LIFE CYCLE ASSESSMENT OF MUNICIPAL SOLID WASTE MANAGEMENT IN NORTH CYPRUS

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ABSTRACT

LIFE CYCLE ASSESSMENT OF MUNICIPAL SOLID WASTE MANAGEMENT IN NORTH CYPRUS

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Integrated solid waste management (ISWM) is used in order to sustain social and environmental quality within a city by using various treatment methods in parallel. On the other hand, in developing countries, solid waste management is one of the biggest challenges in the large cities. The increase in the population, thus the waste generation arises budget deficits for municipalities due to high management costs. The current waste disposal and management method applied in North Cyprus causes pollution to the nature including air, soil, and water due to insufficient leachate and landfill gas management. The purpose of this study is to indicate the optimal solid waste management option for North Cyprus. Local solid waste characteristics data is used to create a data-set that is used for the evaluation. To measure the environmental impacts, life cycle assessment method is used over the current landfilling as well as four other possible solid waste management scenarios. The scenarios comprise of various combinations of different management options. As a result, due to highest proportion of recyclable waste followed by organic waste, the results indicate that applying composting facility together with material recovery facility additional to landfilling demonstrates lower environmental impacts over a long-term period.

Keywords: Life Cycle Assessment, Integrated Solid Waste Management, North Cyprus.

ÖZ

KUZEY KIBRISTA KATI ATIK YÖNETİMİNİN YAŞAM DÖNGÜSÜ DEĞERLENDİRMESİ

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Yüksek Lisans, Sürdürülebilir Çevre ve Enerji Sistemleri
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Entegre Katı Atık Yönetimi, gelişmiş ülkelerde farklı atık yöntemlerini birlikte kullanarak, şehirlerde çevresel ve sosyal kaliteyi sağlamaktadır. Öte yandan gelişmekte olan ülkelerdeki büyük şehirlerde katı atık yönetimi en büyük sorunlardan biridir. Artan nüfus ile birlikte artan atıklar, katı atık yönetim maliyetlerini artırmakta ve belediyelerde finansal sıkıntılara yol açmaktadır. Kuzey Kıbrıs'taki mevcut katı atıklar ve katı atık yönetimi, suya, havaya ve toprağa verdiği zararlarla çevre kirliliğine yol açmaktadır. Bu çalışmanın amacı Kuzey Kıbrıs için en uygun katı atık yönetimini belirlemektir. Değerlendirmede kullanmak üzere veri tabanı oluşumunda yerel katı atık karakteristik verileri kullanılmıştır. Çevresel etkileri ölçebilmek için mevcut katı atık gömme sistemine ve olası dört alternatif katı atık yönetim senaryosuna yaşam döngüsü analiz metodu uygulanmıştır. Senaryolar farklı yönetim metodlarının çeşitli kombinasyonlarından oluşmaktadır. Sonuç olarak, en yüksek oranla geridönüşebilir atıklar ve arkasından organik atıkların mevcudiyeti nedeniyle, gömme metoduna ek olarak kompostlama ve geri dönüşüm tesislerinin uygulanması uzun dönemde en az çevresel etki göstermiştir.

Anahtar Kelimeler: Yaşam Döngüsü Değerlendirme, Entegre Katı Atık Yönetimi, Kuzey Kıbrıs.

I dedicate this work to future environmentalist work for North Cyprus

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LIST OF ABBREVIATIONS

CFC – Chlorofluorocarbons

E-waste – Electronic Waste

FAETP inf. – Freshwater Aquatic Eco-toxicity Potential

FU – Functional Unit

GWP – Global Warming Potential

HTP – Human Toxicity Potential

ILCD – International Life Cycle Data

ISWM – Integrated Solid Waste Management

Kg – kilograms

LCA – Life Cycle Assessment

LCIA – Life Cycle Impact Assessment

LCI – Life Cycle Inventory

LFG – Landfill Gas

MAETP – Marine Aquatic Eco-toxicity Potential

MRF – Materials Recovery Facility

MSW – Municipal Solid Waste

ODP – Ozone Layer Depletion Potential

Pp – per person

SWM – Solid Waste Management

TETP – Terrestrial Eco Toxicity Potential

VOC – Volatile Organic Compounds

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CHAPTER 1

INTRODUCTION

1.1 Urbanization and Challenges for Sustainability

Urban living has brought development for civilizations from social to business aspects. By the start of the 21^{st} Century, people were socializing that cities emerged as the source of the global challenges that countries face today. Urbanizing has become humanity's engines of wealth, power, creativity, development, and economic growth as well as social improvement and activities. Yet it has created further problems such as pollution and disease. Today, more than half of the world population lives in cities which appears to be 80% for developed countries and this rate is expected to be global by 2050. Rapid urbanization has even led to global sustainability problems not only climate change but food crisis, energy and water consumption, social health, finance, and economy (Schellnhuber, et al., 2010; United Nations Human Settlements Programme, 2011). Temperature rise is one of the main causes of climate change. Urban living conditions have proven to be in relation with temperature rises due to intense greenhouse gas emissions especially when there is an unsustainable city planning (Maheshwaria, et al., 2020). An analysis of 174 countries for almost 55 year period from 1960 to 2014 show that there is a persistent increase in average global temperature by 0.04°C per year (Kahn, et al., 2021). Severe weather events, wildfires, rise of water levels, and seasonal changes are some of the effects of the temperature rise. Agricultural activities are mostly affected by these events causing food crisis and water demand.

In most countries, municipalities are responsible of the policies to provide, manage, and maintain what urban living requires of public needs. Public transport, health services, energy, and water supplies as well as city cleaning and waste management are those of the biggest challenges for sustainability. This is because population growth and technology development rates present dramatic increase which becomes challenging to meet the demand and supply along the line (Messinger, 2012).

1.2 Global Issue of Massive Consumption and Solid Waste

There is correlation with the population growth and the increase in consumption levels when compared throughout the years. Nowadays, people are more eligible to reach and find out their needed products to buy either online or from the store. Hence with the population increase, the consumer number is higher which is increasing the production rates of materials and products to meet the demand. Worldwide brands are a good example, since their excessive production levels reduce the cost of product causing higher consumption which leads to unsustainable consumption and accumulation of waste (Linn, 2018). Cities in developing countries, in particular the waste produced is overwhelming local authorities as accumulations of waste exceed its control due to increased consuming (Tacoli, 2012).

This increase leads to the most common major environmental problem of sustainability for municipalities around the globe which is managing solid waste disposal. Not only it is a complex system, but it also requires significant economic activity from collection to disposal. Looking at the World Bank Statistics in 2016, there were 2.01 billion tonnes of solid waste generated around the globe, creating a footprint of 0.74 kg per person per day. With the expected statistical rate of population and urbanization growth, annual waste generation is predicted to increase by 70% from 2016 levels to 3.40 billion tonnes in 2050 (Kaza, et al., 2018).

1.3 Solid Waste Management Solutions

Countries are cooperating to adopt new environmental policies, principals, and law aiming producers and consumers in order to reduce environmental impacts of solid waste. Extended Producers Responsibility (EPR) is one of the greatest examples of policies which require the producer and seller to be responsible to pay for the costs of their product's environmental footprint and impacts (EPR Policies and Product Design, 2006). The actual aim of this act is to create an awareness to reduce the amount of material being used at production and the product to become recyclable and reusable. Another recent example act is banning single use plastics and charging extra for plastic bags at markets and shops (Wagner, 2017). As of 2018, a new legislation was brought in North Cyprus to charge plastic bags extra at stores and marketplaces.

Although, encouraging consumers and producers for sustainable circulation makes a difference on waste levels, it does not demonstrate enough reduction rates when compared to the growth rate. The most important act of handling the excessive waste of a city in most sustainable way is applying a solid waste management system by the authorities in charge which are mostly municipalities (EC-European Green Capital Agenda 21, 2021). Different types of solid waste treatment methods are developed and adopted around the world depending on the local municipal solid waste (MSW) characteristics. More than one treatment method can be applied as an integrated system depending on the characteristic percentages of the solid waste. With the integrated system the solid waste is separated according to its characteristics and treated for a beneficiary output as energy and raw material. Integrated Solid Waste Management (ISWM) not only helps to maintain the municipal solid waste disposal but also give waste a value as a resource (Gregson & Crang, 2015). Countries around the world or municipalities have started to trade solid waste that cannot be treated at their system. This creates global harvesting for municipal solid waste which becomes a useful resource for another country.

1.4 Municipal Solid Waste Problem in North Cyprus

Turkish Republic of North Cyprus is a developing country with political restrictions, lack of economy and financing, and limited area capacity due to being a half island country. Hence, municipal solid waste management is extra challenging when compared with other developing countries. Current methods used are not too sustainable since to a large extent only collection and landfilling or dumping are used. There is a small percentage of material sorting and different treatment methods such as recycling are being applied (KKTC Enformasyon Dairesi, 2019). Details of the current management system are discussed further in Chapter 4.

This situation creates negative environmental impacts due to waste water leakage to soil and groundwater resources, emission of dangerous chemical gases in the city atmosphere, and bad smell that increases with hot weather. Other than environmental impacts these aspects also affect directly the human health and social quality in the city as well as wild animals being eligible to reach out the open dumping facilities.

Considering the island being located in the Mediterranean, is very valuable in tourism aspect. Many tourists visit the country each year for historical remains, beautiful coasts and beaches as well as nature. Hence, there is large number of hotels and establishments available around the country. This also contributes to the amount of municipal solid waste and continuing with the current unsustainable waste treatment plan, North Cyprus might not be as attractive to tourists in future.

Lastly, landscape is limited within the island and with the growing population the current landfill facility is not a sustainable plan for the future. To maintain the waste management operations new sites are going to be needed endlessly. New approaches are required to be adopted to prevent unnecessary occupation of land and instead use for a better demand.

1.5 Goal and Scope of the Study

The aim of this study is to improve the current solid waste treatment system so that it can be operated in sustainable manners. In this regard, the main objective is to design the most effective and efficient Integrated Solid Waste Management System Plan suitable to municipal solid waste characteristics of North Cyprus.

To achieve the study objective, the performances of five different waste management scenarios having a grouping of different waste treatment methods are compared by using Life Cycle Assessment (LCA) Method. OpenLCA software is used as the LCA tool together with Ecoinvent Database. Scenario 1 (S1) focuses on the real-life situation and waste is fully landfilled at the only current Sanitary Landfill facility. Scenario 2 (S2) is an alternative to S1, where Incineration Facility is functioning parallel with the Landfill and waste is equally managed at each. Scenario 3 (S3) involves Material Recovery Facility (MRF) additional to the S2 where recyclables are processed and other waste moves on to Landfilling and Incineration, and Scenario 4 (S4) involves, MRF for recyclables, Composting Facilities which processes organic and bio-waste material, and Sanitary Landfilling for the rest of the solid waste. Lastly, Scenario 5 (S5) comprehends all facilities to function together such that waste categories are treated at the related facility accordingly. This method will help to one who wants to obtain long term detailed environmental footprint of each method when local municipal solid waste characteristics are applied.

The implementation of Integrated Solid Waste Management System in North Cyprus, will be a sustainable practice because the redundant expenses and unplanned area occupation would be avoided as well as the adverse environmental impacts would be reduced.

This study also aims to provide a comprehensive knowledge base for future applications and other research projects about solid waste management in North Cyprus to be undertaken by the Environment Protection Agency. Ultimately, with the results of this study, not only the current system will be evaluated but also which alternative integrated waste management options are suitable to the waste characteristics would be determined. LCA methodology also brings a new fundamental point of view for research work in the area.

1.6 Organization of the Thesis

The thesis continues with Chapter 2 which is the literature review, the background and history of Life Cycle Assessment (LCA) are given in this chapter. After a brief information about early uses and the path of standardisation, some previous research studies that are found to be similar and found to have common purposes are described in detail.

After the investigation of literature, solid waste management (SWM) and Integrated systems are discussed and processes are explained in detail in Chapter 3. The solid waste management methods that are going to be used in this study are explained briefly.

In Chapter 4, current phase of North Cyprus solid waste management is defined. The difficulties and the problems with the current management system are investigated. Unaccomplished projects and future plans are also shared in this chapter.

The method to use Life Cycle Assessment is explained in Chapter 5. Assessment steps start with Goal and Scope definition, subsequently explaining Inventory Analysis and Life Cycle Impact Assessment. Lastly, the assumptions and data obtained in order to be used for the calculations are also demonstrated and explained.

The thesis follows up by results and discussion chapter which is the chapter where results of 11 impact categories are shared by graphs that compares 5 different scenarios. For each category results are analysed carefully and comparative comments are done by the help of graphs. At the end of the chapter sensitivity analysis is carried by checking the results by another impact assessment method.

Chapter 7 is the interpretation and conclusion chapter. A brief summary of the study is given. The contributions to the subject area are referred and recommendations for future works are also shared in this chapter.

CHAPTER 2

LITERATURE REVIEW

During 1960s and early 1970s environmental pollution awareness has started then followed by energy and material scarcity crisis. Rapid increase in energy costs has led companies to seek for energy saving ways. At the same time, customers were also demanding for energy efficient products. Hence, a motivation for environmental profiling of products has emerged. Companies mostly related with production or use of packaging have started to analyse life cycle footprint of products from production to dispose. Some government agents were also interested in such analysis, however, it was found to be impractical since it required thousands of runs on different products (EPA, 1974). Thus initiation for the first life cycle inventories and assessments have begun. For the upcoming years, many researches were performed subjecting problematic projects at the time. For some years, focus was on solid waste generation and management specially in US where landfilling was the widely used disposal method and new practices were needed for sustainability and energy consumptions. Many of these studies have created life cycle inventory of product systems and development both in methodology and applications of LCA by late 1980s (ICCA, 2016). Creating the inventories has helped to form kind of a list of resource uses and relative emissions throughout a process. For assessing a product, a set of indicator scores were calculated which are associated to a number of impact categories such as climate change, toxicity, resource depletion, and acidification.

By the year 1990, many impact methods were developed, however, the first impact assessment methodology to quantify all relevant environmental impacts covering a broad set of midpoint impact categories was CML 92 released at Leiden University Netherlands in 1992 (Heijungs, et al., 1992). Another approach example developed for impact assessment methodology is the Swedish EPS method which focuses on the damages to the environment and human health rather than midpoint impacts (Steen, 1999a,b).

The main difference between endpoint and midpoint LCA assessment is that in endpoint approach, different environmental impact results are ultimately end up into general impacts on human health, ecosystem quality and resource depletion. To demonstrate an example, processes may have impact on different categories as depletion of fossil fuels and acidification both contributing to the final endpoint human health and ecosystem quality. Hence, the endpoint results of each category may cancel out each other. On the other hand, midpoint approach creates more complex accounting and impact results are in detail, which implicates the differences clearly between the impacts of process in impact categories. Therefore, statistical uncertainty rates are lower (Hauschild & Huijbregts, 2015).

Further in 1990 stages of the LCA were acknowledged by the Society of Environmental Toxicology and Chemistry (SETAC). Lastly, a few years later identifying the stages of LCA, Goal and Scope stage was added as the first step. Later in the following years institutions and organisations had started to create inventory databases for varied industrial sectors and vast amount of product systems. However, each database followed their own research background differing the standards and quality of a process. The lack of standards and quality could lead to have opposite results on different studies of the same product or process. After the acknowledgement of the SETAC code of practice, International Organization of Standardization (ISO) has initiated a global standardisation for LCA depending on the previous researches and studies. ISO 14040 is released to understand the principles and the framework followed by ISO 14041 the goal and scope definition, ISO 14042 life cycle impact assessment and finally ISO 14043 life cycle interpretation. A final update for the three was released in 2006 as ISO 14044 as standard detailing, requirements and guidelines. Hence, ISO 14040 series concern the LCA methodology (ISO, 2006b).

Aiming for consistent data standards and quality, ecoinvent database (v 1.01) was released which also covered all industrial sectors in 2003 (ecoinvent, 2022) . At the same year, European Comission (EC) has introduced Integrated Product Policy (IPP) which mentions LCA as the best framework to assess a products life cycle and understand the potential pollution effects. However, the lack of consistent data and the need for a harmony in methodology was also declared. Further in the year 2008, LCA has played a big role for policy support, since the EC has introduced its Sustainable Consumption and Production and Sustainable Industrial Policy (SCP/SIP) Action Plan, incorporating the previous IPP, LCA is stated as the analytical key framework for waste and resource strategies. Later in the following years, need for a strong methodological basis to ensure consistent and reliable results from different studies increasing the comparability is determined by EC. This has led for their next step which has been developing an International Life Cycle Data System (ILCD) involving life cycle inventory data and methodological guidelines. All the guidelines developed by EU Comission’s Joint Research Centre’s (JRC) Institute for Environment and Sustainability are referring from the ISO 14040 and ISO 14044 series (EC-JRC, 2010).

Other than guidelines and standardations softwares are also developed as LCA tools. Impact assessment methods are implemented in the software together with inventory inputs and outputs to the process and the software applies all the calculations automatically creating an end report for the user. Database systems are updated each year to be implemented in the LCA tool with all processes. Ecoinvent database is currently updated to ecoinvent (V. 3.8) in 2022 (ecoinvent, 2022)

To understand the overall applications of LCA, a survey took place in 2006 finding that LCA was used in business strategies, research, development, and design of a product or process and also education and policy development were amongst common applications (Cooper & Fava, 2006).

There are many previous studies involving life cycle assessment method to measure and compare the sustainability level within different waste disposing methods. Studies vary depending on their local waste characteristics and goals. For instance, a study took place back in 2003 to compare composting, biogasification and landfilling for 1 ton of municipal solid waste in Sao Paulo, Brazil (Mendes, et al., 2003) where another study took place in Singapore to compare various waste conversion technologies which are waste to energy systems measuring 1 ton of gas produced from the waste assortment (Khoo, 2009). These disposal options are considered depending on the waste characteristics which determines the volume and the composition of waste types of each area.

A study that was carried out in Asturias, Spain (Nava, et al., 2014) where six different solid waste management scenarios were applied and compared according to effects on Human Health, Ecosystem Quality, Global Warming, and Resource Depletion. The researchers used SimaPro7.1.8 software for the Life Cycle Assessment and for the environmental loads that are linked to materials, transport, and employed energy. Ecoinvent v2.0 (2007) database was used in that study. From the results of the study, it is presented that for Asturias transportation of waste has a significant impact to environment. Among the all scenarios, S-3 which includes, bio-methanisation of organic fraction on source, sorting of mixed fraction and incineration of rejected fraction, showed least impact on analysed impact categories. The scenarios that include landfilling presented higher impact to all environmental categories and incineration increases the effects of the scenarios on Human Health and Climate Change (Nava, et al., 2014).

A similar case study (Erses Yay, 2015), which aims to determine a less environmentally damaging municipal solid waste disposal method when compared to the current system was applied for Sakarya, Turkey. Through the research LCA is used as a management planning tool applied on five different scenarios which alternate the current system. The scenarios include first as landfilling without any gas recovery, second to be material recovery and landfilling, third scenario is material recovery, composting, and landfilling followed by the fourth scenario involving incineration and landfilling and finally material recovery, incineration, composting, and landfilling. The study area characteristics are described in detail as well as waste characteristics. SimaPro 8.0.2 software is used for LCA calculation of each scenario with CML-IA impact method. As a result of the study, since the highest proportion of waste characterisation appeared to be kitchen-waste, composting process was determined to be the ideal method for disposal along with landfilling. Although Scenario-5 with all the disposal methods accounted results in the most environmentally benefitting scenario, it is estimated that it's not economically sustainable at the same time due to high investment and operation costs in short term (Erses Yay, 2015).

Another study (Maalouf & El-Fadel, 2019) took place in Lebanon to identify solid waste disposal alternatives of integrated systems with minimum environmental impacts and reduced emission. The test area serves for 297 municipalities of around 3,000 tonnes of MSW. The functional unit of the study which is also the reference flow of the analysis is selected as 1 tonne of waste generated in the area. Various scenarios were created being total of five scenarios similar to Sakarya case study. Emissions to the environment, economic implications and carbon credit are evaluated in order to compare the alternative solid waste management systems. LCA EASETECH software is used as LCA tool which is tailored to reflect the test area specifications and characteristics. Impact assessment is run using the European Comission – JRC 2011 impact assessment method. Impact categories involved Climate Change, Global Warming Potential for 100 years, Photochemical Oxidant Formation, Stratospheric Ozone Depletion, Acidification, Freshwater Eutrophication, Marine Eutrophication, and Depletion of Abiotic Resources. The study has also conducted economic analysis on each scenario to evaluate in terms of sustainability. It is concluded that the highest environmental impact is seen on scenarios involving landfilling and small amount of material and energy recovery. Further, environmental benefits are achieved in association with maximized recycling and composting which also results in 98% cost savings in emission (Maalouf & El-Fadel, 2019).

Mumbai, India is another example city that is facing challenges for municipal solid waste management due to rapid population growth and economic development (Mehta, et al., 2018). Total waste generation in India is projected to be 165 million tonnes by 2031. Currently, only 70-80% is being collected and 28% is processed by the municipalities. Remaining is being dumped without any control which creates an unhealthy habitat for the environement and the population. Unlike other researches, instead of alternative methods in each scenario, the study mostly focuses on landfilling. This is because it is determined that the country already has economic issues, and high costing implementations would be unrealistic. The need for landfill is obvious and the study is aimed to analyse and understand the benefit level of each variation. The scenarios involve open dumping; sanitary landfill with landfill gas (LFG) collection and flaring; sanitary landfill with LFG collection, flaring and leachate (LT) treatment; composting and sanitary landfilling with leachate treatment. The open source OpenLCA 1.5.0 is used to evaluate each scenario on life cycle perspective. Impact assessment method ILCD 2011 (midpoint) is available with the program and used for this reseach. For LFG generation predictions a further software is used called LandGEM. An importance of LFG recovery and leachate treatment on landfill facilities is determined from the impact assessment results. It is also understood that the fourth scenario comprising of composting and landfilling demonstrates the least results on environmental impacts (Mehta, et al., 2018).

Life cycle assessment can also be used to measure and evaluate the performance of the current state. A study in Romania (Popita, et al., 2017) uses LCA to understand the environmental performance of municipal solid waste management systems in Cluj County. Alternative scenarios to the actual system is created involving different methods of treatment. GaBi software is used for the life cycle asssessment and CML 2001 method is used for Impact Assessment. Scenario-4 which consists of incineration and landfill as final treatment after composting and recycling is fond to be the optimal integrated system for waste disposal in terms of benefitting the environment. Economic factors are not accounted in this study to finalise the sustainability of the scenario (Popita, et al., 2017).

Key information obtained from the previous research which are used as directors for this study are summarised and presented in Table 2.1.

Table 2.1 Literature Review key information summary table

LCA PHASES	LEBANON [1]	INDIA [2]	ROMANIA [3]	TURKEY [4]
Goal	To identify integrated systems with minimal waste associated impacts and reduced emissions.	To assess the relative costs and the environmental and health benefits of alternative MSWM methods	To evaluate the environmental performance of MSWM systems as desicion-support method.	To determine the environmental aspects of a less impactful MSWM system.
System Boundaries	emissions to the environment, economic implications, carbon credit, social health issues			
Parameters & Impacts	collection and disposal methods, sampling and sorting methods, alternative scenarios (4-5), location of the facility, seasonal change, social-economic status			
Functional Unit	1 ton of waste, waste generated at the area			
Softwares Used	EASETECH	OpenLCA	• GaBi4 • European Database included	SimaPro 8.0.2
Inventory Data	Data from EASETECH	Data from OpenLCA	Regional Environmental Protection Agency Data from software	waste characterization study report of Sakarya
IA-Method	European Comission JRC 2011	ILCD 2011 (Midpoint)	CML – IA 2001 Method	• CML- IA 2015 • ReCipe Midpoint (H) V1.04

[1] (Maalouf & El-Fadel, 2019), [2] (Mehta, et al., 2018), [3] (Popita, et al., 2017), [4] (Erses Yay, 2015)

The waste composition is seen to be dependent on consumption and living habits which are driven from traditional and national cultures. Not only the geographic location of the country affects the type of waste, income level per capita also has linear relationship with waste generation rate and the type of the waste. In developing countries, where average income level per capita is less than developed countries, it could be seen that the highest proportion of waste type is bio-waste or kitchen waste (Han, et al., 2018). This is because cities are not fully developed and houses with gardens are more likely to see around the city more than appartments and common living complexes. Therefore, engagement with agricultural activities and availability of farm to city products are higher. In Sakarya (Erses Yay, 2015) and India (Mehta, et al., 2018) studies, it is seen that scenarios involving composting facility is the ideal waste management discipline. This is mostly because kitchen or organic waste constitutes the highest proportion percentage of the overall waste volume. Home cooking culture is also an important factor of kitchen waste. In both countries, cooking is mostly done by the households and there is less availability of buying ready cooked meals. Consequently, life cycle assessment results in composting as the best option for both studies. Similar result situation can be seen for different waste types being higher proportioned.

North Cyprus and Turkish cultures are very similar in consumption perspective, also considering the Mediterranean culture, home cooking is one of the dignified characteristics of the society (Gronau, 2010) . Therefore, a high rate of bio-waste is expected for North Cyprus waste characteristics. Hence, understanding the waste characteristics is the vital step for an optimal solid waste management system.

CHAPTER 3

SOLID WASTE MANAGEMENT

3.1 Municipal Solid Waste

City beauty, land occupation, environmental pollution, social health, and economic considerations make proper solid waste management an ongoing concern that must be taken seriously by all. Indiscriminate dumping of solid waste and inefficient collection system in a populated community would arise many complications. Open municipal solid waste dumps have adverse effects on ecology; previous research has monitored the bio-thermal influence and they have proved that the biological and chemical degradation of dumped waste resulted bio-thermal hazardous influence zones by the effect of thermal radiations (Mahmood, et al., 2022). Hazardous impacts on soil and vegetation of dumped area was also studied by scientists, it is presented that the soil at a dump site showed extremely high pH, TDS and EC regime with a high level of heavy metal contents (Syeda Maria Ali, 2014).Damages to human health from open dumping sites are also proved. People who exposed to an open dump area found to be significantly higher to have respiratory illness and eye infection (Singh, et al., 2021). Dirt, odours, flies, rats, stray animals, and fires are some other examples of consequences to imply the importance of proper solid waste management (Tchobanoglous, 2003).

Authorities in charge of taking care of a community's garbage has to carefully design, locate, and plan from collection to the end of lifecycle of solid waste to be managed sustainably. Hence, to begin with, understanding the characteristics of the waste is important.

3.1.1 Sources and Characteristics

Sources and characteristics of municipal solid waste is important to design the management plan and to determine the types of collection service, vehicles, equipment, processing facilities, and disposal methods to be used.

MSW can be categorized depending on generation source as first and the main being residential, followed by commercial, then institutional, and finally light industry. The source of waste generation determines the characteristics of waste.

Waste characteristics indicate the physical and chemical waste composition, quantities and weight. The time of the year, educational level, economic status, culture, and habits of the community are some of the important factors which causes variance in composition. Also, the type of commercial and industrial operations being involved within the community are important to understand the characteristics. The inventory data for LCA on municipal solid waste requires the characteristics and processes being involved (EPA, 1999).

Table 3.1 summarizes the sources and typical facilities or locations where waste is generated (Tchobanoglous, 2003).

Table 3.1 Sources of Municipal Solid Waste (Tchobanoglous, 2003)

SOURCE OF MUNICIPAL SOLID WASTE	TYPES OF SOLID WASTES
Residential (Households)	Food and Kitchen Waste, plastic/cardboard food containers and packaging, textile, leather, wood, glass, aluminium, cans and bottles, paper, garden waste, e-waste, furniture waste...
Commercial (stores, restaurants, office, market, service shops and stations)	Box and Container types, paper, cardboard, plastics, food waste, wood, glass, metal wastes, ashes, construction waste, public waste
Institutional (Governmental centres, Hospitals, Schools, Prisons)	
Industrial (non-process wastes, Manufacturing, Construction, Refineries)	
City Centre (Municipal Services, cleaning, landscaping, parks and beaches, drainage and road)	

3.2 Management Flow and Disciplines

Some of the concerns to account while planning, starts from waste generation including source reduction, on-site storage, collection and waste transfer to transfer stations, resource recovery or waste treatment/processing facilities which then involves controlling and maintaining water drainage systems, landscaping, odour, dust, litter, and noise control within the city for sustainability (Tanskanen, 2000). These are discussed in detail in the following sub-sections.

3.2.1 On-Site Handling, Storage and Collection

The key functional element is waste storage because collection does not happen at the time that waste is generated. Depending on the location, the waste might be held for several days before collection. Hence onsite handling and storage requires suitable containers or dustbins depending on the source quantity and waste characteristics considering aesthetics, public health, and economics. For instance, the sizes requirement of containers would differ if it’s a single household or an apartment, also between a small business and a large institution (EPA, 1995).

Separation at the source is found to be much easier and it costs less when compared to separating at the transfer station or the facility itself. In most of the developed cities, materials that are plastic, paper, glass, metal, and even e-waste is required to be separated and thrown to a different specific provided container (Zhuang Song, et al., 2008).

Collection phase involves gathering, hauling, and unloading the waste to a transfer station or a treatment facility. Planning and scheduling waste collection services involves identifying the waste quantity, storage types, whether the waste is separated at the source, and the time of the year.

Source separation requires different collection service then generic. The collection vehicle for each material must be different in order to sustain the separated process.

Collection of all recyclable waste together and sorting them in the material recovery facility is called Single Stream Recycling (SSR). In the past decade, SSR has grown rapidly and spread all over the world. The benefits of SSR can be listed as; low collection costs, easy for the participants no need to separate recyclables at the source (Lakhan, 2015). SSR comes more attractive for the communities due to the elimination of sorting process at the individual level. However, the system has some disadvantages like decrease in the quality of sorted plastic and paper due to the contamination in the mixed collection container. The savings from collection phase may be eliminated from the quality loss, which results in a decrease in the recycling rate (Haluk Damgacioglu, 2016).

3.2.2 Transfer and Transport

Transfer of waste to processing facilities are conducted by trucks. Each city has scheduling and routing for the vehicles to pass through the waste containers with determined frequency.

Growing and developed cities tend to locate treatment facilities at the outer edge of the city to increase living standards of residents. Though, the cost of transporting waste to a treatment plant has increased together with the distance. Transfer stations are constructed as an intermediate station where solid waste is shifted from smaller vehicles to a larger to convey the most at once to the facility. Moreover, if the waste is not source separated, it is segregated at the transfer station then transferred to the treatment station improving transportation efficiency (Phelps, et al., 1995).

3.2.3 Waste Reduction and Materials Recovery

The literature states that Reduction, Recovery, and Recycling should be accounted in every solid waste management system to reduce overall costs and increase benefits.

SWM process starts with prevention and reduction incentives before the generation of solid wastes. The aim is to prolong the lifetime of products and dispose of with environment friendly manner.

Waste reduction starts from the production phase of materials and products. Reduction in the material itself, process and packaging, is seen to contribute in declining the quantity of the final disposal.

Materials recovery is mainly obtained by reclaiming at specific locations depending on available tax policies and public interests.

Recycling process is after the use of the product to reincorporate the product as raw material back to production. Widely recycled materials consist of paper, plastic, glass, metal, and electronic waste (e-waste). Recycling also benefits space recovery for landfill and similar processes involving waste handling and storage. There are various material recovery facilities depending on the waste type to recover and technology. For example, to sort and recover paper and plastic different methods and operation are used for each waste category (Tchobanoglous, 2003).

3.2.4 Composting

Composting is amongst the important key factors of sustainable waste management. It can be named under MRF methods since this process has vital role of waste reduction and recovery. It is mostly applied to garden waste and organic non-processed or semi-processed kitchen waste.

Uses of compost vary depending on the waste composition. It is a biological process that derives the output product as biologically stable end product that can be applied on agriculture and landscaping public areas as well as cover material for landfill or fuel.

Presence of pathogens, heavy metals, and odour production depending on organic acids has become a problem in composting facilities. Hence, in order to achieve optimum compost quality, pathogen and odour control are most important stages of the composting process. Otherwise, toxicity and health matters would arise within the community causing composting to not be a sustainable method for future (Tchobanoglous, 2003).

3.2.5 Sanitary Landfill Plant

A sanitary landfill plant should meet the necessity of sustainability with its planning and design. Hence, gas recovery, leachate collection, and treatment system together with groundwater pollution prevention must be addressed at the facility operations. There are different methods of operating, however, all must meet the regulatory necessities as mentioned for a sustainable system.

One of the most common issues faced by applying landfilling is the leachate generation, control, and treatment. There are several applications to prevent groundwater pollution from leachate. However, it can never be minimized to 0%. In fact, the leachate is found to be useful for biodegradation and stabilization of the organic matter in a landfill. Hence the leachate is collected and recirculated with added nutrients to maintain desired moisture, pH, and organic biodegradation (Tchobanoglous, 2003).

Also, some gas emission occurs along with the process, which include ammonia, carbon dioxide, carbon monoxide, hydrogen sulphide, methane and nitrogen. Not only is it toxic to the environment but also critical since it is explosive. Thus, gas control system is also implemented to ventilate the landfill and prevent explosions.

Landfill Gas (LFG) Collection can also be used in gas to energy technologies. Some flaring system is used to collect gas at a certain place to be processed and treated for use. The gas can either be flared or used in gas to energy processes.

3.2.6 Incineration

Incineration process involves conversion of combustible MSW, chemicals, infectious and pathologic wastes into gaseous, liquid, and solid products. The main purpose is to acquire heat energy to be used as a resource. Waste to energy plants decrease the waste volume around 75% while recovering energy from discarded products.

Similar to other treatment methods there is a useful output product as well as residues. The most common residues are ash and fly ash which require to be treated or disposed for public health since they may contain hazardous pollutants. Ash can be recycled into useful material by cementing or asphalting. If not reused the material should be disposed at a sanitary landfill (Abeliotis, 2011).

3.3 Integrated Solid Waste Management (ISWM)

Solid waste management is a complex system because it consists of several technologies and disciplines. These technologies are associated from generation to the disposal of solid wastes. All of these processes have to be carried out in sustainable manners. Sustainability comprises the country's legal, social, and environmental guidelines that protect the public well-being and the environment which are aesthetically and economically adequate. To be sustainable, the disciplines must be considered as an integrated system which involves administrative, financial, legal, architectural, planning, environmental, and engineering functions. For a successful ISWM plan, it is necessary that all these disciplines communicate and interact with each other in a positive interdisciplinary relationship at the same time (Abeliotis, 2011).

There is a hierarchy between each step to obtain most out from the integrated system (Figure 3.1). Source reduction is the first phase aimed to reduce the waste generation at the first place followed by recycling and composting which is the second phase of waste reduction by regaining the materials back in the industry and composting bio-waste. Subsequently, waste that cannot be recycled or composted is taken to combustion process to be burned and used for energy and finally residue from the previous processes is landfilled together with other waste remained to be not suitable to be disposed at previous phases.

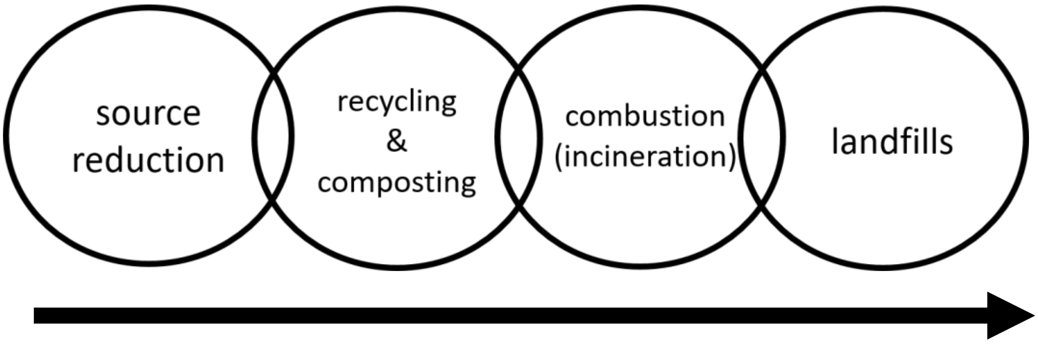


Figure 3.1 Integrated Solid Waste Management Disciplines Hierarchy

3.3.1 Importance and Benefits of Integrated Solid Waste Management

Applying integrated system increases the treatment and reuse or recycle possibility of materials since there is all sorts of disposal methods involved. Not only that, but also the waste treatment hierarchy helps to trigger higher rate of waste volume decrease at landfilling due to increased amount of reuse and recycling from various treatment methods. Besides, some energy production or useful output material is obtained to be used as a resource. Integrated systems are sustainable in all aspects including economic benefits in the long term.

The current solid waste management plan in North Cyprus is dependent on a single management method. Knowing the importance of ISWM, implementation of an integrated system is vital when the specified data is analysed.

CHAPTER 4

SOLID WASTE MANAGEMENT PLAN IN NORTH CYPRUS

Cyprus is the third largest island in the Mediterranean Sea after Sicily and Sardunia. The total surface area of the island is 9251 km^2 where the Turkish Republic of Norethern Cyprus (TRNC) covers 3355 km^2 (KKTC Enformasyon Dairesi, 2019). The Island has a mild Mediterranean climate with rainy winters and hot and dry summers. There are six districts in North Cyprus as; the capital city Lefkoşa, Mağusa, Girne, İskele, Güzelyurt, and Lefke. According to the 2011 census there were 286,257 citizens in TRNC (KKTC İstatistik Kurumu, 2011).

The Country faces many environmental problems such as marine pollution, air pollution, and deforestation due to drought. Environmental concerns are getting more attention in accordance with the climate change. Municipal solid waste is one of the important factors that triggers environmental pollution and consequently social health problems in North Cyprus. For a long period, the only treatment method used for MSW was open dumping. Huge indiscriminate open dumping sites were spread throughout the country, which were one of the main source for environmental pollution. In the past ten years, a new waste management plan and related legislations were implemented. The rehabilitation of the old dumping sites was governed, however, with the current population growth and increase in the industrial activities, the current management plan becomes insufficient. This is because 14 out of 28 municipalities are using Güngör Sanitary Landfill Facility and the other half are still dumping. Moreover, the waste that is being landfilled is not subject to any other treatment methods disregarding the waste characteristics for benefitting (EPA TRNC, 2020). In order to have a sustainable MSW management plan, the waste characteristics and current situation should be analysed and critical points should be diagnosed (Alkan, 2015).

4.1 Environmental Policies and Legislation

According to TRNC laws, 18/2012 Environment Act and 51/95 Municipality Act are the two legal bases for all environmental management activities. 18/2012 Environment Act is an act that was prepared within the scope of European Union Adaptation action. Besides the environmental management part, this act also includes; water resources, municipal waste, wastewater, marine pollution, air quality, industrial pollution, climate change, and biological topics. This act generally specifies the rules about waste. The waste management section of the act includes; general principles of waste management, liabilities and responsibilities, competent authorities, authorization for regulations, improvement of waste management plan and information network, and hazardous wastes.

By authorization of Solid Waste Control legislation, the Local Environment Protection Agency department at the Ministry of Tourism and Environment is in charge of planning and designing the countrywide solid waste management system in the most sustainable manner, publishing annual reports and workshops, running trainings and seminars to increase awareness and following international acts and policies, and acquires necessary acts to take part in policies.

51/95 Municipalities law describes the management, responsibilities and missions of municipalities. Municipalities are the authorized institutions that are responsible from municipal solid waste management. (TRNC Ministry of Tourism and Environment Environmental Law Act 18/2012, 2012; TRNC Ministry of Tourism and Environment Environmental Law Act 21/97, 1997)

4.2 Waste Management Plan

In 2007 the Environment Protection Agency of TRNC started a feasibility and master plan study within the help of EU Financial Aid Program, which had aimed to renew the existing waste management scheme with a modern sustainable waste management system (Konsorsiyumu, 2007). As a result of the study on 27 of

February 2008 Council of Ministers has approved "Turkish Republic of North Cyprus Waste Policy and Solid Waste Management Plan". Solid waste policy and plan had created within the consideration of European Union waste principals. Although the plan generally depends on household waste, it also contains summarized information about other waste types. During the preparation of legislation there was no data for the feasibility and master plan, therefore, different type of waste was collected from different cities at different seasons and waste analysis were done. These results were the first scientific outcomes that have been collected in North Cyprus. At the end of the study, it was declared by the Council of Ministers that the whole municipal waste of the republic was expected to be disposed of in one Central Landfill Facility by the help of three transfer stations. The Central Landfill Facility was decided to be in the village of Güngör which is close to the capital city Lefkoşa and three transfer stations was selected to be in Mağusa, Güzelyurt, and İskele districts (KKTC Atık Politikası ve Atık Yönetim Planı, 2008).

4.2.1 Real life Application Status

There are 28 municipalities in TRNC and in 2008 all the settlement areas were joined to municipalities. Solid waste is being collected, transported, treated and disposed of by the municipalities. On site storages comprise of different sizes of waste containers depending on the size of the community or the industry. Collection vehicles can differentiate within the municipalities but they are mostly second-hand diesel fuel 21 tonne capacity trucks (EPA TRNC, 2020).

The construction of Güngör Sanitary Landfill Facility was completed in 2012, which led to large municipalities to transport their waste to Güngör. Until 2012 all municipalities were collecting municipal solid waste and open dumping them to an out of sight area. There were 72 dumping areas that had been used by 28 municipalities before 2012 (Anderson & Paralik, 2010). Unfortunately, only 10 municipalities have been using Güngör facility until 2019 and 4 additional municipalities have been registered as official disposers. These 14 municipalities are

Lefkoşa, Gönyeli, Girne, Güzelyurt, Lapta, Değirmenlik, Dikmen, Alsancak, Çatalköy, Alayköy, Akıncılar, Esentepe, Tatlısu, and Mehmetçik representing more than 60% of the population. The remaining 14 municipalities continue to use total of 42 wild dumping sites due to long distance and cost of transportation. It is also reported that these municipalities represent small communities with low waste generation rates (EPA TRNC, 2020). However, uncontrolled fires, harms to wild life animals, bad smell, and fatal health effects can be listed amongst some of the impacts of wild dumping sites (Alkan, 2015)

Considering having only one facility and active dumping sites, with the high rate of population growth and industrial development in North Cyprus, the current MSWM Scheme is still found to be sustainably insufficient. Population estimation was made by using the 2006 and 2011 population census. It is referred in the report that the Tourism and Higher Education sectors increases the uncertainties on the current and estimated population and waste generation results. Despite the uncertainties, the number of people or exact number of waste generated does not directly affect the overall purpose of this study. As it can be seen from Table 4.1, the population is predicted to grow 30% in the following 20 years. The waste characteristics represented in Table 4.3 are in percentages and the study functional unit is one tonne of waste.

Table 4.1 The Population Forecast of North Cyprus (EPA TRNC, 2020)

Region	**2006**	**2011**	**2016**	**2020**	**2025**	**2030**	**2035**
Lefkoşa	84,776	94,824	102,923	109,238	117,681	126,776	136,573
Mağusa	63,603	69,741	75,397	80,024	86,208	92,871	100,048
Girne	57,902	69,163	75,899	80,556	86,782	93,489	100,714
Güzelyurt	29,264	30,037	32,047	34,013	36,642	39,474	42,525
İskele	21,099	22,492	24,179	25,663	27,646	29,783	32,085
Total	256,644	286,257	310,445	329,494	354,959	382,393	411,945

According to Güngör facility records, average produced waste per person per year was 793 kg/person/year (2013); 772 kg/person/year (2014); 726 kg/person/year (2015). However according to Eurostat data for EU 28 countries the average was 479 kg/person/year (Eurostat, 2013); 478 kg/person/year (Eurostat, 2014); 481 kg/person/year (Eurostat, 2015). The numbers are much higher than the EU averages; this can be explained by the significant ratio of Tourism, Higher Education, and Military Sector being involved in municipal solid waste, which also eliminates the possible proportionality within the population and amount of waste. The waste amounts were estimated according to the possible economic progresses and population dynamics. According to the estimated results from the study it can be concluded that the total amount of municipal waste will increase around 50% in 20 years period of time. The estimated numbers are presented in Table 4.2.

Table 4.2 Solid Waste Generation Forecast of North Cyprus (EPA TRNC, 2020)

Region	**2016**	**2020**	**2025**	**2030**	**2035**
Lefkoşa	99,986	117,905	132,859	143,127	154,189
Mağusa	46,896	54,415	58,640	63,172	68,055
Girne	68,965	81,710	90,518	97,513	105,049
Güzelyurt	12,957	14,831	15,523	16,722	18,015
İskele	13,860	17,210	18,590	20,027	21,575
Total	242,664	286,071	316,130	340,561	366,883

Within the preparation of integrated solid waste management plan, a characterisation study which includes four seasons was done; and data from the Güngör Sanitary Landfill Facility are presented in Table 4.3. According to the spring and summer data, solid waste characteristics of North Cyprus is 54% biodegradable (almost 40% is food waste) and approximately 45% renewable waste (more than 30% packing waste) (EPA TRNC, 2020).

Table 4.3 Municipal Solid Waste Composition in North Cyprus (EPA TRNC, 2020)

Waste Category	*(%)*
Kitchen, organic waste	39.9
Paper and Cardboard Packaging	3.5
Plastic Packaging	18.4
Glass Packaging	8.0
Metal Packaging	1.8
Other Recyclables	12.1
Yard waste and wood	2.8
Other	13.5

The waste characteristics that is demonstrated in Table 4.3 indicates a significant potential for recycling. The total percentage for bio-degradable materials is 53.9% and total renewable packing waste is 31.7%.

Table 4.4 summarises the solid waste ingredients by listing some examples of the products that are paired with the waste categories.

Table 4.4 Solid Waste Ingredients (Kıbrıs Türk Yatırım Geliştirme Ajansı (YAGA), 2014)

Waste Category	*Solid Waste Ingredients*
Kitchen, organic waste	Food remains, bread, vegetable, fruit
Paper and Cardboard Packaging	Newspaper, journal, notebook, Milk Box, Juice Box, Cardboard boxes
Plastic Packaging	Snack, water and soft drinks, fresh food, dairy Packaging
Glass Packaging	Bottle, Glass, Jar
Metal Packaging	Can, tins,
Other Recyclables	e-waste(Phone, cables)
Yard waste and wood	Piece of tree, branches, grass, garden waste
Other	Stone, soil, dust, ceramic, Cloth, shoe, pillow, carpet, Furniture

Currently the recycling of packaging waste is very limited. Only a few numbers of facilities from private sector and non-governmental organizations manage recycling activities. On 1st of December 2018, Packaging and Management of Packaging Waste Legislation was published for promoting recycling facilities of packaging waste (KKTC Çevre Koruma Dairesi, 2020).

The situation is not much different for organic waste. Despite some composting activities have been started by the government, there is no any facility or business models currently dealing with composting activities. All the green waste composting projects are aborted and unsatisfied the expectations (KKTC Çevre Koruma Dairesi, 2020).

Even though there is a construction waste breaker tool that was funded by EU, no any construction and debris waste recycling activity has occurred in the country (KKTC Çevre Koruma Dairesi, 2020).

4.2.2 Facilities and Uses

In North Cyprus, there are one main landfill facility and three associated transfer stations currently operational for municipal waste management. Detailed information on facilities as Güngör Sanitary Landfill, Gazimağusa Transfer Station and Dikmen Dumping and their current uses are explained in the following sub sections

4.2.2.1 Güngör Sanitary Landfill Plant

The construction of Güngör Sanitary Landfill Facility which was funded by EU Financial Commission has a cost around 7 million Euros. The Facility has fully completed at the beginning of 2012. The facility covers 12-hectare area and gives service for around 60% of population. Besides 14 municipalities situated in Lefkoşa, Girne, and Güzelyurt districts, also military forces and private sector from those districts use this facility. The facility has maximum 2.3 million m^3 waste capacity.

The facility is totally appropriate to EU 1999/31/AB instructions, the leachate was collected and its leakage into undying soil and groundwater was prevented by the impermeable bottom liner system. The leachate is collected by the collection unit and carried to the evaporation units and also landfill gases are collected are released to the atmosphere by help of passive gas collection system (Gronmij, 2012). Moreover, 480 m^2 closed area is prepared for hazardous waste. Approximately 200 kg hazardous waste are being collected monthly. According to the data in 2015, monthly average of the waste coming to facility is approximately 13,500 tons (Alkan, 2015).

4.2.2.2 Gazimağusa Transfer Station

Another project that was completed with the fund of European Union is Gazimağusa transfer station which was aimed to carry all the MSW collected from Gazimağusa to Güngör Facility. The construction of the station had a cost around 400,000 Euro, unfortunately the station has not been used since it has completed. Whenever the second phase of the Güngör facility builds up, the Gazimağusa transfer station will be in use. From transfer station the wastes are planned to be carried by specially designed high volume trucks to Güngör second phase facility (Alkan, 2015).

4.2.2.3 Dikmen Dumping Site

Before the Güngör Landfill Facility there were several dumping sites all around the country. Amongst them, Dikmen dumping site was the biggest dumping sites. It situated at 5 km north of Lefkoşa and it was the collection point of waste from Lefkoşa and Girne districts. Including commercial, industrial, and cattle waste all type waste were dumped to that site. The area had no ground water resource so that ground water pollution was not a big problem, however, the nonprofessional management of the site ended up with uncontrolled fires and leakages to surface streams. Every day 500 tons of waste were dumping to the site and the environmental pollution was unstoppable (Kroeger, 2009).

With the corporation of TRNC Environmental Protection Agency and European Union Commission, a rehabilitation project was prepared and with the funding of EU the project was accomplished. It took two years and around 6 million Euro to complete the project. In the study that was prepared for rehabilitation, it was stated that the volume of dumping area was approximately 1.3 million m^3 with an average depth of 5 m. As a part of the project, the waste that had been spread out for 27.5 hectares area were collected to an area of 11.5 hectares and covered with an impermeable material and soil. During the coverage of waste, landfill and leachate collection systems were planted to the area. The collected leachates are gathered in a storage pool and evaporated. The operation of the area is held by TRNC Environment and Protection Agency.

4.3 Future Project Plans and Researches

TRNC Government has accomplished to reduce the number of dumping sites being used and apply a more sustainable management option for waste management. New transfer stations are also being built such as Girne Transfer Station to support the current system and increase the municipalities being involved (Girne Belediyesi, 2020). However, after a 10 year period with the population growth rate and increase in waste volume, a basic sanitary landfill has started to be insufficient. The 2020 report also suggests that collection services and vehicles are also inadequate for the current waste volume (EPA TRNC, 2020).

One of the proposals is producing energy from solid waste by combustion, the most serious study made on this topic was handled by TRNC Investment and Development Agency (YAGA). In that study, the agency planned a power plant that will produce electricity from household waste, medical waste, whey waters and butchery waste. The power plant will be in compliance with EU standards and, also to 18/2012 TRNC Environment Law. The facility will cost around 90 million dollars and will produce 18 MW electricity per hour. 28 municipalities are planned to be connected to the facility, in order to use the transfer stations and current landfill facility the power plant is planned to be near to Güngör Facility. There are no official published reports about this project other than local newspaper and Environment Protection Agency related documentation. The project is stated to be at the decision state and on hold for the needed changes in legislation (Alkan, 2015).

Packaging waste shares the third biggest portion amongst the solid waste that are collected by the municipalities. 20% of the total packaging waste is shared by plastic waste, then followed by 9% glass, 3.5% paper and cardboard and 1.5% metal packaging waste. The total amount of packaging waste is approximately 80,000 tonnes per year which shows that in the case of continuing existing management system without any recycling facility, more than 1 million tonnes of packaging waste will be landfilled to Güngör facility within the following 20 years. European waste management policy was built up on a basis of constructing a recycler society. TRNC

Government is planning to promote municipalities to implement Extended Producer Responsibility (discussed earlier in Chapter 1), and municipalities have started to place separated waste collection points to the specific points inside the cities.

Currently, organic waste is only gathered and disposed to Güngör landfill by few of the municipalities. Although it is a better management way when compared to incineration or open dumping, landfilling causes unnecessary land occupation fulfilling the landfill area in a shorter time period than it has planned. Organic waste appears to be the second largest waste proportion and a sustainable management option appears to be essential. Within the aim of increasing composting Environment Protection Agency of North Cyprus has planned to implement 7 composting facilities with a total capacity of 38,000 tonnes per year (KKTC Çevre Koruma Dairesi, 2020).

Consequently, this study is going to use the current system and propose an integrated management scheme. Depending on the needs and future plans mentioned above different scenarios are created to understand possible sustainable alternatives. Landfilling is alternated with Material Recovery Facility for recyclables available in the characterisation data, incineration for energy recovery and reduction of waste volume, and composting for organic waste from the characterisation study. Using LCA is going to enable comparison to each scenario and create an environmental impact demonstration for each application in sustainability point of view.

CHAPTER 5

METHODOLOGY AND DATA

5.1 Life Cycle Assessment Methodology

LCA is often represented as a sustainability assessment tool. It evaluates impacts of a product or a system at a life cycle perspective. Hence, not only the used stage of the product is accounted but also the processes from scratch production or harvesting to final disposal stage and the effects of all phases through are calculated. The life cycle perspective helps to identify and prevent the burden shifting the life cycle processes, which might mean that lowering environmental impacts in one process might unintentionally cause for a possible larger environmental impact in other processes (Hauschild, et al., 2018).

One of the greatest benefits of LCA is that it covers a broad range of environmental issues at once. The subjects include; climate change, freshwater use, land occupation, aquatic eutrophication, toxic impacts on human health and environment, and depletion of fossil fuels. The reason for considering multiple issues is to avoid burden shifting. For instance, incineration besides a sanitary landfill facility helps reduce the waste volume that saves more space for the long run. However, air pollution levels are much higher due to gas emissions from the incineration.

Usually physical products are studied through LCA and the term product system is the life cycle perspective where all the processes contribute to deliver the function of the product is accounted. It is easy to compare the impacts of different processes and product systems since LCA is quantitative. Thus, deciding between the product systems depending on their contribution to overall impact is easier.

Overall calculation route starts by mapping thousands of emissions and resource uses as well as geographical locations if available. Subsequently, the complexity is reduced by the classification of thousands of flows into manageable number of environmental issues mentioned above. Factors from cause and effect models are used to calculate potential impacts on the environment from the accounted emissions and resource uses (SAIC, 2006).

Comprehensiveness of LCA is its main methodological strength as it enables large amount of processes and flows to be accounted for thousands of resources use and emissions at different locations and time periods. On the other hand, it may also be a constraint since it requires simplification and generalisation of the product system. Correspondingly, it is expected that there are some uncertainties in mapping the resources and emissions and their impacts. Therefore, it is more accurate to state that LCA addresses impact potentials of the product systems (Guinée, et al., 2011).

Another strength of LCA methodology is the "best estimate" principle which means that the less statistical possible impacts are neglected and same deterrent is applied to each modelling. This is also a limitation as it would not account problematic events. For instance, a nuclear power plant appears as environmental friendly by neglecting the small possibility of explosion causing a huge disaster.

Final suggested limitation of methodology is that LCA is able to depict which or what product system is better for the environment, nevertheless it cannot determine whether or not it's the best option. And so, it would not be correct to define a product as sustainable in absolute terms. The correct way is to understand the impact difference of each product with LCA reference.

According to ISO 14040 Standards, the method comprises of four fundamental phases for a successful LCA. These are goal and scope definition, inventory analysis, impact assessment, and interpretation (EC-JRC, 2010). Figure 5.1 demonstrates the four phases of LCA.

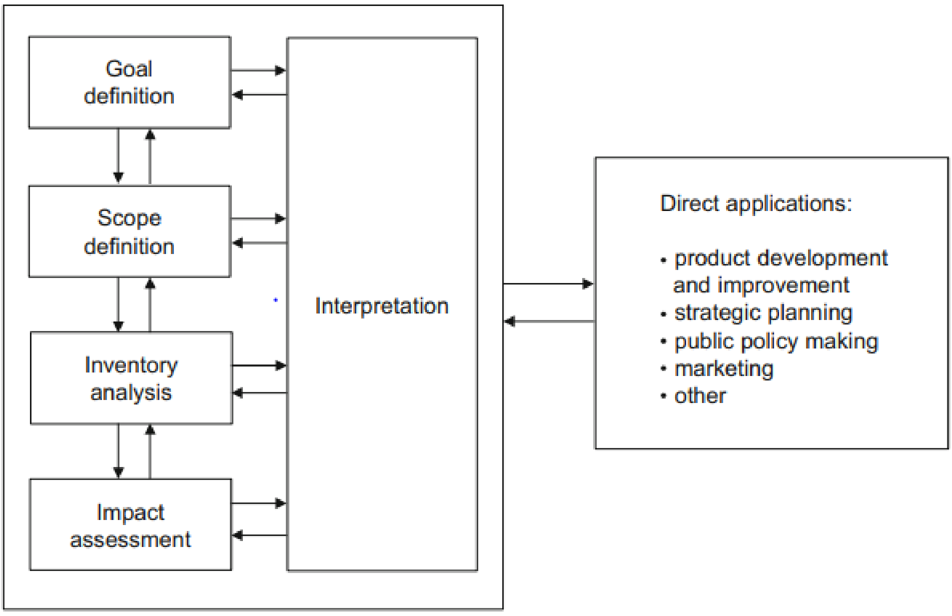


Figure 5.1 Phases of LCA modified from the ISO 14040 standard (Hauschild, et al., 2018).

LCA method is chosen to be used for this study for several reasons. One of the main reasons is that it evaluates and creates the impact results from a broad perspective. Therefore, each item included from solid waste collection to disposal phases such as air, water and soil emissions from the multiple facilities that are involved and emissions from the transport vehicles are calculated for the overall impact. Obtaining quantitative results also provides easier understanding of the impact levels. Also, five alternative scenarios are created to be evaluated and LCA enables to compare each scenario. Impact comparison between each scenario is going to assist on specifying the least harmful solid waste management plan for North Cyprus.

5.1.1 Goal and Scope Definition

The goal and scope of the study determines the purpose of the study in detail. According to ILCD, the goal should identify the applications of results, methodological limitations, reason of the study, target audience, disclosing comparative studies, and research group of the study (EC-JRC, 2010).

For determining the scope of the study, ILCD states that deliverables, modelling the operation of the processes, system boundaries and requirements, and functional unit should be explained.

The goal and scope of this study is that LCA methodology is used to compare integrated solid waste management alternatives in North Cyprus for assessing and comparing corresponding environmental impacts. More than 300,000 inhabitants were found to have generated 242,664 tons of municipal solid waste in 2016 with an average waste composition data presented in Table 4.3.

Waste composition data is used from the characterisation study (Chapter 4) that is reported by Environment Protection Agency (EPA TRNC, 2020). Collection vehicles have a waste capacity of 21 tons with average diesel fuel consumption; however, real time data is not obtained. Therefore, fuel consumption data is alternated according to scenarios and used from LCA database which is covering South Cyprus solid waste management system that represents similar distances with North Cyprus.

5.1.2 Selection of Functional Unit

The functional unit is the reference flow of the system to be assessed. The functional unit of this study is influenced from the literature and determined as the composition of 1 tonne of waste which is set as the reference flow within the management system. Five different scenarios were created to combine different management methods and compare the environmental impact by obtaining pollution levels.

5.1.2.1 System Boundaries and Scenarios

The system boundaries underline the indirect emissions of SWM systems such as electricity and fuel use to maintain and operate the facilities. There are also direct operational emissions, which are from the equipment and waste degradation. Also, down streaming emissions due to energy generation, materials substitution, and management of residues are included (Tillman, et al., 1994).

System boundaries also demarcate the product systems being involved. Life cycle stages such as production, manufacturing, transportation, use, and disposal are presented in corresponding diagrams demonstrated below. The process starts with the life cycle stage where the reference flow is delivered into the system.

The first solid waste management scenario is the current situation, based on which the other four alternative scenarios are assessed through this study. The system boundaries, diagrams, and detailed scenario information for this study are explained below.

Scenario 1

The baseline Scenario 1 (S1) is application of the real life Güngör Facility as the only solid waste management system where 100% of the municipal solid waste is collected and transferred for landfilling. The waste composition is used from the characterisation study previously mentioned and presented with Table 4.3 (EPA TRNC, 2020). Firstly, the mixed waste is collected and transported to the facility with regular disel fuel 21 tonne capacity collection vehicle. The vehicle travel distance from Girne Transfer Station to Güngör Facility (around 25 km) and from Lefkoşa city centre to Güngör Facility (around 15 km) is measured by using Google Maps Road directions (Google, 2021). The average travelling distance for both cities is calculated to be 20 km per vehicle. Passive landfill gas (LFG) collection system is applied at the landfill to allow landfill gas to be emitted and released from the covered landfill area. An impermeable clay bottom liner system is also applied to prevent soil and ground water pollution from the leachate. Also, leachate collection system is applied which gathers the leachate from the landfill and delivers the leachate to evaporation pond for disposal. Figure 5.2 shows the flow chart diagram of S1 with system boundaries inside the frame boundaries.

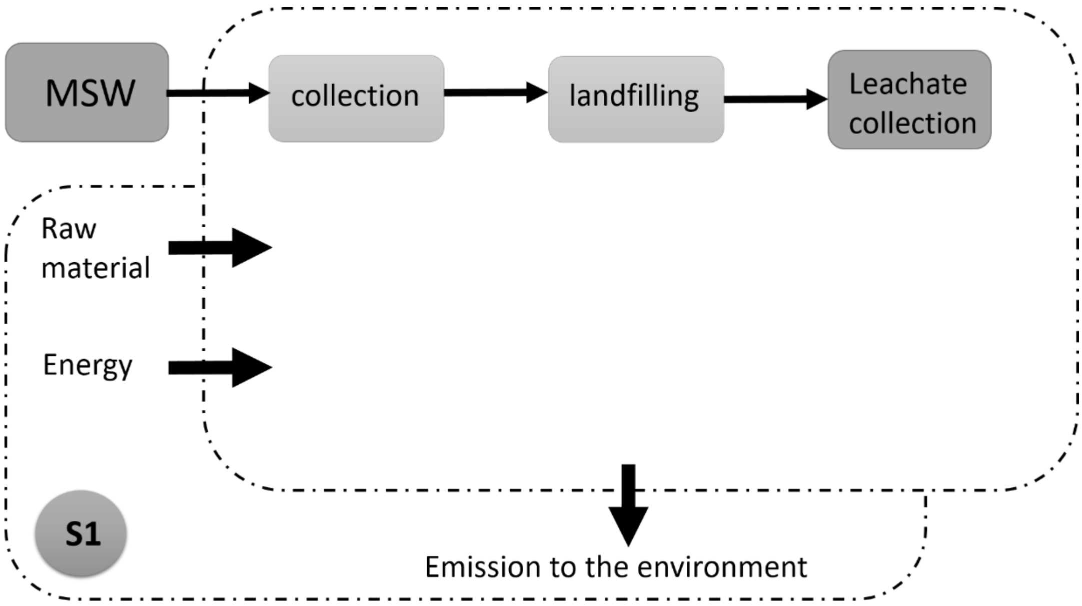


Figure 5.2 System Boundaries for Scenario 1 (S1)

Scenario 2

Scenario 2 (S2) is an integrated system of two treatment facilities as Incineration and Landfill. In S2 it is assumed that 50% of the waste is directly landfilled and other 50% is incinerated. Recovered material from the incineration such as metal scraps and final residue is again landfilled. Unsorted mix waste is collected with diesel fuel 21 tonne capacity waste collection vehicles and transported separately to the incineration and landfill facility with an average distance of 20 km each. There is electrical and thermal energy being recovered, while metal scraps and remaining residue is transferred to be landfilled. With this application the waste volume is expected to scale down as most of the waste is being burned and only incombustibles and recyclables are landfilled directly.

The calculations involve separate transportation impacts since the first service is for the incineration followed by a second transportation service to the landfill and a third routing from incineration to landfill.

There is also leachate collection done at the landfill facility to minimise the leakage pollution to the soil. The Figure 5.3 illustrates the system boundaries for an integrated system of landfill and incineration scenario for North Cyprus.

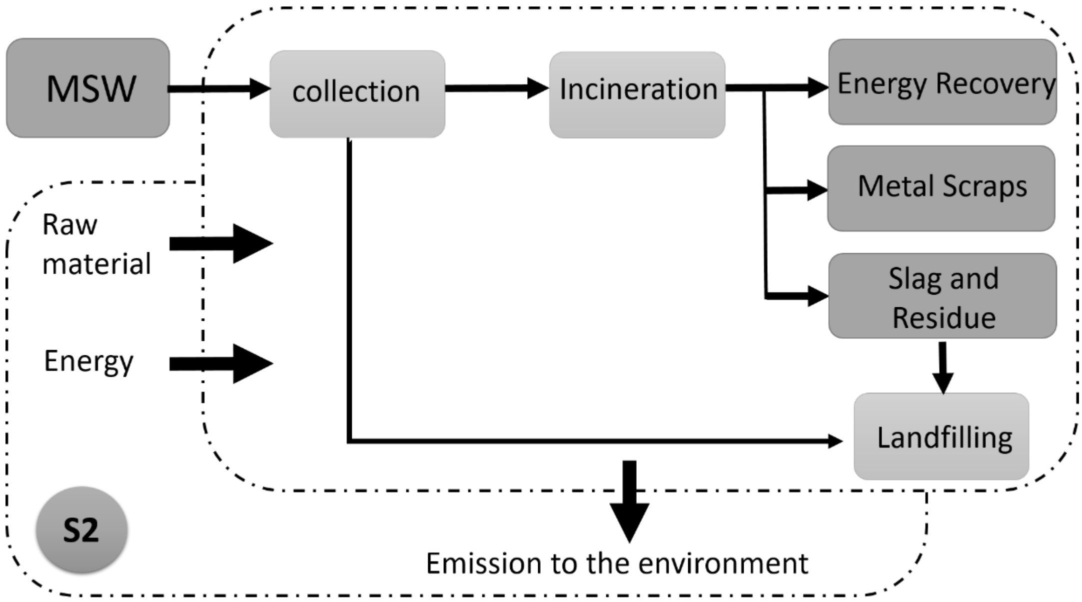


Figure 5.3 System Boundaries for Scenario 2 (S2)

Scenario 3

Scenario 3 (S3) assumes that the waste is sorted at the source as; recyclables and other waste which are collected separately. Hence calculations involve different vehicles in collection process creating two collection services as recyclables and other waste. Collection vehicles are diesel fuel 21 tonne capacity vehicle travelling an average of 20 km distance from collection to the facility. Recyclables representing 43.8% from the Table 4.3 such as plastics, paper, glass, and metals are collected together and transported to the MRF to be separated and recycled to be used in as a raw material.

The remaining organic waste and other 56.2 % non-recyclable waste is collected and transported partially 50% to the Incinerator and 50% Landfill Plant. The subsequent processes are the same as Scenario 2. However, metal scraps are not directed to landfilling but instead gained back for recycling since there is MRF. Hence, less material is being burned and landfilled since a portion is separated to be recycled providing more space within the landfill. Figure 5.4 represents the system boundaries and flow chart of MRF, Landfill and Incineration scenario (S3).

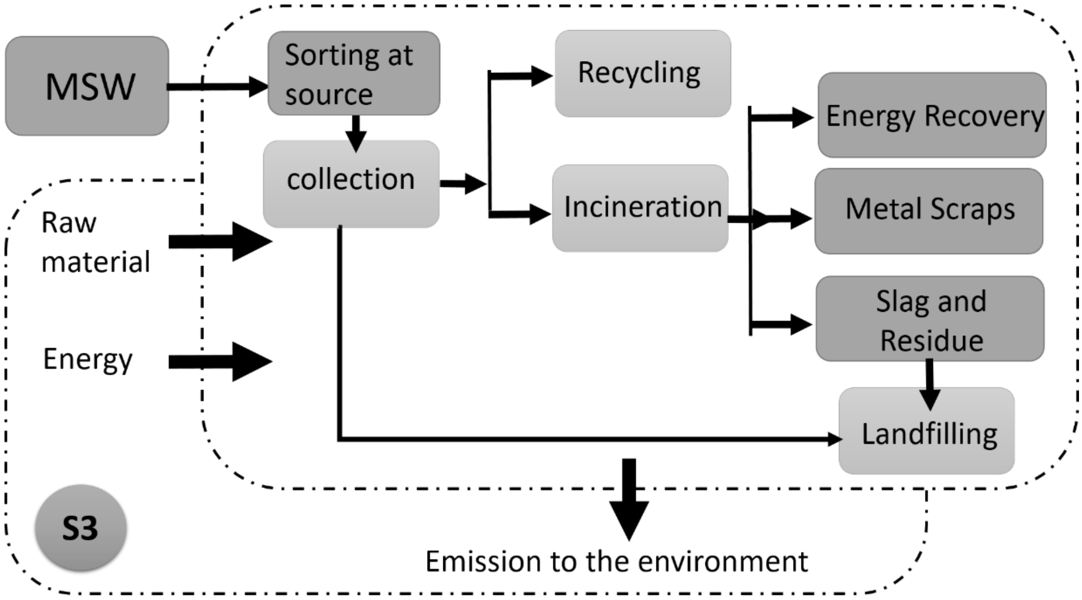


Figure 5.4 System Boundaries for Scenario 3 (S3)

Scenario 4

Scenario 4 accounts the MSW characterisation of North Cyprus being treated in three integrated management methods as Recycling, Composting, and Landfilling. This scenario also assumes that the waste is sorted at the facility. There is a different collection service for each type of waste by using diesel fuel 21 tonne capacity vehicles travelling for average of 20 km for each service. Bio-waste (kitchen waste and wood waste) being 42.7 % is collected together while recyclables (papers, plastics, metal, and glass) being 43.8% are collected together. The mixed other waste that cannot be neither recycled nor composted as only 13.5% is transported to the Güngör Landfill Facility by an additional transport service.

Additionally, the compost material is also reused in agriculture. However, depending on the waste characteristics sometimes compost quality might not be good enough to be a useful product. Therefore, the remains can be used in landfills cover material. Figure 5.5 shows the system boundaries and flows and product systems of Scenario 4.

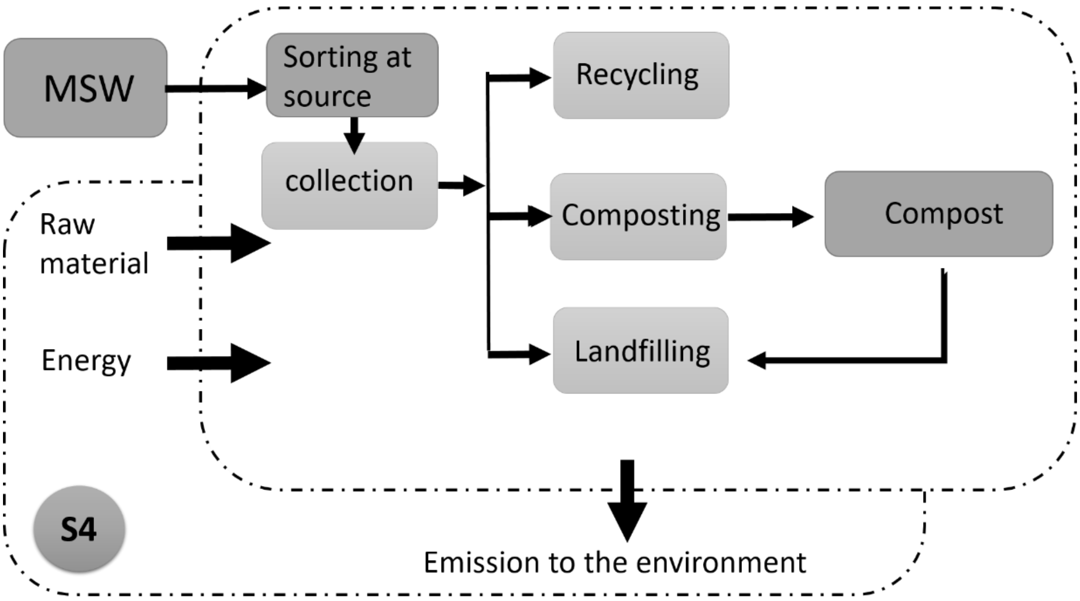


Figure5.5 System Boundaries for Scenario 4 (S4)

Scenario 5

Scenario 5 comprises of a well-developed integrated solid waste management system which involves MRF, Incineration, Landfill, and Composting facilities.

This scenario also assumes that the waste is sorted at the source and collection service is applied accordingly. Diesel fuel vehicles with 21 tonne of waste capacity are collecting each type of waste separately as organic, recyclables, and other waste. Although Recycling, Incineration, and Composting Facilities aid to reduce waste volume, there is still some proportion of waste that is landfilled without any of these treatment methods are applied.

Each vehicle travels an average of 20 km carrying organic waste being 42.7% to the composting facility, recyclables as 43.8% to the MRF and 6.75% waste to incineration and 6.75% to landfilling directly.

Further, incineration and composting facilities have outputs that are also disposed at the landfill site. Nevertheless, some outputs are useful at the landfill site to be used as covering material. Also metal scraps are regained since there is a material recovery facility. Figure 5.6 shows the system boundaries and product systems of Scenario 5.

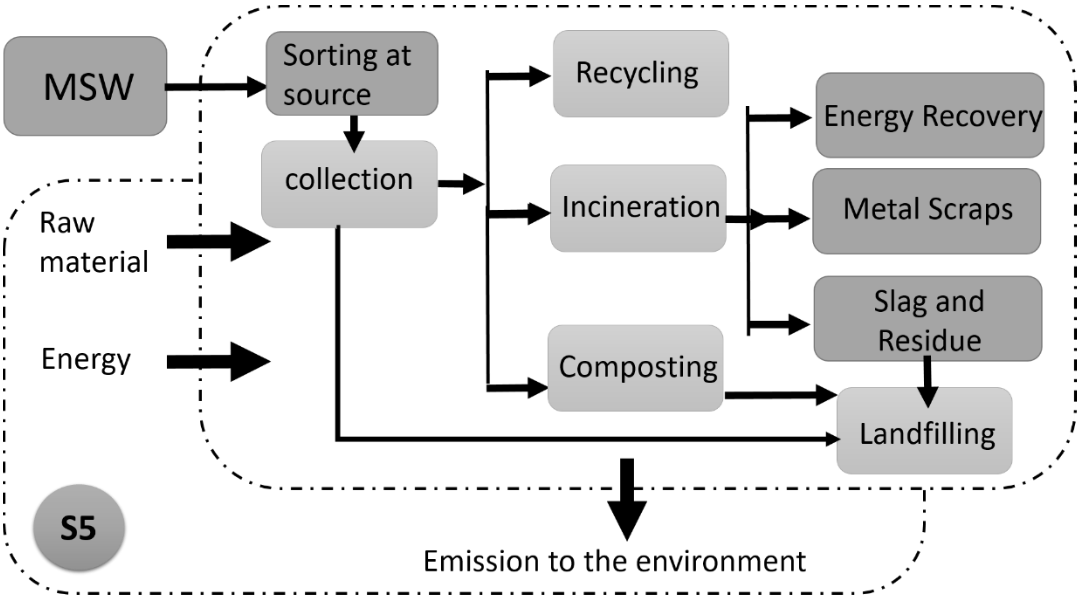


Figure 5.6 System Boundaries for Scenario 5 (S5)

5.1.3 Life Cycle Inventory Analysis

The inventory analysis is understanding the physical flows determined as the input of resources, materials, and products together with the output of emissions, waste and valuable products for the product system on life cycle assessment models (Vigon, et al., 1994).

Data reflecting the test area characteristics were mostly obtained from the local environment related agency reports, published sources, and previous researches as reported in the literature.

LCI data for individual waste treatment processes are extracted from the Ecoinvent 3.7 database (discussed later in Section 5.2). An existing similar database to Scenario 1 is tailored to have characteristics of North Cyprus Güngör Treatment Plant.

All processes used from the Ecoinvent database are from a real-life data obtained and have their own characteristics. The chemical input output data of the product systems involved through the scenarios such as incineration, composting, and material recovery, are used from the Ecoinvent database. A generic data of carbon dioxide emission rates of a non-diesel collection van from the database is used. The local specific data such as waste characteristics, transport distance, and landfill facility characteristics that are the critical values are implemented to the database according to the data collected from the local resources.

The operational specifications listed in the database are represented for landfill in Table 5.1, incineration in Table 5.2 and composting in Table 5.3 together with implemented data of North Cyprus solid waste characteristics are summarised for each process.

Table 5.1 lists the input waste composition proportions being input, upper heating value of landfill water and lower heating value of landfill gas, waste degradability percentage, and short-term and long-term emission potentials. Upper and lower heating value of landfill gas and landfill water (leakage) is vital to prevent explosions, apply the necessary collection process accordingly. Overall degradability of waste is the amount of waste that is degraded over 100 years and relative amount of methane is emitted. This information is beneficial if LFG collection system is planned to be applied (SAIC, 2006).

Table 5.1 Process Specifications of the Landfill Process (ecoinvent 3.7 database)

Process	*Process Specifications*
Landfill	• "Inventoried waste contains 3% paper; 0.5% Mixed cardboard; 18.4% plastic packaging; 8% glass packaging; 2.8% green and natural products (wood); 39.9% compostable material; 1.8% metals packaging; 12.1% non-packaging recyclable; 13.5% other." • "waste composition (wet, in ppm): upper heating value 13.27 MJ/kg; lower heating value 11.74 MJ/kg; • "Overall degradability of waste during 100 years: 18.73%." • "Waste-specific short-term emissions to air via landfill gas and landfill leachate. Long-term emissions from landfill to groundwater (after base lining failure)."

Table 5.2 describes the data representation used in the incineration process. The process is recommended to be used for average municipal waste mixture. A single specific waste representation is not suitable to be used. A specific waste mixture is required to be input individually. Upper heating and lower heating values are required to determine if the energy content is required as liquid or gas after combustion. Net energy production levels are also given depending on the input waste proportion. Recovered metals are landfilled in Scenario 2 and regained as raw material in Scenario 3, and 5. Finally, long-term and short-term emission potentials are listed.

Table 5.2 Process Specifications of the Incineration Process (Ecoinvent, 2021)

Process	*Process Specifications*
Incineration	• "Waste composition (wet, in ppm): upper heating value 13.05 MJ/kg; lower heating value 11.7 MJ/kg; "Share of carbon in waste that is biogenic 61.1%." • "One kg of this waste produces 0.2221 kg of slag and 0.02224 kg of residues, which are landfilled. Additional solidification with 0.008896 kg of cement." • "Net energy production: 1.39MJ/kg electric energy and 2.85MJ/kg thermal energy." • "Recovery of metal scrap to recycling: 9.7909g iron scrap, 1.2162g aluminium scrap, 0.12319g copper scrap." • "Waste-specific short-term emissions to water from leachate. Long-term emissions from landfill to ground water."

Table 5.3 represents the listing of the composting process specifications for the items that can be named under bio-waste and can be composted for further use from the database.

Table 5.3 Process Specifications of the Composting Process (Ecoinvent, 2021)

Process	*Process Specifications*
Composting	• "Bio-waste in the current process is defined as follows: Biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, comparable waste from food processing plants, it also includes forestry or agricultural residues and manure." • "It does not include sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood."

5.1.4 Life Cycle Impact Assessment

The impact assessment method that is used for all scenarios is the most commonly used method CML (baseline) 2015 (GreenDelta, 2019). There are eleven impact categories implemented within the calculations and each one is associated with many impact factors. Table 5.4 lists all the impact categories (Fazio, et al., 2018).

Table 5.4 Impact Categories associated in CML (baseline) 2015 method (GreenDelta, 2019)

Impact Categories	*Category*
Acidification Potential	Emission to Air
Climate Change (GWP 100)	Emission to Air
Depletion of Abiotic Resources (elements, reserves)	Resource
Depletion of Abiotic Resources (fossil fuels)	Resource
Eutrophication (generic)	Emission to Air Emission to Water
Freshwater aquatic Ecotoxicity (FAETP inf)	Emission to Air Emission to Water Emission to Soil
Human toxicity (HTP inf)	Emission to Air Emission to Water Emission to Soil
Marine aquatic ecotoxicity (MAETP inf)	Emission to Air Emission to Water Emission to Soil
Ozone layer depletion (ODP steady state)	Emission to Air
Photochemical oxidation (high Nox)	Emission to Air
Terrestrial ecotoxicity (TETP inf)	Emission to Air Emission to Water Emission to Soil

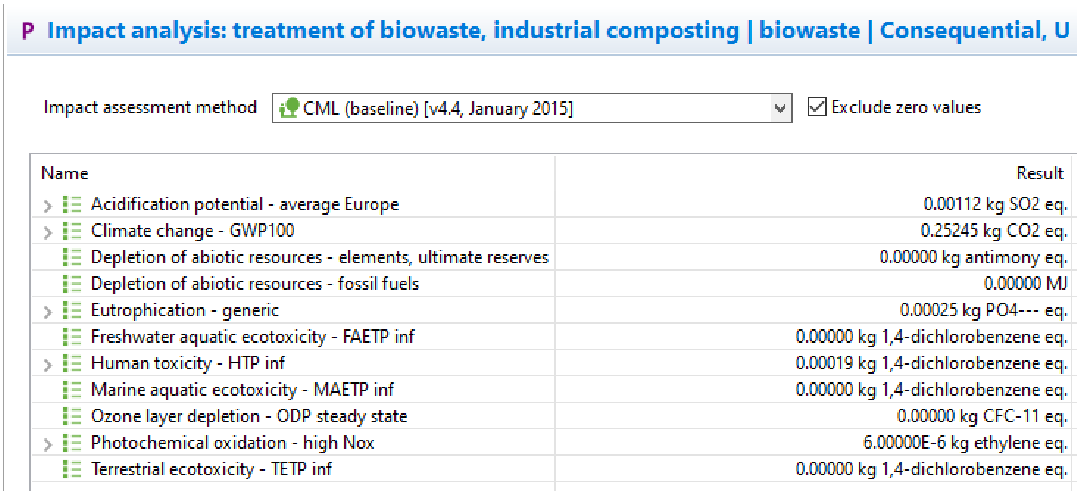
The units are generalised for all the impact categories and there is a normalization value for each. These values are determined from national or worldwide organizations such as European Commission Joint Research Centres (JRC). Normalalisation data for all impact categories are set to be EU 25 in this study. Normalisation involves organising the data to ensure that dependencies are correctly implemented using database constraints. For example, for Acidification Potential only substances that are emission to air is accounted (from Table 5.4). However, all output flows that are from each process have their own units. To be able to equate all together, they are multiplied with the Acidification Potential Normalisation Factor which appears to be $2.8130986161E^{10}$in Table 5.5 . So all elements that are to be accounted for Acidification Potential would have the same unit and thus, can be equated together to obtain the final value. Applying normalisation is needed to avoid redundancy and data duplication (EC-JRC, 2014). Table 5.5 shows the Normalisation factor and the unit of each impact category is used from the OpenLCA software.

Table 5.5 Normalisation Factors and Units of Impact Categories (GreenDelta, 2019)

Impact Category	*Normalisation Factor*	*Unit*
Acidification Potential	$2.8130986161E^{10}$	kg SO_2eq.
Climate Change (GWP 100)	$5.0218836986E^{12}$	kg CO_2eq.
Depletion of Abiotic Resources (elements, reserves)	$8.4641204022E^{7}$	kg antimony eq.
Depletion of Abiotic Resources (fossil fuels)	$3.1489842757E^{13}$	MJ
Eutrophication (generic)	$1.3186114794E^{10}$	kg PO_4--- eq
Freshwater aquatic Ecotoxicity (FAETP inf)	$5.1907319227E^{11}$	kg 1.4-dichlorobenzene eq.
Human toxicity (HTP inf)	$7.7816608342E^{12}$	kg 1.4-dichlorobenzene eq.
Marine aquatic ecotoxicity (MAETP inf)	$1.1672661986E^{14}$	kg 1.4-dichlorobenzene eq.
Ozone layer depletion (ODP steady state)	$8.9415770777E^{7}$	kg CFC-11 eq.
Photochemical oxidation (high Nox)	$8.4755284868E^{9}$	kg ethylene eq.
Terrestrial ecotoxicity	$4.8622828623E^{10}$	kg 1.4-dichlorobenzene eq.

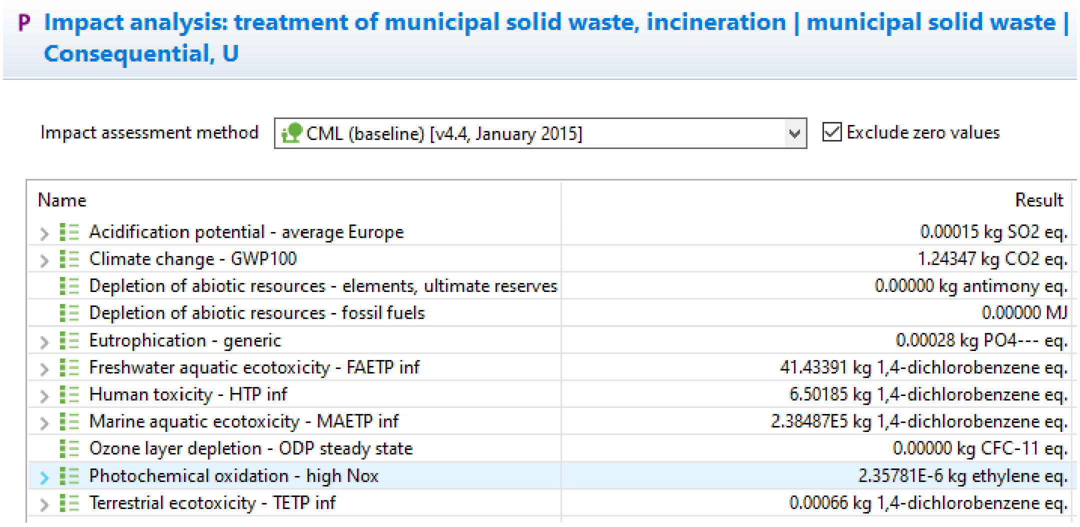
(TETP inf)

The OpenLCA Software enables Impact Analysis and also run individually for Landfilling, Incineration and Composting processes without any integration or relation with other processes or flow components such as waste collection service. This is done to understand the level of impact that each process incorporates individually. Figures 5.7, 5.8, and 5.9 show the impact assesment screenshots from the OpenLCA software using CML (baseline) 2015 IA method.



Name	Result
Acidification potential - average Europe	0.00112 kg SO2 eq.
Climate change - GWP100	0.25245 kg CO2 eq.
Depletion of abiotic resources - elements, ultimate reserves	0.00000 kg antimony eq.
Depletion of abiotic resources - fossil fuels	0.00000 MJ
Eutrophication - generic	0.00025 kg PO4--- eq.
Freshwater aquatic ecotoxicity - FAETP inf	0.00000 kg 1,4-dichlorobenzene eq.
Human toxicity - HTP inf	0.00019 kg 1,4-dichlorobenzene eq.
Marine aquatic ecotoxicity - MAETP inf	0.00000 kg 1,4-dichlorobenzene eq.
Ozone layer depletion - ODP steady state	0.00000 kg CFC-11 eq.
Photochemical oxidation - high Nox	6.00000E-6 kg ethylene eq.
Terrestrial ecotoxicity - TETP inf	0.00000 kg 1,4-dichlorobenzene eq.

Figure 5.7 Impact Assessment of Industrial Composting (GreenDelta, 2019)



Name	Result
Acidification potential - average Europe	0.00015 kg SO2 eq.
Climate change - GWP100	1.24347 kg CO2 eq.
Depletion of abiotic resources - elements, ultimate reserves	0.00000 kg antimony eq.
Depletion of abiotic resources - fossil fuels	0.00000 MJ
Eutrophication - generic	0.00028 kg PO4--- eq.
Freshwater aquatic ecotoxicity - FAETP inf	41.43391 kg 1,4-dichlorobenzene eq.
Human toxicity - HTP inf	6.50185 kg 1,4-dichlorobenzene eq.
Marine aquatic ecotoxicity - MAETP inf	2.38487E5 kg 1,4-dichlorobenzene eq.
Ozone layer depletion - ODP steady state	0.00000 kg CFC-11 eq.
Photochemical oxidation - high Nox	2.35781E-6 kg ethylene eq.
Terrestrial ecotoxicity - TETP inf	0.00066 kg 1,4-dichlorobenzene eq.

Figure 5.8 Impact Assessment of Incineration (GreenDelta, 2019)

P Impact analysis: treatment of municipal solid waste, sanitary landfill | municipal solid waste | Consequential, U

Impact assessment method: CML (baseline) [v4.4, January 2015] ☑ Exclude zero values

Name	Result
Acidification potential - average Europe	4.21895E-5 kg SO2 eq.
Climate change - GWP100	0.68586 kg CO2 eq.
Depletion of abiotic resources - elements, ultimate reserves	0.00000 kg antimony eq.
Depletion of abiotic resources - fossil fuels	0.00000 MJ
Eutrophication - generic	0.00296 kg PO4--- eq.
Freshwater aquatic ecotoxicity - FAETP inf	1.93624 kg 1,4-dichlorobenzene eq.
Human toxicity - HTP inf	0.18762 kg 1,4-dichlorobenzene eq.
Marine aquatic ecotoxicity - MAETP inf	935.22733 kg 1,4-dichlorobenzene eq.
Ozone layer depletion - ODP steady state	0.00000 kg CFC-11 eq.
Photochemical oxidation - high Nox	0.00013 kg ethylene eq.
Terrestrial ecotoxicity - TETP inf	0.00138 kg 1,4-dichlorobenzene eq.

Figure 5.9 Impact assessment of Landfill (GreenDelta, 2019)

5.2 Software and Database Selection

5.2.1 Used Software

There are several Life Cycle Assessment software programmes that have been used in the literature, however, for the MSW, commonly employed software are GaBi, SimaPro, and OpenLCA. In the software selection, some characteristic features should be checked as listed below (Heinrich, 2010);

- Completeness of Scope; Concurrence of the environmental indicator and the characterization model is associated with the impact category.
- Environmental Relevance; Critical parts of the impact pathways in accordance with the subject research area.
- Scientific Robustness and Certainty; Data should be validated against monitoring data or the uncertainties should be reported.
- Documentation, Transparency and Reproducibility; Accessibility of the model documentation, the characterization factors and the applied input data.

- Applicability; Characterization factors provided for the important elementary flows for the impact category in a form that it is straightforward to apply.

- Stakeholders’ Acceptance; It should be endorsed by competent authorities, and the used metric must be understandable for users of the LCA, business and policy contexts.

Within the scope of these factors and considering the free access option with easy user interface, OpenLCA software is selected to be used. The latest version can be freely downloaded from its website www.openlca.org. The software does not involve database and any impact methods. Users can create their own datasets from scratch but also, it demonstrates and introduces the OpenLCA Nexus Platform. This platform is an interface which lists all the available databases and impact assessment methods. OpenLCA Nexus cooperates with many worldwide known database organisations such as Ecoinvent, European Commission Joint Research Centres, IPB and many others. The platform enables ordering, purchasing, and downloading of these wide known databases. Once the order is done, the database can be uploaded to the free and empty OpenLCA software as a special file format that is called Zolca file.

The software requires inputs and outputs as datasets and further automatically runs all necessary calculations for the LCA methodology by linking each input and output flow of each process to an environmental factor and matching each factor with an impact category.

Figure 5.10 illustrates an input/output page of a process in OpenLCA. Here in the specific picture, the first inflow phase of each scenario is created. MSW characteristics of North Cyprus are implemented to the system. This process is then implemented in other processes as the main MSW composition.

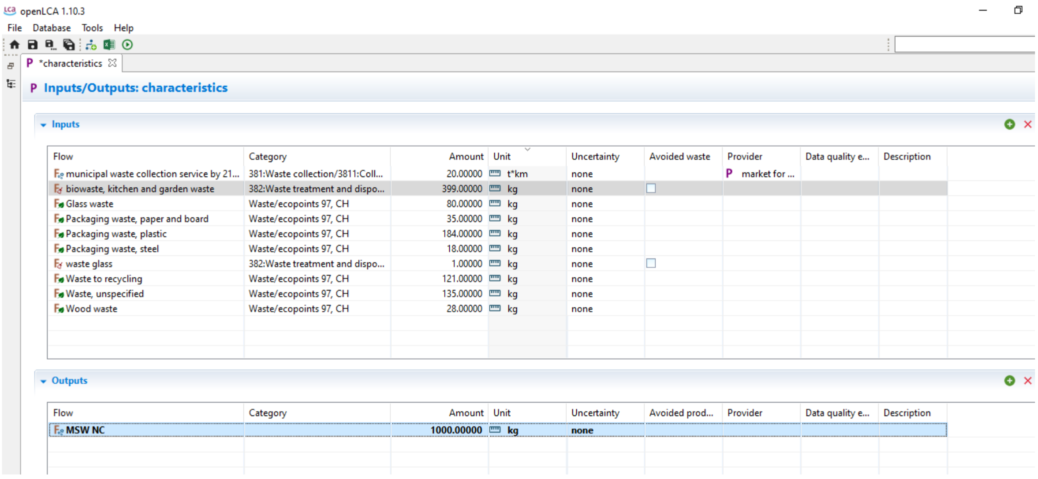


Figure 5.10 Screenshot of MSW Composition Process from OpenLCA Software

In Figure 5.11, Scenario 5 product system is created with all the inputs and outputs demonstrated. The inputs consist of different collecting services for recyclables, organic waste, and other waste. There is extra two vehicle service seen because as described in Scenario 5, vehicles are carrying residue back to landfill and recovery materials to MRF after incineration.

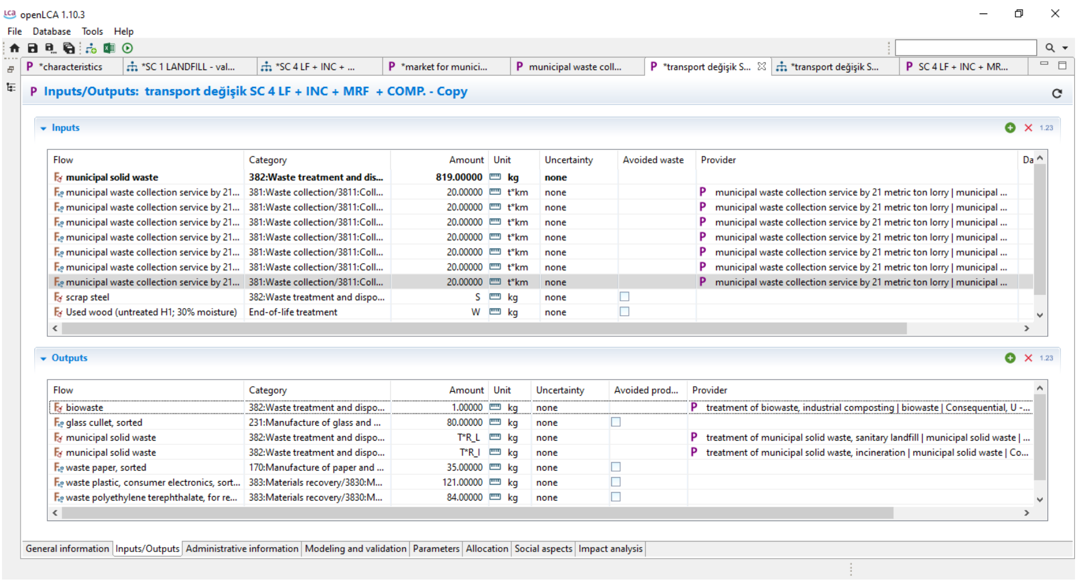


Figure 5.11 Screenshot of Scenario 5 Input/output Flow Page from OpenLCA Software

Figure 5.10 and Figure 5.11 demonstrate the scenario inputs and outputs. They are all connected to a rooting more detailed provider system which has raw materials as inputs and outputs.

For example, in Figure 5.12 a detailed provider system for collection service is demonstrated. In detailed provided system all relative processes are accounted from the scratch until the final market place of the service or products. So, for waste collection process, input flows involve manufacturing process of the motor vehicles, manufacturing of petroleum, and even construction of roads. All output flows are obtained from these processes and accounted for the impact assessment. As seen from the Figure 5.12 there are many outputs that not all could fit in the screenshot. All are assigned for the process by the database.

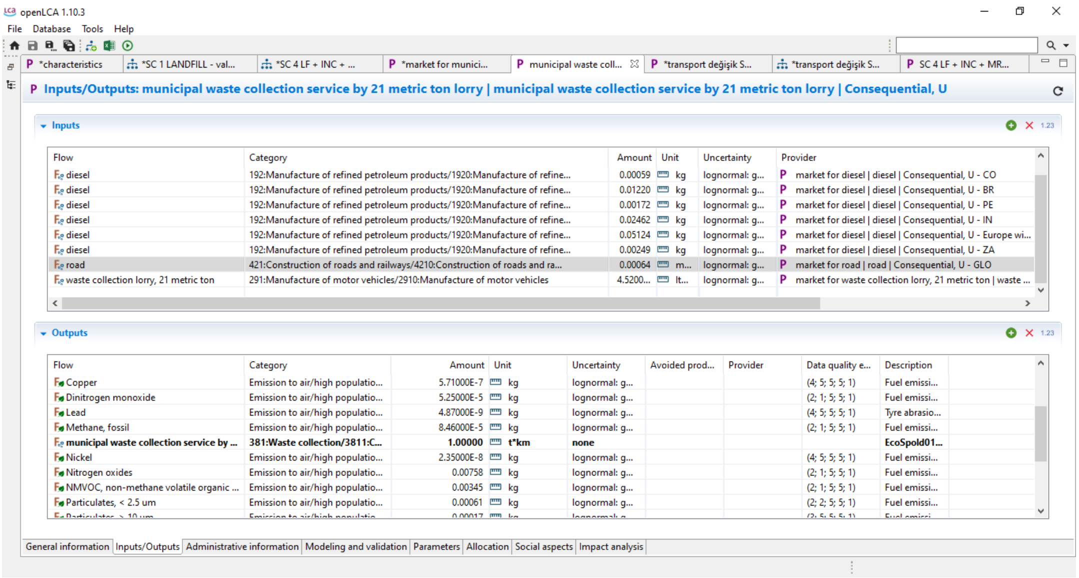


Figure 5.12 Municipal Solid Waste Collection Service Process Inputs and Outputs Screenshot from OpenLCA

Databases are created from previous researches. Data is collected from tests, laboratories and researches then accredited datasets are created. Hence for LCA studies, there are pre-set generalised datasets that can be used. But all data may not be sensitive and choosing the most suitable data is important. Therefore, it is important to know which database to use for a research.

5.2.2 Used Database

Ecoinvent is a non-profit association based in Zurich, Switzerland. The association offers high quality worldwide data as background database for LCA or other environmental assessments. Its aim is to provide high quality, affordable data for researchers, policy-makers, private enterprises, non-governmental organisations and global academic communities. Hence by applying to Ecoinvent for "Academic Licence", this study was approved to have free access for Ecoinvent v2.2 & v3.7.

This database, is one of the first LCA databases with thousands of processes that consist of production, treatment, management, and many more operations from vast amount of locations. There are multiple licences to access the database as student, LCA expert, and business based. Each licence has different pricing and details are provided on ecoinvent website (www.ecoinvent.org). GreenDelta which is an engineering consulting company on LCA and it is in cooperation with the OpenLCA software, enables students from Non-OECD countries to have free access for certain databases. There is a short and easy application process through OpenLCA Nexus platform. The application requires details on the academic project, cover letter, and proof documentation of student enrolment.

The use of ecoinvent database has aided to support the scenarios where local data is unavailable. Although the values are pre-set, they can be altered according to the real-life values. New input or output flows can be added as well. Hence adjusting all the values, flows and connections of the processes impact assessment is applied and project results are obtained.

CHAPTER 6

RESULTS AND DISCUSSION

OpenLCA software links the associated impacts with the inputs and outputs of the product system. These impacts are then calculated depending on the ratio of the inputs in categories as emission to air, water, soil, and depletion of resources. North Cyprus solid waste characteristics data presented in Chapter 4, Table 4.3 is implemented to the product systems within the database. Since the assessment is done from collection to disposal stage of waste, collection trucks and carriage distances given in Chapter 5, Section 5.1.2.1 are also included as input data to the system. The impact categories are then calculated as eleven sections of CML (baseline) 2015 impact assessment method.

Here in this chapter, the results are summarised and the calculation methods are explained simply for each category by evaluating the flows of CML (baseline) 2015 IA method used. Emission substances and elements are briefly indicated which are then normalised to impact category units and demonstrated in charts. Comparison and review of the environmental impact results of the five scenarios were also provided for each impact category.

To measure the calculation validity and data reliability, a validation analysis is also done by using another impact assessment method called ILCD 2011 (midpoint) and results are presented at the end of the chapter.

6.1 Acidification Potential

Acidification Potential mainly accounts oxides of sulphur, nitrogen oxides, and ammonia that is emitted to air from the proccesses involved within the scenario. The unit is characterised as kgSO_2eq (Dincer & Abu Rayash, 2020).

Sulphur oxides, nitrogen oxides, and ammonia are mostly obtained from the direct release of landfill biogas that is caused by short-term leaching in sanitary landfill. Emissions from short-term leachate treatment also releases above mentioned elements causing acidification. Hence, processes that are associated with leachate and biogas are more likely to demonstrate higher acidification impact. Incineration process also contributes acidification by the emission from the waste composition and transfer coefficients. Despite there is some filtration applied to modern incineration systems, some amount of fuel and thermal Nitrogen oxides are still emitted. Looking at Figure 6.1 demonstrating Acidification levels for each scenario, in S2 each with 50% waste input, landfilling appears to be the most effective emitter followed by incineration. Small amount of ammonia is also expected to be released through composting process.

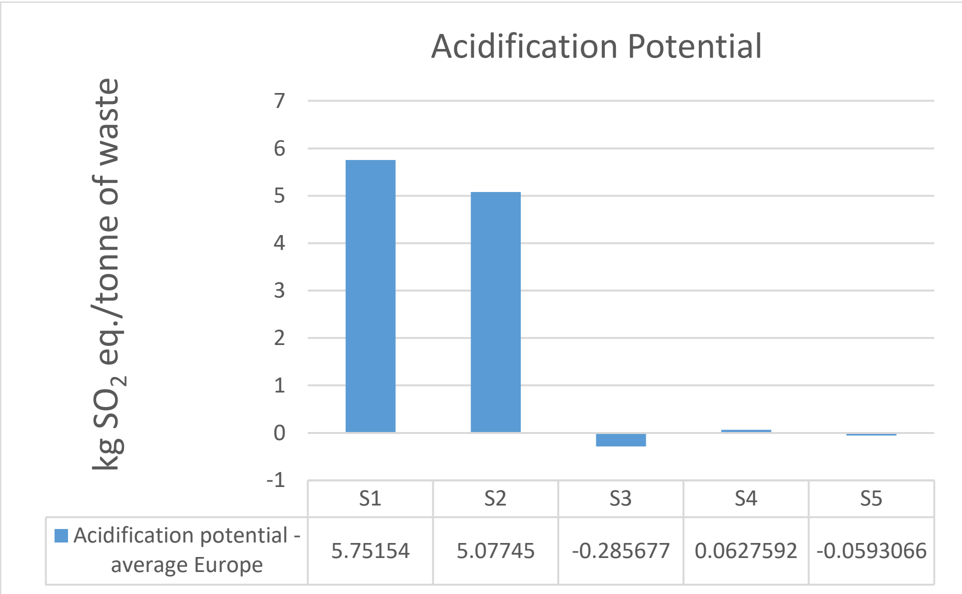


Figure 6.1 Acidification Potential

6.2 Climate Change Potential

Global Warming Potential (GWP) is the common metric for presenting different gasses at a common scale, often as CO_2 equivalent that is integrated for 20, 100, and 500-years. CML Climate Change accounts for 100-year timescale analysis (Houghton, et al., 1990).

Substances such as carbon dioxide, carbon monoxide, and methane that are emitted from incineration or landfill facilities as biogas are accounted. Biogenic carbons, methane, and dinitrogen monoxide substance are emitted through composting process. Emissions from short-term leachate treatment and incineration of resulting sludge are also causing releases of these substances to air. Therefore, the results of Climate Change (GWP 100) impact shown in Figure 6.2 illustrate that the highest impact contributor is in Scenario 2 with only landfilling and incineration facility.

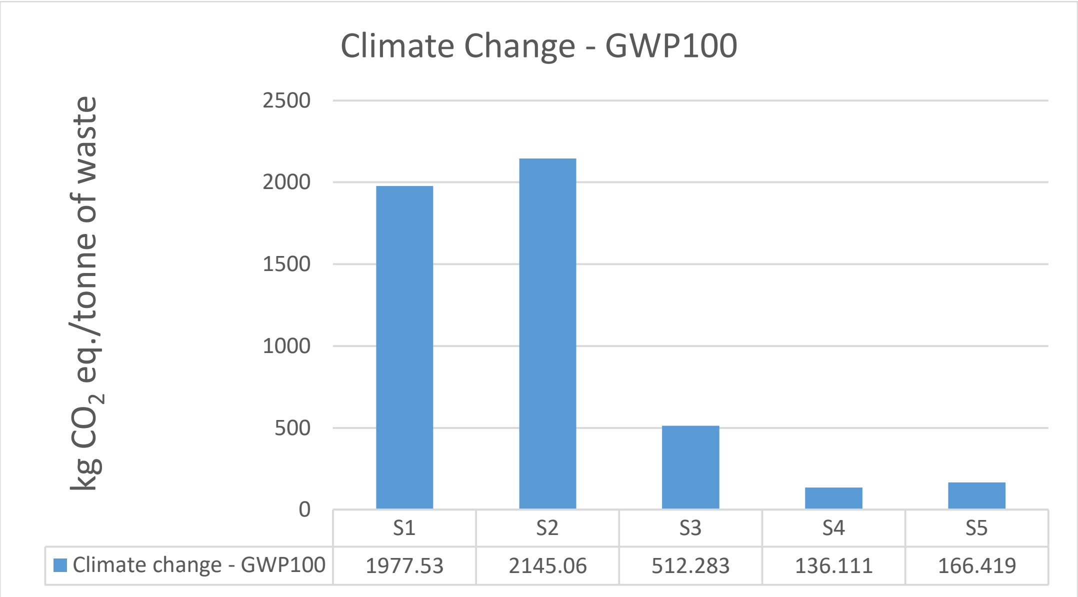


Figure 6.2 Climate Change

6.3 Depletion Potential of Abiotic Resources

Depletion of resources for elements measures the use of non-renewable resources for processes in each scenario by considering the life cycle use of antimony and its equivalent per capita per year (Dincer & Bicer, 2018).

Overall depletion of abiotic resources impact is very low which are close to zero. This is because waste treatment process use less raw material than other processes such as material production or manufacturing. Therefore, this impact can be neglected from the overall interpretation. The lowest depletion value is resulted in Scenario 4 in Figure 6.3, demonstrating around 98% lower depletion value than the highest value which appears to be in Scenario 2. Scenario 3, 4 and 5 involve MRF and composting systems which enables waste to be reduced before landfill or incineration. Therefore, the results are relatively lower than the other scenarios.

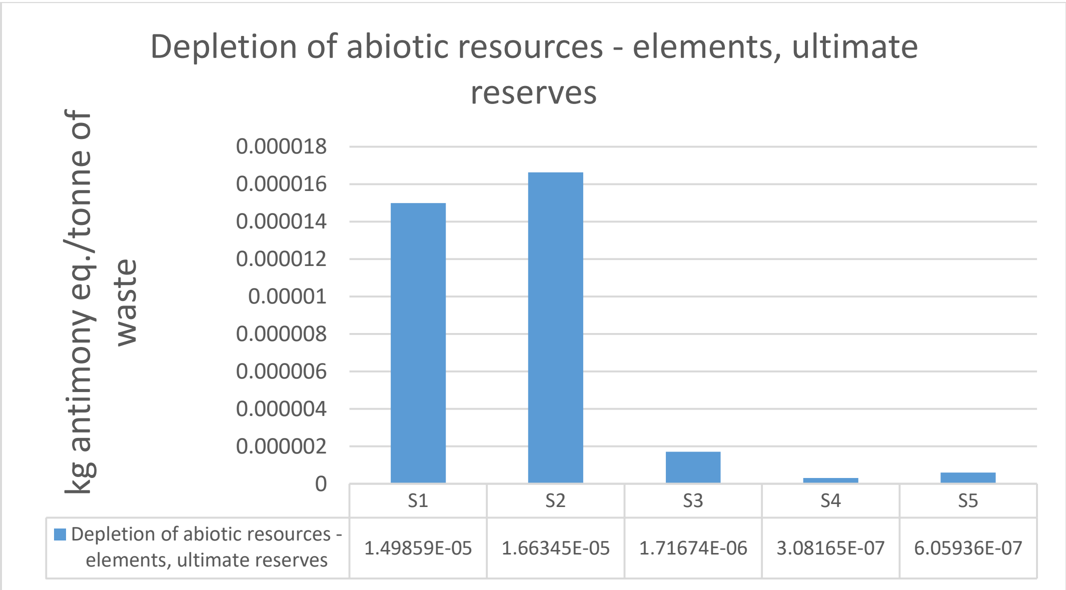


Figure 6.3 Depletion of Abiotic Resources (elements, ultimate reserves)

6.4 Depletion Potential of Fossil Fuel Resources

Depletion basically calculates the predetermined indicators which are selected as representative for fossil fuel consumption. The data is calculated in energy with unit of Mega Joules (Oers, et al., 2020).

Figure 6.4 presents the fossil fuel depletion impact occurs for each scenario. The main indicator is fuel used for transportation vehicles and operation of incineration, composting and MRF units. The most crediting alternative system is Scenario 3. Scenario 1 consists of only landfilling operation results as the highest of all other scenarios.

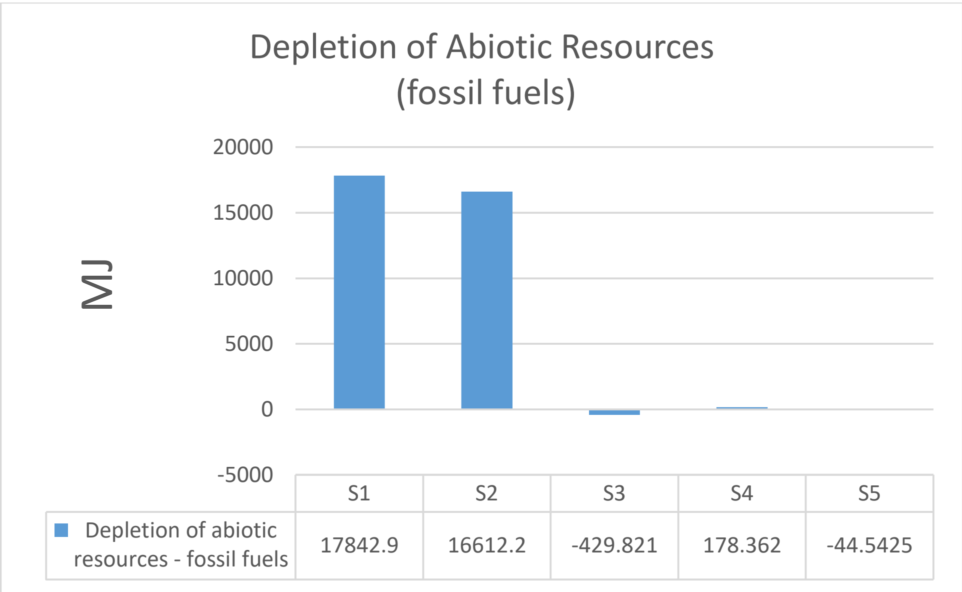


Figure 6.4 Depletion of Abiotic Resources (fossil fuels)

6.5 Eutrophication Potential

Eutrophication is boost of minerals and nutrients in a water resources, which causes deterioration of water quality (Heijungs, et al., 1992).

In CML (baseline) 2015 method, mainly Phosphates, Nitrogen, and Ammonia are accounted to demonstrate Eutrophication. Even though there are impermeable linings, leachate is never prevented 100% according to the literature. Long-term landfill leachate is one of the main reasons for eutrophication. Some water emissions are also possible from incineration residue. However, greatest impact mostly occurs from landfill leachates. The Figure 6.5 indicates the eutrophication impact for each scenario.

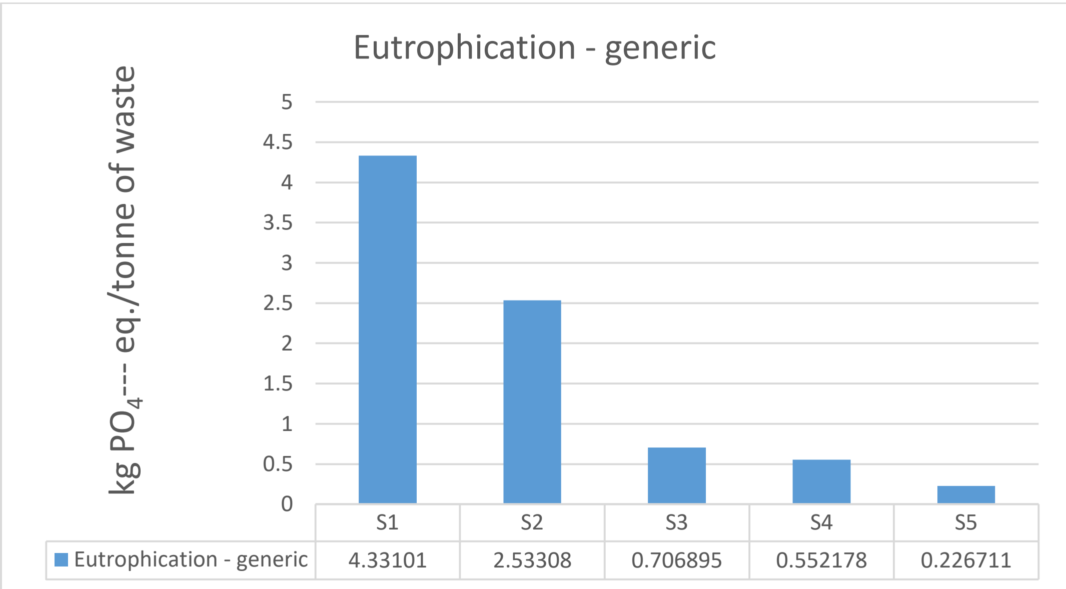


Figure 6.5 Eutrophication

6.6 Freshwater Aquatic Eco-toxicity Potential

Toxic substances emissions to air, soil, and water is considered as exposure and effects (Dincer & Bicer, 2018).

CML (baseline) 2015 method accounts mostly metal substances that are emitted from processes such as copper, zinc, mercury, lead, and many more, then they are all neutralised in to equivalent of dichlorobenzene. Groundwater and soil emission are mostly seen from long-term landfill leachate; and air emission is associated with surface water. Air emission appears from the direct release at incineration facilities and some amount from metal recovery facilities. Figure 6.6 illustrates the levels of emissions comparing each scenario.

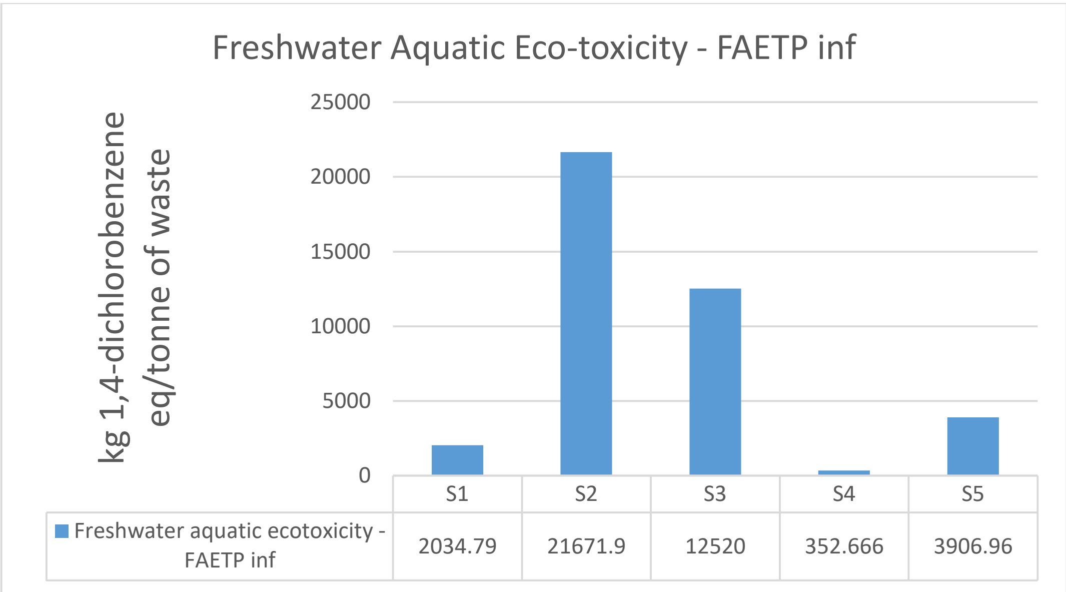


Figure 6.6 Freshwater Aquatic Eco-toxicity

6.7 Human Toxicity Potential

Human toxicity evaluates the substances that are dangerous to human health to inhale, ingest, be exposed of or contact. Therefore, the calculation reflects the potential harm when a unit of certain chemicals are released to the environment by the processes involved. Harmful chemicals are mostly released through electricity production process from fossil fuels (Acero, et al., 2016).

CML (baseline) 2015 measures Human toxicity from the metals and chemical compounds from the long-term water, air, and soil emissions. Since evaluated substances are almost similar to Freshwater Aquatic Eco-toxicity Potential (FAETP) calculations, the same indicators are influenced as impact reason. Hence results appear to be in similar phenomenon as FAETP. Figure 6.7 demonstrates the Human Toxicity potential for five tested scenarios.

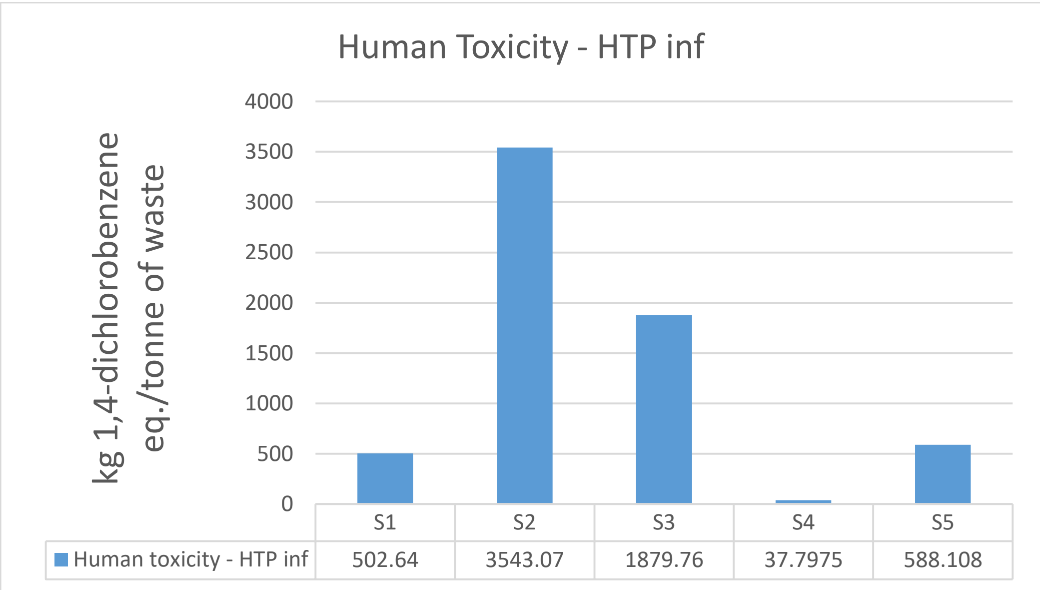


Figure 6.7 Human Toxicity

6.8 Marine Aquatic Eco-toxicity Potential

Similar to FAETP and Human Toxicity the impact method considers the metals emitted from the processes. Long-term and short-term emissions are associated as ground water and surface water pollution, respectively. Air emissions from landfill gas or incineration residue, and water and soil emissions from the landfill leachate are some of the indicators. Substances such as compounds of Benzene are also accounted as soil emissions. Figure 6.8 presents Marine Aquatic Eco-toxicity (MAETP) for each scenario.

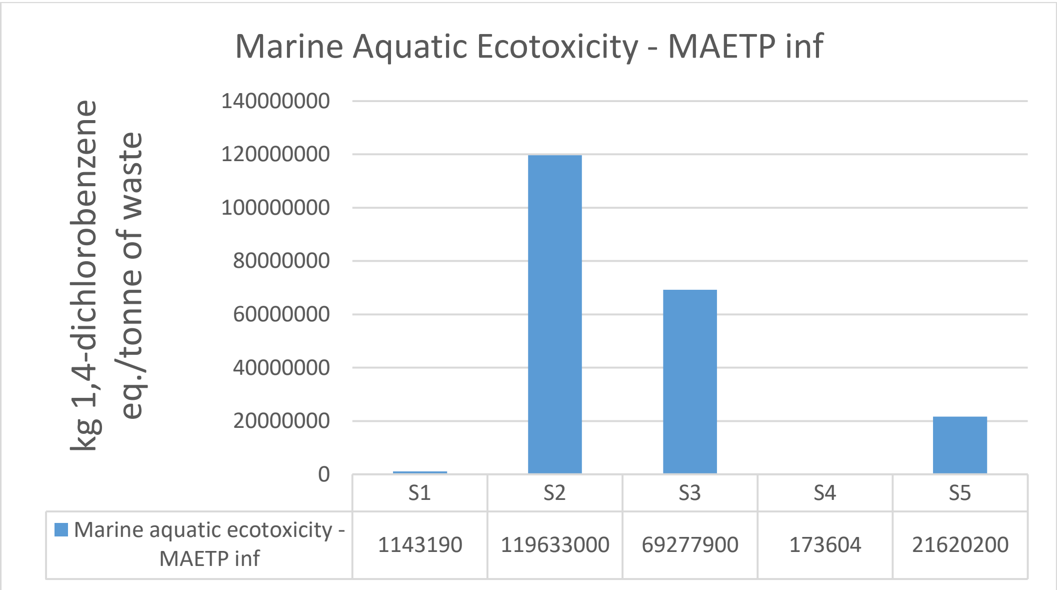


Figure 6.8 Marine Aquatic Eco-toxicity

6.9 Ozone Layer Depletion Potential

The ozone layer related substances are calculated relative to the potential of chlorofluorocarbons (CFC-11), and therefore the ozone depletion potentials are given as CFC-11 equivalents (Solomon & Albritton, 1992).

Ethane, propane and methane compounds that are emitted to air are the main impact indicators when calculating the ozone layer depletion potential (ODP) in CML (baseline) 2015 method. Methane from biogenic resources are not directly associated with ODP. The impact analysis on ozone depletion is shown in Figure 6.9.

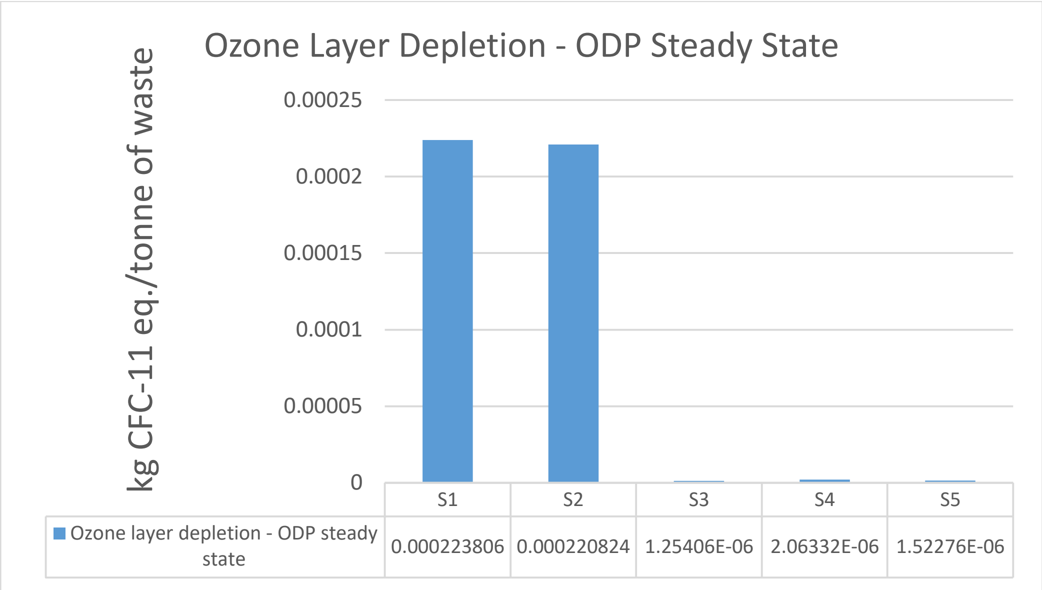
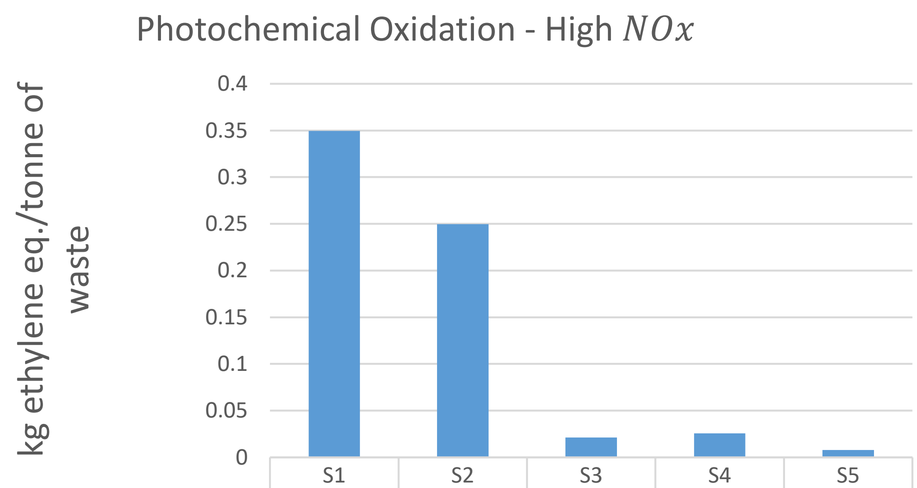


Figure 6.9 Ozone Layer Depletion

6.10 Photochemical Oxidation Potential

Degradation of volatile organic compounds in light and Nitrogen Oxide (NO_x) causes photochemical oxidation (Photochemical Ozone Formation). Ozone compounds are reactive compounds and there are harmful biological effects on plants, animals, and human (Stranddorf, et al., 2003).

Also, carbon monoxides from the processes such as waste transportation vehicles, methyl, benzene, ethanol releases from the chemicals are directly accounted for photochemical oxidation. Waste containing chemicals mostly contain these elements and landfill gas includes NO_x and chemicals mentioned above. Therefore, processes involving landfill without any material recovery or composting unit appears to be reasonably higher than the other systems. Figure 6.10 demonstrates the Photochemical Oxidation impact potential of each scenario.



	S1	S2	S3	S4	S5
Photochemical oxidation - high Nox	0.349681	0.249742	0.0212298	0.0257802	0.00769204

Figure 6.10 Photochemical Oxidation

6.11 Terrestrial Eco-toxicity Potential

Terrestrial eco-toxicity occurs mostly because of pesticide emissions which damages and pollutes agricultural soil and another toxicity cause is the use of sulphuric acid and steam during a conversion process (Aroussi & Benyahia, 2012).

Soil related processes are mostly produce leachate which are landfill and incineration. The Figure 6.11 illustrates that as the landfilling proportion gets lower or increases so does the toxicity level. Thus, landfill facility seems to be directly a main cause of terrestrial eco-toxicity. Implementing MRFs before incineration and landfilling in Scenario 3 results in toxicity credit. The levels slightly increase when composting is involved instead of incineration in Scenario 4. Scenario 5 also demonstrated credit. This is because of the decreased amount of landfilling material being processed after MRF, compost and incineration.

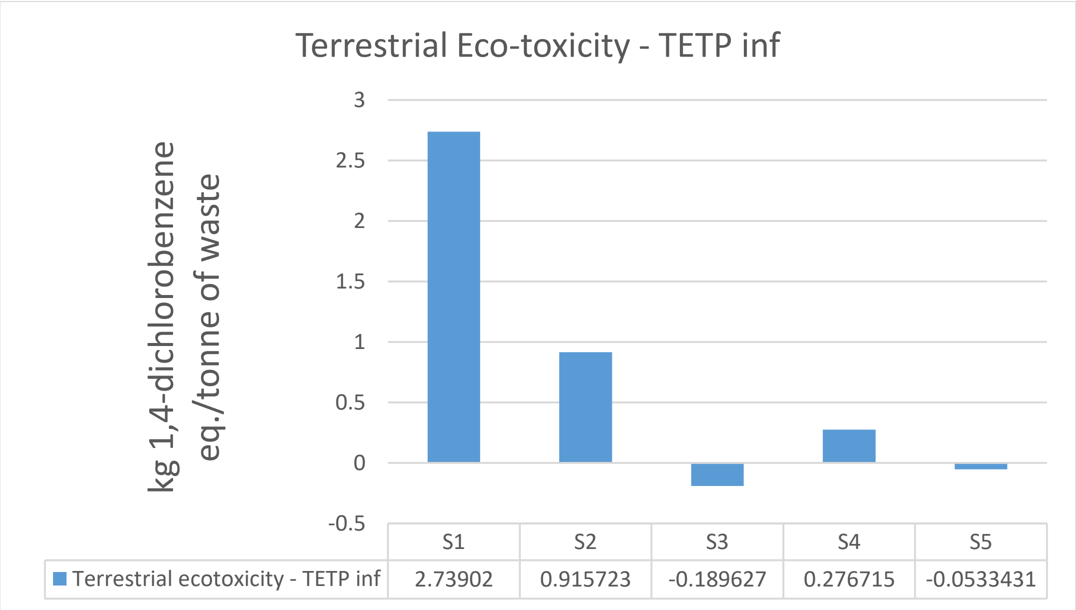


Figure 6.11 Terrestrial Eco-toxicity

6.12 Sensitivity Analysis and Validation

6.12.1 Impact Assessment Method Validation

Comparing two different impact assessment methods is a way of measuring the validity of the impact assessment method used throughout the study. In Figure 6.12, Sensitivity of the Climate Change Impact by using CML (baseline) [v4.4, January 2015] and ILCD 2011, midpoint [v1.0.10, August 2016] impact assessment methods are given. Figure 6.12 shows the climate change impact category results for both methods which appears to be the only category to have same units in both methods. The differences between the impact assessment methods are below 0.5% for each scenario which indicates that there were no significant changes between the impact assessment methods.

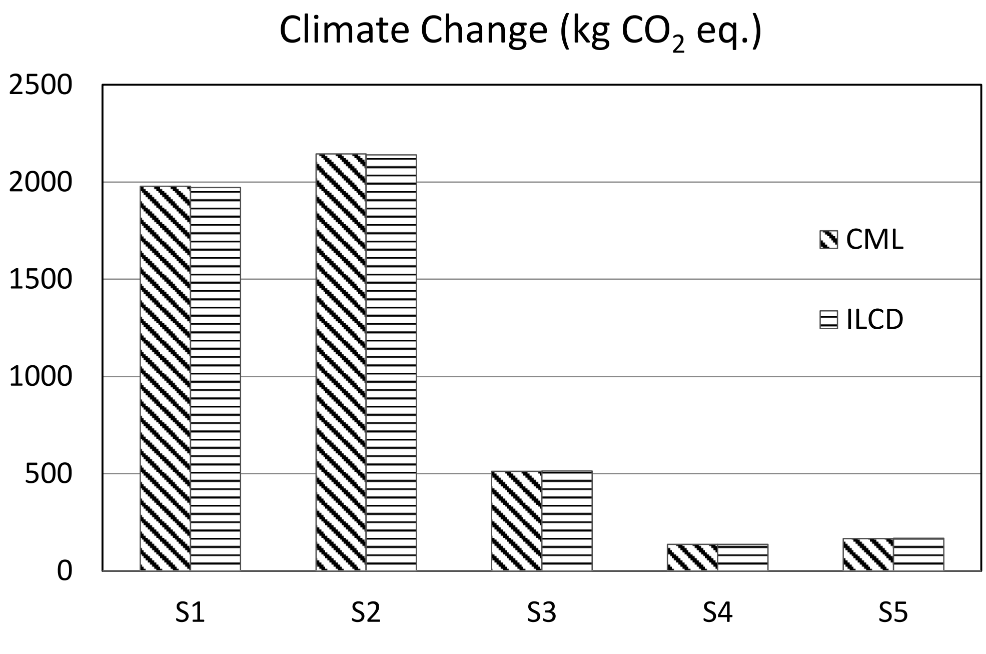


Figure 6.12 Sensitivity analysis with CML (baseline) [v4.4, January 2015] and ILCD 2011, midpoint [v1.0.10, August 2016] impact assessment methods.

6.12.2 Sensitivity Analysis

In order to assess the key parameters of the study, one factor at a time sensitivity analysis have been carried out. In this method, a selected parameter should be varied one at a time to obtain the key parameter that has a significant impact on emissions (Maalouf & El-Fadel, 2019) . Organic waste fraction is selected to be used as the examined parameter. Organic waste fraction is the sum of kitchen waste 39.9% and garden waste 2.8% from the Table 4.3. The fraction is changed from 42.7% to 51.2%, increasing by 20 % for different scenarios. The results are evaluated as the lowest impact change occurs when the values are closer to zero percent and the highest as the value is greater. Negative and positive values indicate benefit and adversative environmental impact, respectively. Table 6.1 shows the percentage change ratios of each impact category that are resulted from increase in the organic waste for Scenario 1 (S1), Scenario 2 (S2) and Scenario 4 (S4).

Scenario 1 consists of landfill facility solely operating and all (100%) MSW is landfilled. The system overall is not incorporated with waste treatment processes other than natural degradation of organic compounds. Therefore, increasing organic waste proportion did not cause a great difference on impact categories. The highest change rate is -2.86% for human toxicity and the minimum impact is seen on eutrophication as -0.13% change. This is because landfill leachate is the main indicator over the impact categories and changing the organic proportion does not demonstrate significant effect over all categories.

In Scenario 2, incineration and landfilling facilities are jointly operating. Overall impact of 20% increase in organic waste composition has contributed positively on human toxicity with - 4.58 % where negative increase on FAETP with 6.47 % occurs.

Looking at Scenario 4, which includes composting and material recovery with landfill facility, the change in rate percentages appears to be more significant when compared to other two scenarios. Increasing the organic waste ratio also increases the amount of waste volume to be composted. Not only that, the presence of MRF together with composting facility decreases the overall volume of landfilled waste as well. All impact categories are demonstrating negative values, which indicates benefit to the impact category. Acidification potential appears to be the highest impact and it is reduced when organic waste is increased by - 61.89 %

Scenario 4 follows a negative value with highest percentage trend when compared with other two scenarios. This is because, the most efficient method of organic waste treatment is composting. Therefore, considering that S1 and S2 is not associated with any composting process, the impact expectation is relatively low. Consequently, impact categories that are sensitive to organic waste demonstrates relatively low and high impact rate through different scenarios such as Human Toxicity and Climate Change.

Table 6.1 Sensitivity to organic waste fraction

Impact Categories	*S1**	*S2*	*S4*
Acidification Potential	0.28%	0.43%	-61.89%
Climate Change - GWP100	-2.02%	-4.33%	-30.99%
Depletion of Abiotic Resources - elements. ultimate reserves	2.27%	4.12%	-15.71%
Depletion of Abiotic Resources - fossil fuels	1.64%	2.39%	-15.91%
Ozone Layer Depletion	1.44%	2.67%	-15.74%
Eutrophication	-0.13%	-0.26%	-6.44%
Freshwater Aquatic Eco-toxicity - FAETP inf	2.69%	6.47%	-15.58%
Human Toxicity - HTP inf	-2.86%	-4.58%	-21.62%

Marine Aquatic Eco-toxicity - MAETP inf	0.71%	1.45%	-15.65%
Terrestrial Eco-toxicity - TETP inf	0.66%	1.20%	-15.93%
Photochemical Oxidation - high Nox	-0.71%	-1.32%	-18.15%

*Scenario 1 represents the current operating landfill facility in North Cyprus.

6.13 Interpretation of the Impact Category Results

For the current situation in North Cyprus, Scenario-1 was planned accordingly as the base-case and the results of S 1 are real life impact potentials if waste management scheme continues to be used the same way. Looking at the impact category results for S1, only landfill to 8 out of 11 appears amongst the highest impact potential levels when the current waste characteristics applied. Also, according to Figure 6.5 S1 is the highest contributor in Eutrophication when compared to others. Hence, landfill facility appears to be the main cause amongst other treatment or disposal methods. As the use of landfill gets less in each scenario with the involvement of other processes the eutrophication factor also decreases. This also indicated that the current system being applied in North Cyprus is not the best option in terms of eutrophication. Moreover, although Landfilling does not involve any combustion process, the landfill biogas is being emitted and the leachate that occurs from the landfill waste causes peak impact in acidification. Therefore, the assessment proves that current waste management scheme is not sufficient and sustainable according to the waste composition data.

Scenario 2 demonstrates slightly less impact levels when compared to S1 because of the incineration facility. However, peak impact levels are seen in FAETP, Human Toxicity, Marine Aquatic Eco-toxicity, and Climate Change categories amongst all scenarios. In overall, S1 and S2 demonstrates the highest impact results when compared to the other scenarios.

In Scenario-3 processes proves lower impact levels compared to S1 and S2. There are even some credits determined in Acidification, Terrestrial Eco-toxicity and Depletion of fossil fuel impact levels as a negative value. This is because, incineration is done after material recovery and residue is landfilled with other solid waste. Therefore, less materials are disposed at landfilling and incineration facilities. Further, Impact categories mostly affected by the incineration facility in S1 depicts relatively less impact results due to introduction of MRF. The results of ODP do not seem related to incineration but to materials recovery and recycling.

Scenario-4 appears to be the least contributor to Climate Change (GWP 100) which involves MRF, Composting and Landfilling facilities. Recycling and composting affect the impact to decline when compared to S-1 and -S2 with only Landfill and Incineration facilities. This is because, overall treated waste volume is reduced as new facilities are introduced in each scenario. S1 and S4 Fossil depletion results indicate that in all of the methods other than landfilling, the waste is somehow recovered, recycled, and gained back to the cycle aiding in reduction of fossil fuel use in long term. There are two alternative systems with relatively lower freshwater toxicity which are S1 and S4. The most common factor between these scenarios is that there is not an incineration process involved within the system. Those which appear to involve incineration presents difference in toxicity depending on the waste proportion disposed at the incineration facility. For instance, in Scenario-5, all alternative three methods are integrated and less waste is being incinerated while in S2 only landfill is adjusting incineration.

From the sensitivity analysis, the sensitivity of Scenario-4 is proved to be high to organic waste. Considering the high portion of food waste ratio in North Cyprus waste characteristics, S4 appears to be most suitable scenario in environmental perspective.

CHAPTER 7

CONCLUSIONS

Population growth rate has been a concern for many countries in regards of municipal solid waste management. Integrated solid waste management was developed as a sustainable long term solution for this obstacle. Growing cities together with the population growth in North Cyprus has also become problematic from municipal solid waste management point of view.

In this study, data from a previous North Cyprus solid waste characterisation study has been used to establish a Life Cycle Assessment and find the optimal integrated management option. Five different combined waste management systems were created in the study and the available data was used to asses the performances of the scenarios by the help of the OpenLCA software programme.

The software uses database which combines all the possible factors causing emissions as inputs and outputs through the life cycle of the processes. In this study, Ecoinvent database has been used for preset data. Impact analysis were carried by using the CML-IA (baseline) 2015 method which uses fundamental calculation methods to account input flows to diagnose social and environmental impacts of the runned processes. The five different combined systems were compared based on their performances in 11 different environmental impact categories. The results showed consistency with the literature.

The approach of this study is that the results, calculations and evaluations, are based on the compositional characteristics of the solid waste being generated. The optimal solution is the best option depending on the characteristics and the most suitable disposal selection.

Knowing that, landfill is the only method applied currently and results implicate the inadequacy of the method. There isn’t any benefit obtained from the facility. In integrated systems, landfill is the final port of the extractions of other processes and some waste that cannot be treated. Thus, it is used as a buffer to other processes.

In all of the impact category scenario comparison charts, it is easy to see that the most harmful method to use is incineration. It mostly induce to the highest values of impact results when compared with other processes and this is quite coherent since the highest proportion of solid waste consist of recyclable wastes followed by organic and kitchen wastes.

From the sustainable environmental point of view, the results demonstrate the existing MSW management scheme is not the best sustainable option with the current solid waste composition. However, it is also easy to interpret that involving MRF systems and composting contributes on reducing the overall impact levels at all scenarios. This is also because the waste is separated and less proportion is involved in inceneration and landfill. Therefore, the waste characteristics of the country showed good harmony with MRF and composting processes.

On the other hand, incineration facility is a benefitiary technology which disposes waste and produces energy at the same time. Though with the waste characteristics, it may turn out to be a source for emmission polluting the environment more than benefitting.

Overall, according to the results of 11 impact categories, it can be concluded that Scenario-4 presents the minimum impact to the nature. Scenario-4 assumes that the waste is separated at the source depending on the material and collected separately. Further, a material recovery facility eliminates the waste to be disposed in parallel with a composting facility. In composting facility, organic waste is processed to generate energy and also reduce the waste amount to be landfilled. According to the waste characteristics data, more than half of the North Cyprus municipal solid waste is either organic or recyclable waste. Hence, treating and recovering more than half of the solid waste increases the lifetime of the Landfill Facility since reduced waste volume would be landfilled. Also environmental impacts of landfilling is reduced due to decreased landfill volume.   However to comment if it is sustainable or not an economical analysis which will include carbon credit and break even point should be accounted.

Even if Material Recovery Facilities cannot be employed for financial obstacles, recyclable waste could be separated and exported for trade to other countries.

Composting Facility is also proposed along with landfilling. Not only the compost would benefit the nation-wide agriculture, but also gaining energy would subsidy another deprivation through the island.

Applying both facilities would help local production rates to increase since most of the products, food and services are important to the island. Hence, both facilities enable materials as raw material to be reused at production levels. As a result, adopting integrated solid waste management system creates sustainability on economic circulation as well as environment.

7.1 Limitations of the Study

Area specific or local data is one of the significant limitations of the study. Other than characterisation data and generic data about the current process, detailed information such as vehicle types used for waste collection, number of vehicles, routing of collection are not obtained. Since the functional unit is 1 tonne of waste and the calculations are run over the functional unit reference flow, data like carriage routing, and vehicle types and features were not critical for the life cycle evaluation.

Another limitation would be software specific limitations. The software used is a free software which does not provide all the features a commercial software would conclude. Full life cycle assessment end report is one of the lacking features the OpenLCA software offers.

7.2 Future work

A detailed field research could be done for more specified data. Some of the data is used from Ecoinvent database can be obtained by a detailed further research. This data includes fuel consumption levels of vehicles and specifying vehicle types and obtaining emission rates and emission substances of vehicles. Also, a more recent characterisation study could be done and municipal solid waste inputs could be detailed when input to the system. For example, instead of plastic packaging, plastics could be categorised and input separately depending on its plastic types. The simulation created in this study is alternated dataset according to North Cyprus. Therefore, by obtaining local data, created data-sets can be implemented as an input or output data on the ready simulation done through this study to run and result for more relative analysis.

A future work could be done to analyse costs of implementing each scenario to evaluate in both financial and environmental terms and conclude on a sustainable option. There are studies for other countries that analysed and listed the cost data for processes in the literature. Also, there are studies that these values are used to calculate the average as the cost of processes. By applying the same method would conclude same results as the other studies. By applying previously used cost calculation data which would lead to same result as previous literature, would affect the results not to be specified for North Cyprus. Another problem is that previous papers concluding the costs already have an implemented facility within their country in another city to obtain costs and apply on scenario-based research. However, in North Cyprus there is only one treatment method being applied at the moment.

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