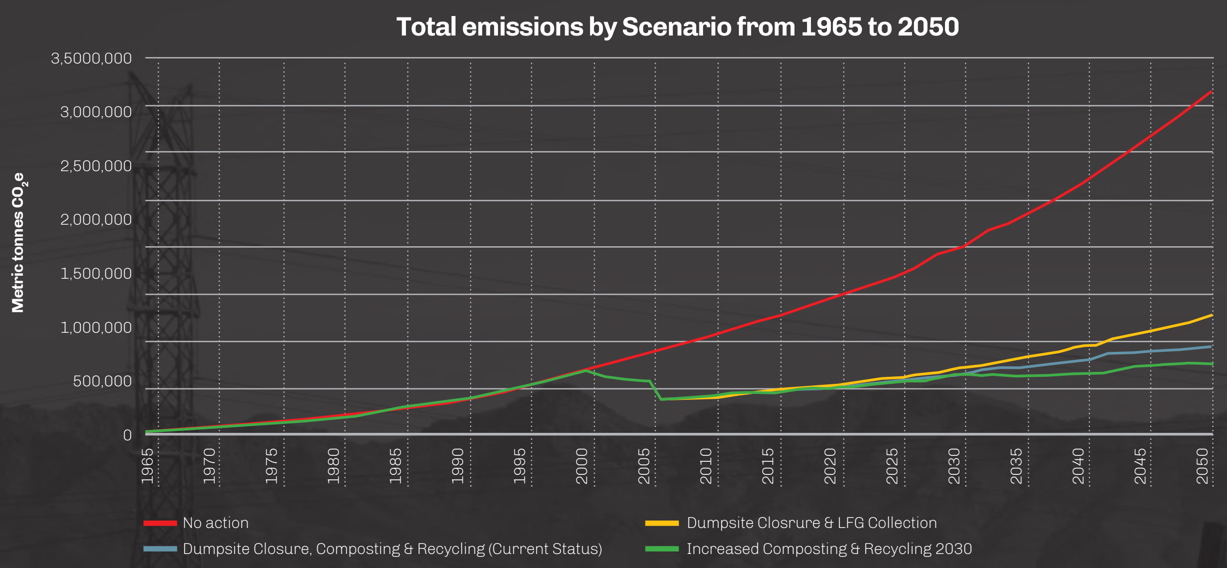


Figure 6.4
Total GWP of MSW management in the Tel Aviv metropolitan area by scenario from 1965 to 2050

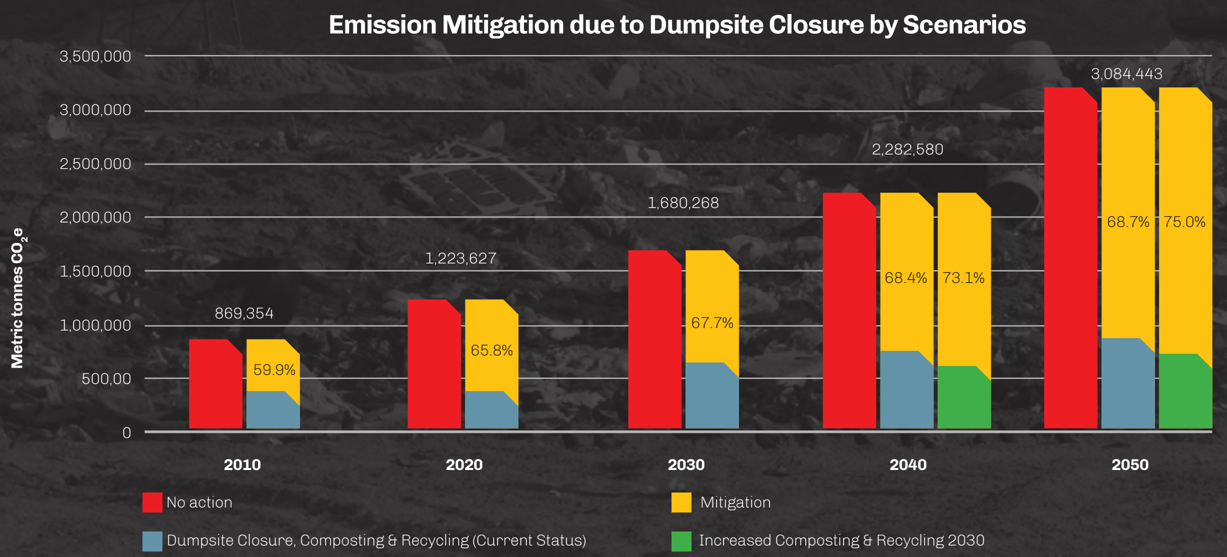


Figure 6.5
Emission mitigation due to closing the Hiriya dumpsite (Current Status) and potential mitigation due to raising rates for alternative treatment by 2030

Scenario "Dumpsite Closure & LFG Collection": This scenario depicts the closing of the Hiriya dumpsite by diverting all waste to sanitary landfilling since 1999. This scenario also considers the installation of an LFG collection at the closed Hiriya dumpsite in 2005. However, this scenario does not consider any other waste treatment like composting or recycling. Hence, this scenario sheds a light on the potential emission mitigation only due to moving from uncontrolled dumping to sanitary landfilling including LFG management.

Scenario "Current Status" depicts the actual state of the waste management in the Tel Aviv metropolitan area. It therefore considers the actual facilities which are in operation in 2018. About 50% of MSW is still diverted to sanitary landfilling. Hence, it calculates the emissions of the waste management system in the Tel Aviv metropolitan area as it is described in chapter 6.1.3 to 6.1.4.

Scenario "Increased Composting & Recycling 2030": It is assumed that additional steps regarding the increase of recycling and composting are implemented such that the recycling and composting rates meet the current EU-average (2016) by the year 2030: 29.4% Recycling and 16,5% Composting (Eurostat, 2018). Although this might not match the exact plan of Hiriya Recycling Park, this scenario points out additional potential future benefits that could be realized by further improvements in the waste management.

The four scenarios were modelled with SWEET. The assumptions and limitations of the method are described in chapter 3. Figure 6.4 shows total emissions of MSW management in Tel Aviv metropolitan area by scenario. The total emissions are summarized as GWP in tonnes CO_2 equivalents and include CO_2, NOx, black carbon, CH4 and organic carbon.

After 1998, the year of the dumpsite closure, the emissions of the scenarios begin to diverge. In 2005, the year when the LFG collection at Hiriya was installed, another major impact on the emissions can be seen. This causes a vast difference in GWP by 2050 between scenario "No Action" and "Dumpsite Closure & LFG Collection" (mitigation of 65.1%). This again shows the importance and vast potential of taking immediate action towards sustainable waste management.

When comparing the "Current Status" scenario with the "No Action" baseline, the vast mitigation of emissions is impressive: By 2050, Tel Aviv saves about 2,100,000 tCO_2-e (68.7%). These are the climate benefits of the cities' current waste management system, in which 100% of the collected waste is treated in an environmentally sound manner and no waste is landfilled without prior treatment.

Scenario "Increased Composting & Recycling 2030" points out benefits of further improvements in the waste management system. By minimizing the amount of waste being landfilled and by raising rates for alternative treatment, emissions can be mitigated even further. This results in potential savings of about 2,300,000 tCO_2-e (75.0%) by 2050, despite the fact that effects of energy substitution (incineration) are not considered.

Comparing the scenarios "No Action", "Current Status" and "Increased Composting & Recycling 2030" more closely, Figure 6.5 shows the total mitigation of emissions in time steps of ten years, beginning in 2010, three years after the LFG collection was installed.

As can be seen in Figure 6.5, emission mitigation rises significantly with every decade up to 68.7% (Current Status) and 75.0% (Increased Composting & Recycling 2030) by 2050. If effects of energy recovery (due to incineration) were accounted for, it can be expected that there would even be net negative emissions, as shown in the Vienna case study (see 5.1.8).

The actual emission mitigation shown in Figure 6.5 underlines again the urgency for immediate action in regions, where there is neither treatment nor environmentally sound final disposal. In order to avoid lock-in effects, the sooner a municipality is able to act, the better.

ES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPS

07

DISCUSSION OF RESULTS

7.1 Climate Benefits due to Dumpsite Closure

In each of the case studies, the assessment of emissions has shown significant mitigation effects of each scenario compared to the "No Action" baseline, by 2050. For instance, Scenario "LFG Collection" already shows a large mitigation potential, by only installing an LFG collection and flaring device (Brasília 50.6%, Vienna 38.1%, Tel Aviv 65%).

When comparing the cities' actual waste management system (as of 2018) with the "No Action" scenarios, the vast mitigation of emissions in all three case studies is impressive: By 2050, Brasília saves about 1,000,000 tCO_2-e (70.6%), Vienna about 950,000 tCO_2-e (80.0%) and Tel Aviv saves about 2,300,000 tCO_2-e (75.0%). These are the climate benefits of the cities' current waste management systems, in which 100% of the collected waste is treated in an environmentally sound manner and no waste is landfilled without prior treatment. Beginning with the "closure" of the sites, the long-term mitigation effect is due to the constant decrease of emissions at the disposal sites, since no organic waste has been or will be deposited.

Furthermore, if the avoided emissions due to the substitution of energy (for district heating and cooling) at the waste-to-energy plants are considered, like it is done in the Vienna case study, the emission savings can even result in net GWP credits: compared to the "No Action" scenario, the estimation of emission displays a mitigation of -108.4% (-942,000 tCO_2-e) by 2020 and -115.2% (-1,368,000 tCO_2-e) by 2050.

7.2 Lessons Learned

According to experts from the waste authorities, who contributed data to these case studies, the determining factor for the closure of dumpsite was a **vigorous political will** and **significant subsidies.** This was the result of the growing awareness about environmental issues in society and amongst policy makers. The formation of a political will led to **legal regulations** which facilitated the transition from controlled dumping to sanitary landfilling. The combination of regulations and **financial incentives** from a landfill charge forced the landfill operators to act. Hence, these regulations made it possible that waste without prior treatment is no longer sent to the analysed landfills.

A sustainable and smoothly functioning waste management system needs **long-term planning** and ongoing improvement. It has to involve **multiple stakeholders** and consist of waste prevention strategies, an attractive collection scheme, eco-friendly waste treatment, as well as environmental awareness training for children and adults.

The case study of Brasília shows in particular, that closing a dumpsite can be realized in a relatively short amount of time. In addition, it proves the feasibility of steering a change of habits and working conditions of the informal sector and transform it into a formal system.

The importance of this case study is the potential impact the success story of Estrutural can have on other municipalities around the world, which also seek to finally act regarding uncontrolled disposal of waste. Furthermore, promoting **public relations** is another major factor which highlights the importance of sustainable waste management for society, and facilitates a positive perception of authorities or companies who are implementing it. In the case of Tel Aviv and Vienna this is of great help, for instance, when inventing new collection schemes or building new facilities. A critical building block in the solution is the involvement of people.

The way individuals conduct themselves, both in their own households and throughout the urban area as a whole, has a major impact on the area's waste management system. By **promoting "waste awareness"**, for instance with the education centre, the people's behaviour has been taken into consideration in the planning, building, and operation of the Hiriya Recycling Park.

The three case studies highlight the fact, that each city is a unique and complicated case, with their own political, governance, technical, economic and social circumstances. However, based on this study it is possible to create a standard analytical and decision-making template that can be used for any waste management owner who wants to close their dumpsite. Therefore, the lesson one can learn from the case studies is that **each regional waste management faces unique challenges and needs to involve all stakeholders in deriving unique solutions** on a regional level, particularly the political will, regulatory requirements, and the public demand.

However, the case studies deliver proof that closing dumpsites and setting up a sustainable waste management is a difficult task – but it is feasible.

7.3 Applicability of SWEET

Given the underlying assumptions on which these emission estimations are based (such as the specific emissions quantification model, local/regional waste composition, technology performance, estimation of emissions factors, etc.) the results of emissions assessments are not 100% transferable to other countries. Furthermore, comparing the results of different emissions assessments of the same waste management system should be done only by considering their different set of assumptions, such as system boundary, method, quantification model, etc.

ES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPS

[CO_2 70% BY 2050, BRASÍLIA WILL SAVE ABOUT 1,000,000 CO_2-E (70.6%)]

07 DISCUSSION OF RESULTS

However, comparing different scenarios within the same system boundary by applying a constant set of assumptions, as is done in this study, allows valuable conclusions regarding differing emissions of different scenarios. It can thus provide the reader with valuable insights into emissions mitigation due to sound waste management practices, without conducting an in-depth Life-Cycle Assessment of waste management practices.

Based on the experience of conducting this research study, SWEET is, overall, an easy to use tool to estimate LFG emissions of a waste management system. After months of extensive use, the author's reflection on working with SWEET can be summarized as follows:

- For the purpose of comparing future scenarios, it is easy to use and requires only basic input data like mass balances, composition data and growth rates.
- For a simple assessment of future scenarios, the user does not necessarily require in-depth knowledge in environmental science and engineering. This makes it very easy to do a first screening estimation. Doing that, the figures produced by SWEET can be used directly for demonstration purposes.
- If the user wants to model historic emissions and compare different scenarios over decades, basic knowledge of environmental science and the understanding of the calculation methods would be helpful, because the user might want to extract and compile the emission data on his or her own. For that, it is very helpful to use the assumptions and restrictions that are fully described in the tool.
- The more diverse a waste management system and the intended scenarios are, the more laborious using the tool becomes, as the user might want to create several files and compile the data on their own. This was the experience of the author in creating the estimations with the same scope for the cities of Vienna, Austria and Tel Aviv, Israel.

Summarizing the above, SWEET would be suitable for a first assessment of emissions mitigation due to improvements in a waste management system. In particular, it would be beneficial for municipalities in low and middle-income countries that want to communicate positive climate effects and have compelling arguments ready for relevant stakeholders before making the first steps of improving their waste management practices.

ES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPSITES #CLOSINGDUMPS

CLOSING A DUMPSITE CAN BE REALIZED IN A RELATIVELY SHORT AMOUNT OF TIME

08

CONCLUSION

Closing a dumpsite has extensive climate benefits. The estimation of emissions highlights large climate benefits resulting from the closure of dumpsites and the implementation of sustainable waste management practices.

In each city of the case studies, 70-80% of emissions (1,000,000-2,000,000 tCO_2-e) will be saved by 2050 because of closing their dumpsites and implementing integrated waste management systems, compared to a fictive "No Action" scenario, in which all waste is still dumped without prior treatment. Potential improvements, which are most likely to happen, are not even considered.

With further potential improvements, which are most likely to happen in each city, even more savings of emissions can be expected. Considering the emergency of the climate change issue, closing dumpsites should become a political top priority.

Closing a dumpsite is possible in a short period of time.
Another strong message from the case studies is the following: Closing a dumpsite, even the largest in Latin America, is possible in a short period of time, if there is political will and the involvement of many stakeholders. Changing habits, by integrating the former waste pickers into formal waste managing practices, is also feasible.

As a middle income country, the case study of Brasília is, in particular, representative in many respects of municipalities in the low and middle-income countries in terms of environmental and human health impacts associated with waste management. If the biggest dumpsite in Latin America can be closed, other dumpsites around the world can be closed too.

Closing a Dumpsite requires multi-stakeholder involvement because dumping requires organizational, technical, financial and social alternatives. As we can see in the case studies, the goal is to establish and constantly improve a sustainable and smoothly functioning waste management scheme. This has to involve multiple stakeholders and consist of waste prevention strategies, an attractive collection scheme, eco-friendly waste treatment, but also environmental awareness training for children and adults.

Closing a dumpsite is feasible.
The presented case studies show that we know how to treat our waste in an eco-friendly manner, and that we have the knowledge and the resources to take action. ISWA has resources on developing strategies via its "Roadmap for Closing Waste Dumpsites" (ISWA, 2016)

Closing dumpsites must happen, starting today.
The quicker we act, the more harm to our planet can be avoided. Because the untreated waste of today causes the emissions of tomorrow – ACT NOW.

For more information on the **ISWA's Closing Dumpsite Campaign** visit:
closingdumpsites.iswa.org/

09 REFERENCES

ABRELPE. (2016). Panoramados dos Resíduos Sólidos no Brasil 2015. Retrieved from http://abrelpe.org.br/panorama/

ABRELPE. (2017). Report on Technical Visit for Monitoring Technical Guidelines for Operation of the new Landfill and Closure and Recovery of the "ESTRUTURAL Landfill". Internal Document, not publically available.

ABRELPE & ISWA. (2018). Report of Visit SLU Brasília. Internal Document, not publically available.

Agamuthu, P. (2011). Chapter 8 - Municipal Waste Management. In T. M. Letcher & D. A. Vallero (Eds.), Waste (pp. 109–125). Boston: Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-381475-3.10008-7

Alfaia, R. G. de S. M., Costa, A. M., & Campos, J. C. (2017). Municipal solid waste in Brazil: A review. Waste Management & Research, 35(12) 119, 0734242X1773537. https://doi.org/10.1177/0734242X17735375

Blight, G. (2011). Chapter 30 - Landfills – Yesterday, Today and Tomorrow. In T. M. Letcher & D. A. Vallero (Eds.), Waste (pp. 469–485). Boston: Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-381475-3.10030-0

CCAC. (2018). Science. Retrieved from http://www.ccacoalition.org/en/science-resources

CCAC MSW Initiative. (2017). Solid Waste Emissions Estimation Tool (SWEET) version 2.0. Retrieved from http://www.waste.ccacoalition.org/document/solid-waste-emissions-estimation-tool-sweet-version-20

CCAC MSW Initiative. (2018). Solid Waste Emissions Estimation Tool (SWEET) User Manual. Retrieved from http://www.waste.ccacoalition.org/document/solid-waste-emissions-estimation-tool-sweet-version-20

EPA USA. (2017). LFG Energy Project Development Handbook, Chapter 1: Landfill Gas Energy Basics. Retrieved from https://www.epa.gov/sites/production/files/2016-07/documents/pdh_chapter1.pdf

European Parliament and Council. (2008). Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives. Official Journal of the European Union, 3–30. https://doi.org/2008/98/EC.; 32008L0098

Eurostat (2016). Guidance on municipal waste data collection. Retrieved September 6, 2019, from https://ec.europa.eu/eurostat/documents/342366/351811/Guidance+on+municipal+waste+reporting/0710f1a4-6b68-4d48-ac4c-75901bc0644b

Eurostat. (2018). Municipal Waste Statistics. Retrieved September 10, 2018, from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Municipal_waste_landfilled,_incinerated,_recycled_and_composted_in_the_EU-28,_1995_to_2017.png

Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz, and R. V. D. (2007). Changes in Atmospheric Constituents and in Radiative
Forcing. In and H. L. M. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor (Ed.), Climate Change 7: Physical Science Basis (pp. 129–234). Cabridge, UK and New York: Camebridge University Press. https://doi.org/10.1103/PhysRevB.77.220407

Global Methane Initiative. (2018). About Methane. Retrieved August 17, 2019, from https://www.globalmethane.org/about/methane.aspx

Governo Do Distrito Federal. (2008). Diagnóstico Do Sistema De Limpeza Urbana De Distrito Federal. Provided by SLU. Not available online.

Governo Do Distrito Federal. (2018). PDGIRS – Plano Distrital De Gestão Integrada De Resíduos Sólidos (Vol. 3). Brasilia, Brazil. Retrieved from http://www.so.df.gov.br/wp-conteudo/uploads/2017/12/MINUTA-PDGIRS.pdf

Hiriya Recycling Park. (2017a). Dan Region Association pf Towns "Hiriya" Recycling Park. Retrieved from https://www.hiriya.co.il/eng/Presentations_download?year=2017

Hiriya Recycling Park. (2017b). Hiriya Recycling Park – 2017. Retrieved from https://www.hiriya.co.il/eng/Presentations_download?year=2017

Hiriya Recycling Park. (2018a). Dan Region Association of Towns. Retrieved October 12, 2018, from https://www.hiriya.co.il/eng/Dan_Region_Association_of_Towns

Hiriya Recycling Park. (2018b). Internal Report. Not publically available.

Hiriya Recycling Park. (2018c). Operational Principles. Retrieved November 21, 2018, from https://www.hiriya.co.il/eng/Operational_Principles

Instituto de Políticas Economicas Aplicada. (2010). Pesquisa sobre Pagamento por Serviços Ambientais Urbanos para Gestão de Resíduos Sólidos. Retrieved from http://www.mma.gov.br/estruturas/253/_arquivos/estudo_do_ipea_253.pdf

IPCC. (2006). Chapter 2: Generation, Composition and Management Data. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5.

IPCC. (2007). Climate Change 2007. Working Group III: Mitigation of Climate Change. Chapter 10: Waste Management.

IPCC (2007b). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Retrieved from http://www.ipcc.ch / pdf/assessment-report/ar4/wg1/ar4_wg1_full_report.pdf

Israel Ministery of Environmental Protection. (2014). Waste Composition Survey Israel 2012-2013. Only in Hebrew. Retrieved from http://www.sviva.gov.il/InfoServices/ReservoirInfo/ResearchAndPublications/Pages/Publications/P0701-P0800/P0749.aspx

Israel Ministery of Environmental Protection. (2018). Waste: Facts and Figures. Retrieved August 22, 2018, from http://www.sviva.gov.il/English/env_topics/Solid_Waste/FactsAndFigures/Pages/default.aspx

ISWA. (2009). Waste and Climate Change. ISWA White Paper. Retrieved from https://www.iswa.org/home/news/news-detail/browse/40/article/iswa-white-paper-on-waste-and-climate-change-released/109/terms-and-conditions/

ISWA. (2015). Wasted Health - The Tragic Case of Dumpsites. https://doi.org/10.1007/s13398-014-0173-7.2

ISWA. (2016). A Roadmap for closing Waste Dumpsites. International Sollid Waste Association. Retrieved from https://www.iswa.org/fileadmin/galleries/About ISWA/ISWA_Roadmap_Report.pdf

ISWA. (2017). First Taste of Success for ISWA's Close the Dumpsites Campaign. Retrieved September 17, 2018, from https://waste-management-world.com/a/first-taste-of-wwsuccess-for-iswas-close-the-dumpsites-campaign

Kaza, S.; Yao, L. C.; Bhada-Tata, P.; Van Woerden, F. (2018). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development;. Washington, DC: World Bank.

Retrieved from: https://openknowledge.worldbank.org/handle/10986/30317

Lamport, C. (2000). Waste Management in Austria, GHG Mitigation effects of the landfill regulation. Workshop on Best Practices in Policies and Measures. Retrieved from https://unfccc.int/files/meetings/workshops/other_meetings/application/pdf/aut.pdf

MA48. (2013a). Collection of Residual Waste, Recyclables & Hazardous Waste from Households. Retrieved from https://www.wien.gv.at/umwelt/ma48/service/publikationen/pdf/sammlung-abfaelle-altstoffe-en.pdf

MA48. (2013b). Waste Management in Vienna. Retrieved from https://www.wien.gv.at/umwelt/ma48/service/publikationen/pdf/abfallwirtschaft-en.pdf

MA22. (2018). Initiative "natürlich weniger Mist" – Projekte zur Abfallvermeidung. Retrieved December 21, 2018, from https://www.wien.gv.at/umwelt/ma48/beratung/abfallvermeidung/

Ma48. (1994). MSW Composition 1993/1994. Not publically available.

Ma48. (1998). MSW Composition 1997. Not publically available.

MA48. (2004). MSW Composition 2003/2004. Not publically available.

MA48. (2007). Landfill Site Rautenweg. Retrieved from https://www.wien.gv.at/umwelt/ma48/service/publikationen/pdf/deponie-rautenweg-en.pdf

MA48. (2013). Waste to Energy – Treatment of Residual Waste. Municipal Department 48 - Waste Management, Street Cleaning and Vehicle Fleet. Retrieved from https://www.wien.gv.at/umwelt/ma48/service/publikationen/pdf/waste-to-energy-en.pdf

MA48. (2018a). 48er Tandler. Wiener Altwarenmarkt. Retrieved October 27, 2018, from https://48ertandler.wien.gv.at/site/

MA48. (2018b). Abfallvermeidung. Retrieved December 21, 2018, from https://www.wien.gv.at/umwelt/ma48/beratung/abfallvermeidung/

MA48. (2018c). Internal report. Not publically available.

MA48. (2018d). MSW Composition 2015. Not publically available.

Majdinasab, A., Zhang, Z., & Yuan, Q. (2017). Modelling of landfill gas generation: a review. Reviews in Environmental Science and Biotechnology, 16(2), 361–380. https://doi.org/10.1007/s11157-017-9425-2

Ministério do Meio Ambiente. Law 12,305, of 2 august 2010. Unofficial Translation. (2010). Brazil.

Ministry of Environmental Protection Israel. (2014). Landfilling Policies: Past and Present. Retrieved November 20, 2018, from http://archive.sviva.gov.il/English/env_topics/Solid_Waste/landfilling/Pages/Landfilling-Policies-Past-and-Present.aspx

Ministry of Environmental Protection Israel. (2017). Maintenance of Cleanliness Fund. Retrieved November 2 0, 2018, from http://archive.sviva.gov.il/English/env_topics/Solid_Waste/PlanningAndPolicy/Pages/Maintenance-of-Cleanliness-Fund.aspx

Saveyn, H., Eder, P., Ramsay, M., Thonier, G., Warren, K., Hestin, M. (2016). Towards a better exploitation of the technical potential of waste-to-energy. EUR 28230 EN. DOI:10.2791/870953

SLU. (2016). Relatório Da Análise Gravimétrica Dos Resíduos Sólidos Urbanos Do Distrito Federal 2015. Provided by SLU. Not available online.

SLU. (2017). Um ano de operação do Aterro Sanitário e tudo pronto para fechar o lixão. Realtório e atividades 2017. Brasilia, Brazil. Retrieved from http://www.slu.df.gov.br/wp-content/uploads/2018/05/relatorio_anual_de_atividades_slu_2017_final.pdf

SLU. (2018a). Data on mass balances of MSW management in the Federal District 1970-2016. Data provided by SLU (Serviço de Limpeza Urbana do Distrito Federal). Not publically available. Brasília, Brazil.

SLU. (2018b). Um ano de operação do Aterro Sanitário e tudo pronto para fechar o lixão. Realtório e atividades 2018. Brasilia, Brazil. Internal Document, not yet published.

UNEP. (2012). Waste and Climate Change. Global Trends and Strategy Framework. Retrieved from https://www.un-ilibrary.org/environment-and-climate-change/global-waste-m anagement-outlook_765baec0-en

UNEP, & ISWA. (2015). Global Waste Management Outlook. Retrieved from https://www.un-ilibrary.org/environment-and-climate-change/global-waste-management-outlook_765baec0-en

Wien Energie. (2018). Müllverbrennungsanlagen. Retrieved November 20, 2018, from https://www.wienenergie.at/eportal3/ep/channelView.do/pageTypeId/67831/channelId/-49065

Wikipedia. (2018). Federal District (Brazil).

Wilson, D. C., Velis, C., & Cheeseman, C. (2006). Role of informal sector recycling in waste management in developing countries. Habitat International, 30(4), 797–808. https://doi.org/10.1016/j.habitatint.2005.09.005

10 APPENDICES

10.1 List of Tables

10 APPENDICES

10.1 List of Tables (Continued)

10.2 List of Figures

A Global Initiative by

ISWA
International Solid Waste Association

www.iswa.org / iswa@iswa.org