EVALUATION OF WASTE MANAGEMENT SYSTEM IN IZMIR-KARABURUN PENINSULA FROM SUSTAINABILITY PERSPECTIVE

A Thesis Submitted to
the Graduate School of
İzmir Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

in Environmental Engineering

by
Haniyeh HAJATNIA

July 2022
İZMİR

ACKNOWLEDGEMENTS

First and foremost, I would like to express my heartfelt and most sincere gratitude to my advisor, Assoc. Prof. Dr. Hatice Eser ÖKTEN for her enthusiasm on the subject and for providing guidance and feedback throughout this experience.

I would also like to thank my Master’s Thesis Committee and Jury Members, Assoc. Prof. Fehmi Görkem ÜÇTUĞ and Assist. Prof. Dr. Mehmet Ali KÜÇÜKER for their time and insightful contributions.

Furthermore, I am also thankful to my friend, classmate, and Ph.D. candidate, Bora OKAN, for his unwavering support and dedication for many valuable hours.

Last but not least, I am grateful to my father, who has not been with us for many years but whose memories we cherish in our hearts. I sincerely thank my mother, for I could not have been here today without her patience, love, and strength. I owe my deepest gratitude to Peyman; I am endlessly thankful for the unreserved love and support through the entire thesis process and every day. Finally, to my little sister and my proofreader for always being there for me and telling me that I am awesome even when I didn't feel that way.

ABSTRACT

EVALUATION OF WASTE MANAGEMENT SYSTEM IN IZMIR-KARABURUN PENINSULA FROM SUSTAINABILITY PERSPECTIVE

Global solid waste generation is constantly rising, hence the need for management strategies that implement environmental improvements. The sustainable municipal solid waste management strategy for municipalities must include collection and transportation. The collection and transportation sector have been neglected while it is one of the most significant polluters. As a result, this study aims to model municipal solid waste transportation using Life Cycle Assessment (LCA) software which we used CCalC2 for this study and CML2001 methodology was used. To demonstrate how different approaches to waste management through transportation can reduce environmental impacts, LCA modeling was done for the three districts of Urla, Çeşme, and Karaburun, all of which are located on the Karaburun Peninsula. Each district was assigned three scenarios, with Scenario 0 representing current municipal practices, Scenario 1 representing a 50% reduction in plastic waste, and Scenario 2 representing a 50% reduction in all renewables. Results showed that only plastic separation might not be enough to achieve significant e reductions in environmental impacts. It has been demonstrated that in the transportation sector of Urla and Çeşme, Scenario 1 had a CO_2 reduction of 3.7% and Karaburun had a CO_2 reduction of 3.8% while Scenario 2 represented at least a 20% reduction of carbon footprint in all three districts. Findings of this research will support municipalities in the roadmaps they will choose for the Municipal Solid Waste Management applications.

ÖZET

İZMİR-KARABURUN YARIMADASINDAKİ ATIK YÖNETİM SİSTEMİNİN SÜRDÜRÜLEBİLİRLİK PERSPEKTİFİNDEN DEĞERLENDİRİLMESİ

Küresel katı atık üretimi ile birlikte çevresel indikatörlerde iyileşmeye yol açabilecek yönetim stratejilerine ihtiyaç artmaktadır. Belediyeler için sürdürülebilir belediye katı atık yönetimi stratejisi, toplama ve taşımayı içermelidir. Toplama ve taşıma sektörü en önemli kirleticilerden biri olmakla birlikte ihmal edilmiştir. Sonuç olarak bu çalışma, belediye katı atık taşımacılığını Yaşam Döngü Değerlendirmesi (YDD) yazılımı kullanarak modellemeyi amaçlamaktadır. Ulaşım yoluyla atık yönetimine farklı yaklaşımların çevresel etkileri nasıl azaltabileceğini göstermek için, tümü Karaburun Yarımadasında bulunan Urla, Çeşme ve Karaburun ilçeleri için YDD modellemesi yapıldı. Her bölgede, halihazırdaki belediye uygulamalarını temsil eden Senaryo 0, plastik atıklarda %50'lik bir azalmayı temsil eden Senaryo 1 ve tüm yenilenebilir kaynaklarda %50'lik bir azalmayı temsil eden Senaryo 2 olmak üzere üç senaryo tanımlanmıştır. Sonuçlar, çevresel etkiyi azaltma hedefine ulaşmak için yalnızca plastikleri ayırmanın yeterli olmayabileceğini göstermektedir. Urla ve Çeşme ulaşım sektöründe senaryolardan birinde % 3,7 CO_2 azaltımının olduğu ve Karaburun'da % 3,8 CO_2 azaltımının olduğu, Senaryo 2'nin ise her üç ilçede de karbon ayak izinde en az % 20'lik bir azalmayı temsil ettiği ortaya konmuştur. Bu araştırmadan elde edilen bulgular, ilgili belediyelerin sürdürülebilir Evsel Katı Atık Yönetimi uygulamalarında izleyecekleri yol haritasını belirlemelerinde destek olacaktır.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Table **Page**

CHAPTER 1

INTRODUCTION

Caused by the increase in population and industrialization, especially in developing countries, municipal solid waste management (MSWM) is critical in terms of sustainability due to the overpopulation growth rate, urbanization, industrialization, and economic expansion. As people became wealthier and as availability and accessibility of goods increased due to improvements in the logistics sector, solid waste generation increased simultaneously (R. Rajput et al., 2009). Despite country-specific reductions in MSW (such as Japan) as a result of significant efforts, an increase of roughly 70% is anticipated for Asian countries by 2050. Moreover, in the next 25 years, worldwide generation of MSW is expected to reach 3.4 billion tons (Kaza et al., 2018). The municipal waste generation trends of several OECD (The Organization for Economic Cooperation and Development) countries have been increasing and decreasing throughout the years. However, when the most recent years' data were examined a clear increasing trend was observed for countries such as Türkiye and Germany (Figure 1.1).

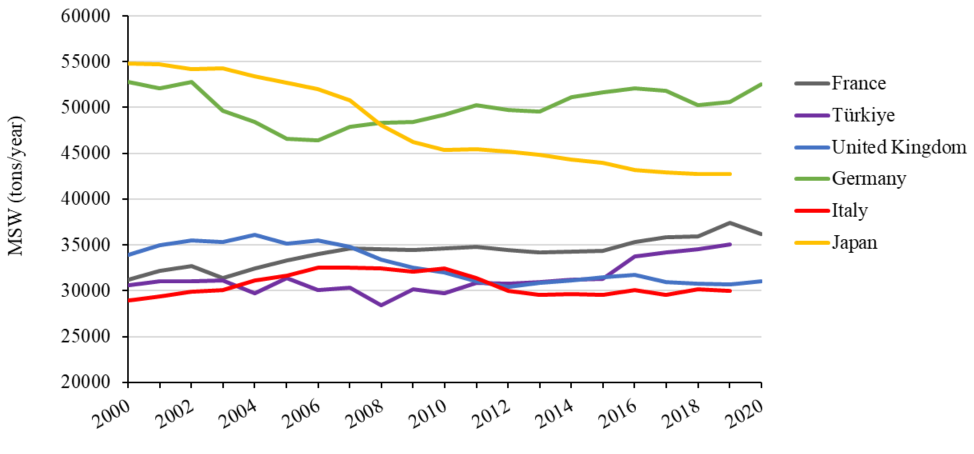


Figure 1.1 Municipal solid waste generation for countries (2000-2020) (OECD, 2022).

Since municipal solid waste is one of the major problems on our planet today, the management of this issue has gained significant importance. Therefore, waste collection, transportation, processing and disposal stages have become essential for safe and sustainable practices of municipal solid waste management (MSWM) for urban areas (Asefi et al., 2018). The approach to MSWM has evolved significantly in the last decades, shifting the weight from treatment and disposal to source reduction and reuse.

1.1 Evolution of Municipal Solid Waste Management

In the era of climate change and resource depletion, sustainable municipal solid waste management practices not only facilitate reduction in overall emissions but also present an important source for elements, energy, etc. (urban mines). With the rapid urbanization in the second half of the 20th century, the focus was mostly on transferring the municipal waste away from the cities. Early MSWM generally disposed of waste in open dumps, which was an improper method of disposal because such unsanitary landfills posed environmental risks and led to ecological imbalances involving air, water, and land pollution. (Tchnobanoglous et al.,1993). In fact, on April 28, 1993 the methane gas accumulated in an open dump in Ümraniye, Türkiye, has exploded resulting in 50 deaths (38 recorded, bodies of 12 people were never recovered). Waste was being transferred to the open dump for 4.5 years and there were no collection systems for biogas or leachate. Safe disposal of municipal solid waste includes landfills as can be observed in the old MSWM hierarchy (Figure 1.2). Landfills are engineered structures that enable safe biodegradation of waste while collecting the produced leachate and biogas for further treatment. That hierarchy assessed the waste as something to get rid of as fast as possible. Then, firstly the land unavailability became an issue, followed by the overall emissions related to municipal waste components.

Urban areas have been expanding due to urbanization and the fields that are suitable for landfilling began to overlap with the urban areas. The landfill sites need to be in a safe distance from the human settlements, airports (due to feeding bird flocks), and water resources (in case of any accidental leaching). Moreover, once a site is used for landfilling it cannot be used for any other structure due to possibility of consolidation in the ground. The environmental footprints of the components of municipal solid waste were questioned when the dire effects of climate change started to attract attention. Life cycle assessment studies have shown that the intrinsic cradle-to-grave operation of the old MSWM hierarchy dismisses the value still embedded in the waste. For example, in the production and sale of a loaf of bread, all stages from the farmland to bakery needs to be evaluated. Emissions data for growing the wheat including fertilizer, water, pesticide use and harvesting, transportation to the mill, processing grains to produce flour, transporting the flour to a bakery, machinery to produce dough (with other inputs such as yeast and water), baking and packaging should be collected and analyzed. Therefore, a stale loaf of bread that is put in the garbage is never simply a loaf of bread, it entails energy and raw materials.

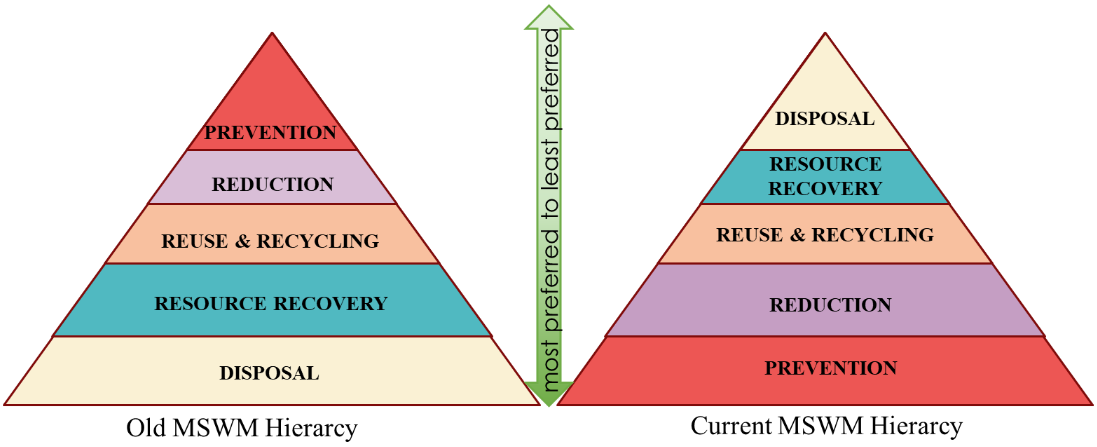


Figure 1.2 MSWM Hierarchies

The current hierarchy ranks the stages in a reverse order by emphasizing prevention and reduction of waste generation the most and disposal of waste the least. Then reuse, recycle and re-purpose stages become important. For example, a worn out t-shirt can be downcycled to become a cleaning fabric or a metal box can be re-purposed as a flower pot. In the next stage, the current MSWM hierarchy evaluates the waste as a resource for material (i.e. precious elements) and energy. RDC Environment SA (2019) has conducted an LCA with aluminum cans for the years 2006 and 2016. The functional unit was one thousand 33 cl aluminum beverage cans. When the authors compared the years 2006 and 2016, they have found significant decreases in the environmental impacts. The global warming potential was calculated to be 115.4 kg CO_2-eq in 2006 and it decreased to 77.2 kg CO_2-eq in 2016. Acidification potential decreased from 0.643 (2006) to 0.317 moles H^+-eq (2016). Water scarcity potential decreased from 13.6 (2006) to 10.1 m^3 H_2O-eq (2016). The reason for these decreases was explained with the increase in percentage of recycled aluminum cans. Therefore, the cradle-to-cradle circular approach not only serves to reduce greenhouse gas emissions and hence mitigate the effects of climate change, it also mitigates other environmental impacts.

1.2 Municipal Solid Waste Management in Türkiye

Generated municipal solid waste in Türkiye has increased from 31 million tons in 2001 to 34.7 million tons in 2020 (TURKSTAT, 2022). The main disposal method has shifted from municipality dumping site to landfills starting from 2004 (Figure 1.3). Currently the main MSW disposal method is landfilling, accounting for the 69.4% of the collected waste. Recently, as recycling efforts are accelerating due to nation-wide projects such as Zero Waste Project (http://zerowaste.gov.tr/), some small portion of the collected waste was being sent to recovery facilities.

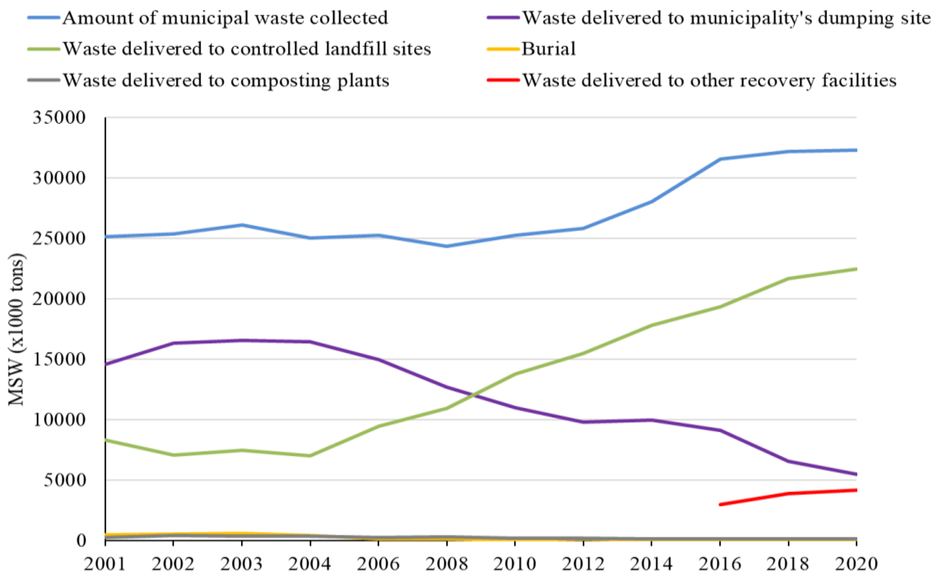


Figure 1.3 Waste distribution based on disposal method

SWMAP, or the Solid Waste Management Action Plan, was released by the Turkish Ministry of Environment and Forestry in 2008. This plan illustrates the state of affairs in Turkey and establishes a strategic timetable for waste management activities. Studies on waste management are being planned at both the county and regional levels as a result of the SWMAP (TMEF, 2008). The metropolitan municipalities are in charge of setting up solid waste management plans and providing source collection, transportation, and recovery of the municipal, industrial, and medical wastes, as per the Turkish Law of Metropolitan Municipalities. (Official Gazette, 2004). Solid waste is usually carelessly dumped in open pits throughout Turkey. This process results in a number of environmental issues, including surface and underground water pollution, unchecked landfill gas emissions into the atmosphere, the formation of dust and odors, and aesthetic pollution. In addition, as the population grows, urban areas expand and landfill areas are engulfed by cities. Creating a regional and national waste plan and ensuring its sustainability is the SWMAP's main goal. (Gorkem Akinci, 2012).

1.3 Motivation

Environmental issues caused by MSW management include global warming, risks to human health, photochemical ozone formation, stratospheric ozone depletion, ecosystem damage, and the depletion of renewable and mineral resources. (Laurent et al., 2014). Managing solid waste is a major challenge in developing nations. Due to the need for more land to eventually dispose of these solid wastes, disposal issues have become more challenging as the annual waste generation rises in direct proportion to population growth and urbanization. (Schubeler,1996). Municipal solid waste management practices that are applied in Türkiye need to change and evolve if sustainability were the primary concern. A tool is needed to calculate the environmental impacts of these practices in order to reduce the dangers that come with them. The life cycle assessment (LCA), which is based on ISO 14040 and 14044 standards, is the main methodology employed to assess the environmental impact of the various stages of any system in general and MSW management in particular. (ISO 2006a; 2006b) (Javier Pérez, 2020).

This thesis aims to quantify and compare the three scenarios that evaluated the environmental impacts of different municipal solid waste management practices. The scenarios assess the most optimum system for collection and transportation of MSW for Urla, Karaburun and Çeşme municipalities through life cycle assessment.

1.4 Thesis Overview

There are five chapters in this thesis. An overview of the history and development of solid waste management is provided in the first chapter's introduction. Environmental impacts change annually as a result of population growth, industrialization, and changes in the waste management hierarchy. The second chapter focuses on additional literature reviews in the fields of waste management and LCA studies to highlight any research gaps. The methodology chapter of the thesis is the third chapter. The case study is the Karaburun Peninsula, which includes the districts of Urla, Çeşme, and Karaburun. The municipality or research studies were used to collect the data for the related districts. In the selected LCA software, CCalC2, three scenarios—Business as usual, scenario 1 and scenario 2—were defined. Nine models in total were created to estimate the environmental effects of the peninsula of Karaburun's waste transportation system. The results from the modeling section and the methods used to get them are covered in the fourth chapter. The fifth chapter concluded this study with a few suggestions on the further studies that can be conducted.

CHAPTER 2

LITERATURE REVIEW

There has been a recent increase in the development of tools to support decision-making with regard to regional and national planning in various nations within the field of solid waste management. The alternative methods for managing solid waste follow a general hierarchy (waste hierarchy) that includes prevention, getting things ready for reuse, recycling, other types of recovery (like energy recovery), and disposal. (Directive 2008/98/EC2008).

Municipalities must collect and transport municipal solid wastes as part of their sustainable urban municipal solid waste management (MWSM) strategy (MSWs). However, the collection and transportation of MSWs have consistently proven to be challenging when modeling integrated MSWM systems while taking into account environmental and energy aspects. (Taşkın & Demir, 2020).

The pre-collection and treatment stages are followed by the collection/transport stage, during which the waste is gathered and transported to facilities for recovery and disposal. Each of these stages has an increasing effect; for example, materials that are discarded represent wasted energy and non-renewable resources; waste disposal creates air, soil, and water pollutants; and materials that are transported to treatment facilities produce air emissions, use energy, and have an adverse impact on the economy and public health due to congestion, damage, and accidents on the roads. (Miller et al., 2014).
In 2020, the global transportation sector generated about 7.3 billion metric tons of carbon dioxide (CO2) emissions, making it one of the worst polluters. (https://www.iea.org/topics/transport) After the energy sector, transportation-related activities in Turkey accounted for 22.3 percent of all GHG emissions. Additionally, the processes used to treat agricultural waste were responsible for 28.9% of the methane emissions. (Republic of Turkey Ministry of Environment and Urbanization, 2018).

The life cycle assessment (LCA) approach is a systematic method for assessing the environmental impacts over the course of a system, product, or process by taking into account energy, material, and emission criteria. (Curran, 2013). The most suitable management option in terms of the environment, economy, and society (social LCA) can be determined by comparing the environmental effects of various MSWM technologies using life cycle assessment (LCA). (Damgaard et al. 2010). LCA is used to assess, pinpoint, and diagnose any potential negative effects of various MSWM practices. According to reports, the LCA method holds promise for resolving issues. (Rebitzer et al. 2004). Consequently, a method with reduced environmental impacts and more resource recovery might be picked after evaluating the LCA of various waste treatment systems for particular wastes (Iqbal et al., 2020). The most practicable strategy for sustainable waste management and energy recovery has been suggested by a number of studies that used LCA of various waste kinds in a range of scenarios. (Arena et al., 2015; Dong et al., 2018b; Jensen et al., 2016).

The EU Landfill Directive started to be enforced in Nottingham in 2001, and Wang and He (2020) used four time-related scenarios to examine the past and future perspectives of municipal solid waste management through LCA. The 2030 landfill target was also assessed and compared to the historical scenarios, and the future scenario was created to meet the local 2025 recycling target. Both the GWP100 per ton of MSW and the GWP100 per person were measured in Nottingham, and both showed a decrease over the previous 16 years. The conclusion stated that the MSW management system could become a net saver of GWP100 by replacing open windrow composting with anaerobic digestion (AD), pretreating residual waste before incineration, and separating food waste at the source and treating it via AD.

In Ravi et al. (2021), the treatment processes were the scenarios for Visakhapatnam city in India. Scenario (S1) was the baseline scenario of an unlined landfill, which was the current practice in Visakhapatnam; the waste systems of MSW in Visakhapatnam (open dumping) contributed to significant environmental impacts compared to alternative scenarios, which were Scenario (S2): Engineered Landfill without Energy Recovery and Scenario (S5): Incineration with Energy Recovery and Residual Energy. There were five scenarios with engineered landfills, incineration, and anaerobic digestion of food waste for which different MSW management alternatives were compared based on a life cycle perspective As a result of being able to compare the environmental effects of several alternative waste treatment technologies, the results showed that the application of LCA was a useful tool for planning integrated waste management systems.

Dastjerdi et al. (2021) compared six scenarios in total, the current waste management (baseline scenario) and alternative scenarios, for residual waste in NSW, Australia. In this study, energy recovery played a crucial role in the management of residual waste before it was finally disposed of at a landfill. Scenario 1 (Sc1) made the supposition that all of the waste was combined and burned. According to Scenario 2 (Sc2), food waste was segregated, managed by AD, and three other waste classes were dumped. In scenario 3 (Sc3), non-combustible waste was landfilled, plastic and other combustible waste were treated through incineration, and food waste was separated and managed through AD. Each class of materials was handled differently in scenarios 4 and 5Plastic waste was dealt with through recycling, and combustible materials were used to recover energy through incineration and gasification. Contrarily, AD was used to treat food waste. According to the study, it is feasible to treat a different class of waste in NSW with a particular waste management technology in order to reduce environmental burdens and increase resource recovery.

In Taşkın and Demir (2020), the case study was on Kayseri city, located in Turkey, and three separate scenarios were modeled. Three transfer stations were assumed to be serving three regions for Scenario 1. The results showed that building a transfer station for transferring the MSWs instead of direct transfer to a sanitary landfill area reduced the GWP impacts by 44.9% and the cumulative energy demand scores by 51.7%. When modeling integrated sustainable MSWM systems, the LCA approach should be viewed as a useful decision-making tool for gathering data on environmental and energy impact levels.

The studies that were mentioned above were tabulated (Table 2.1). Lack of attention has been on the transportation and collection inventory of MSW compared to the treatment studies. Furthermore, there hasn't been a paper on Izmir's MSW collection optimization. In this study, we examine each step from the perspective of the municipalities and compute the scenarios using the actual methods for disposing of municipal solid waste in the cited districts rather than hypothetical facilities.

Table 2.1 Studies on the environmental performance of MSWM practices.

#	Country and Ref.	Functional Unit (FU), Software (SW) & Methods	Scenarios (S) or Options	Impact Assessment of Parameters	Results
1	Wang and He (2020) **Nottingham England**	1 ton MSW GWP 100a method	S1:2001/02 S2:2006/07 S3:2016/17 S4: future scenario	GWP	In Nottingham, the GWP100 per ton of MSW and the GWP100 per person have both decreased significantly over the past 16 years. The anaerobic digestion (AD) of food waste at the source, pretreating residual waste before incineration, and replacing open windrow composting with AD could make the MSW management system a net saver of GWP100, according to the LCA results of the future scenario.(Wang et al., 2020)
2	Cheela et al. (2021) **India**	1ton SW EASETECH Method	Scenario (S1): Baseline Scenario (S2): Engineered Landfill without Energy Recovery Scenario (S3): Engineered Landfill with Energy Recovery Scenario (S4): Anaerobic Digestion of Food Waste and ResiduesDumped in engineered Landfill without Energy Recovery Scenario (S5): Incineration with Energy Recovery	GWP, Terrestrial acidification, Freshwater eutrophication, Marine water eutrophication, Human toxicity, Terrestrial ecotoxicity, Freshwater ecotoxicity, Marine ecotoxicity	In terms of GWP, FEW, HTP, TE, FWT, and MET emissions reduction, scenarios S4 and 5 perform the best (S5). Both the S4 and S5 options combine processes with engineered landfills, which don't usually involve gas recovery. When comparing the environmental profiles, the most efficient treatment options are anaerobic digestion (S4) and incineration (S5).(Ravi et al., 2021)

(Cont. on next page)

Table 2.1 (cont.)

3	Dastjerdi (2021) **Australia**	1 ton SW OpenLCA 1.9, and by employing Ecoinvent V3.5	BSc (landfill) Sc1 (incineration) Sc2 (landfill and AD) Sc3 (integrated treatment) Sc4 (integrated treatment) Sc5 (integrated treatment)	Global warming, Human health Human carcinogenic toxicity Human non-carcinogenic toxicity Fine particulate matter formation Ozone formation, Human health Stratospheric ozone depletion	The highest amount of electricity per ton of waste was produced by Scenario 3, which combined anaerobic digestion for food waste, incineration for combustible and plastic waste, and landfilling for non-combustible waste. Additionally, the results of the LCA showed that scenario 5, which was assumed to treat plastic waste through recycling and combustible waste through gasification, could have the least negative effects on global warming, freshwater and marine ecotoxicity, and human non-carcinogenic toxicity.
4	Andersen (2012) **Denmark**	1 ton SW EASEWASTE organic household waste.	six home composting units, two incineration, and one landfill scenario	GW, POF, NE, AC, HTw, Hta	In most cases, composting at home had minimally harmful environmental effects.the environmental advantages of substituting compost for fertilizer and peat in backyard gardening (savings in GW, NE, ETw, HTw, and HTs) and the decrease in greenhouse gas emissions from the composting process (which contributes to GW).(Andersen et al., 2012)

(Cont. on next page)

Table 2.1 (cont.)

5	Taskin and Demir (2020) **Türkiye Eskisehir**	1 ton SW SimaPro method LCA	Three separate scenarios were designed for Eleven district municipalities to reveal a workable MSW system integration model.	ADP , ODP, GWP100a, AP, EP, POCP	The findings indicated that building a transfer station for the MSWs rather than transferring them directly to sanitary landfill areas could reduce the GWP impacts by 44.9 percent and the CED scores by 51.7 percent.(Taşkın & Demir, 2020)

GWP: Global Warming Potential; AP: Acidification Potential; HTP: Human Toxicity Potential; ODP: Ozone Depletion Potential; POCP: Photochemical Ozone Potential; EU: Eutrophication Potential; ADP: Abiotic Depletion Potential; POF: Photochemical Ozone Formation; NE: Nutrient Enrichment; AC: Acidification; HTw: Human Toxicity via water; HTa: Human Toxicity via air.

CHAPTER 3

MATERIALS AND METHODS

This thesis constructs three scenarios in order to quantify the environmental impacts of different municipal solid waste management practices within Urla, Karaburun and Çeşme municipalities. Life cycle assessment was conducted using the CCaLC2 software (http://www.ccalc.org.uk/ccalc2.php). The functional unit was chosen as 1 ton based on the rate of MSW generation, and the system's lifetime was considered ten years. In terms of operations, system boundary consisted of collection and transportation of MSWs. The disposal methods and their assessment were not included in this study. Therefore, practices such as composting, landfilling and waste-to-energy subsystems were excluded from the system boundaries (ILCD Handbook, 2010).

3.1 Case Study Sites

Izmir is the third most prominent and populous city in Turkey and is located in the western part with a 12,007 km^2 (4635,9 m^2) area and an elevation of 2 m (/izmir.ktb.gov.tr) with thirty districts in the province. One of Turkey's largest peninsulas is the Karaburun Peninsula, located in the country's far western region. The town (administrative center) Karaburun, which is situated at a crucial juncture in the Peninsula's extremity, shares the same name as the peninsula itself. It lies entirely within the boundaries of the province of İzmir, west of the city of İzmir, and is encircled by the Aegean Sea. Two other sections, Urla and eşme, have their areas entirely contained within the geographical formation of the peninsula, with the exception of the Karaburun district itself. The peninsula generally has a quite hilly earth structure. The Bozdag mass extending in the north-south direction in its central part forms the highest part of the peninsula, reaching 1212 meters (Akdag Hill). The mountains descend perpendicularly to the sea, dramatically affecting the Karaburun Peninsula's settlement. Some parts of Mordogan, Yeni Liman, Badembuku and Denizgiren regions are flat. The typical Mediterranean climate of Izmir is distinguished by long, hot, and dry summers and mild to cool rainy winters. Izmir's total annual precipitation averages 690 mm, with 78 percent of that falling from November through March. The average temperature over the past 33 years there has been recorded as 18 0C. (TSMS,2011).

According to the results of the Address Based Population Registration System (ADNKS) announced by the Turkish Statistical Institute in 2020, as of 31.12.2019, approximately 4.4 million people resided in İzmir. Compared to the previous year, the population increased by 46,732 people, and a population increase of 1.08% was experienced. The population density of İzmir is 364 persons/km^2 (Ve, 2020). The amount of municipal waste collected throughout the province in 2019 was 1,971,904 tons.

This thesis includes three municipalities, namely Urla, Çeşme and Karaburun, as the study sites (Figure 3.1). Due to their location, these districts are touristic in nature, which means that there are significant discrepancies between summer and winter populations. Depending on the fluctuations in population, the municipal solid waste production quantity and quality also changes. For example, the summer populations of Çeşme and Urla are estimated to be approximately 3-4 times the winter populations. Also in the spring and summer seasons, the garden wastes are increasing due to yard maintenance. However, the garden and yard wastes were not included in this study. Detailed information on the selected municipalities are given in the following sections.

Figure 3.1 Çeşme, Urla and Karaburun municipal territories (Source: ArcGIS Online, 03.07.2022)

3.1.1 Urla Municipality

Urla district center is 38 km from İzmir. There is the Aegean Sea in the north and south of Urla, Seferihisar district in the south, Çeşme district in the west and Güzelbahçe district in the east. The area of the district is 728 km^2. The main crops in the district, which is 65 meters above sea level, are olive, figs, laurel, and artichokes. Urla, is located across the Karaburun and Foça openings from the Izmir Gulf, the summer months are hot, the winter months are warm and rainy due to the constant breeze. The district does not have any important rivers. The annual average temperature in Urla, where the Mediterranean climate predominates, is 16.8 degrees, with a relative humidity of about 61 percent. Urla has 37 neighborhoods. Urla is reported to have 72741 registered residents as of 2021.

3.1.2 Çeşme Municipality

Çeşme is located at the far end of the Karaburun Peninsula, surrounded by seas on three sides, in the west of Turkey. Çeşme, whose lands are surrounded by Urla District in the east, the Aegean Sea in the south and west, and Karaburun District in the north, is 80 km from İzmir and 8 miles from Chios, Greece. Çeşme has 25 neighborhoods and its area is 260 km^2. Çeşme's 2021 population was 48167. It has Turkey's few beaches in terms of both domestic and foreign tourism. Clear sea, sun, fine sand and sulphurous waters emerging in the sea along with beaches with natural touristic opportunities are scattered among the various coves of up to 29 km. Çeşme is known for its ancient historic heritage. It was used to be known as Cysus in the first age, and it was the Ildır pier of Erythrai, one of the 12 Ionian cities estimated to have been founded in 1000 BC on the western coast of Anatolia.

3.1.3 Karaburun Municipality

The Karaburun Peninsula forms the northern part of the Urla Peninsula, which is the most protruding land part of the Aegean Region, which forms a large part of the western part of the Anatolian Peninsula, extending towards the Aegean Sea. It is surrounded by Çeşme in the south and Urla in the east. Karaburun district center is 100 km from İzmir and 46 km from Çeşme District. The shores of the peninsula are 14 miles from Foça, 20 miles from Lesbos in Greece and 15 miles from Chios. Karaburun has 16 neighborhoods. Karaburun had a population of 11927 in the year 2021.

3.2 Population and MSW Projections

The world population is projected to reach 8.5 billion in 2030, and to increase further to 9.7 billion in 2050 and 11.2 billion by 2100. As with any type of projection, there is a degree of uncertainty surrounding these latest population projections. In order to calculate the effects of waste generation over the next 10 years, population and waste projections have been formulated for this study. Due to the data from prior years, the methods of linear regression, forecasting, and Bank of Province approaches were used to compare results and choose the most accurate approach.

3.2.1 The Bank of Provinces Approach

The Bank of Provinces defines the population increase rate based on a factor (P) that is calculated, hence the increase rate is limited (Equation 1). Then the future population is calculated using the P factor (Equation 2). This method is the widely accepted and utilized method for projects in the public sector.

$$P = \left[\left(\frac{N_{next}}{N_{previous}} \right)^{\frac{1}{(t_{next} - t_{previous})}} - 1 \right] * 100 \qquad \text{(Eq. 1)}$$

N_{next}: Next census population

$N_{previous}$: Previous census population

t_{next}: Next census year

$t_{previous}$: Previous census year

If P is equal to or lower than 1, then it is taken as 1. If P is equal to or higher than 3, then it is taken as 3. If P value is between 1 and 3, then the actual value is used.

$$N_{future} = N_{last} * \left[1 + \frac{P}{100} \right]^{n} \qquad \text{(Eq. 2)}$$

N_{future}: Future population projection

N_{last}: Last census population

n: the year difference between the last census and the projection year.

3.2.2 Linear regression

Linear regression is based on the name linear we understand that the result would be a straight line. The equation for the linear regression is as below:

$$H = mx + c \qquad \text{(Eq. 3)}$$

Where H is the hypothesis, m equals slope, c equals intercept, and x is the year. Using data from 2007 to 2021, a linear graph was created. The calculated slope and intercept of the provided data were used to project the next ten years.

3.2.3 Forecasting

Using data from previous years as an inputs, forecasting is a technique that produces accurate predictions of the future course of trends. For this method, Excel forecasting tool was used.

3.3 Life Cycle Inventory

In the first phase, we identified system details. For instance, the functional unit based on the waste generation in this research is defined as 1 ton, the mass units are based on kilograms, the energy unit is kWh, the distance in kilometers, and the volume unit is a meter cube. Then we defined the raw materials such as lubricant oil, steel product for the container material, water usage, and detergent for cleaning the trucks and transfer stations. The LCI data were collected from the municipalities, scientific literature, and the Ecoinvent database. Based on the current MSWM system in the Karaburun Peninsula, the collection and waste transportation data, the capacity of a diesel truck, average transported waste per day, the mean velocities and truck routes, and the distance between the landfill and the transport station were done by research and municipality databases. The locations of current transfer stations and ramps within the municipalities of Urla, Çeşme, and Karaburun were determined by visits. Each trip from the waste containers to the transfer stations and then to the landfill were calculated.

CCalC2 software was used to model trucks and semi-trailers in accordance with their load capacities. For each district, the number of waste trucks, their average number of trips, empty weight, container capacity, and mean trip distances were calculated. Three databases are included in CCaLC2: User database, Ecoinvent, and CCaLC. Publicly accessible data and data produced during tool development constitute the CCaLC database. With the kind consent of Ecoinvent, the CCaLC2 tool includes the Ecoinvent database, a private database. The user builds and populates the user database. (The University of Manchester, 2013). Based on the CCalC2 databases, we defined the raw materials as follows:

1. Alkylbenzene sulfonate, linear, petrochemical:

Detergent usage was defined based on unofficial correspondence with the Urla Municipality Cleaning Works Division based on every 1 ton of municipal solid waste. It was assumed to be valid for other municipalities too.

2. Lubricant oil:

Based on our market studies and analysis, the trucks' use of lubricant oil is calculated based on the kilometers they travel in the collection and transportation processes; thus, we calculated the day-to-day trips and, based on the waste generation, obtained the oil lifetime. Regarding our research, the lubricant oil should change every 15.000 km; hence the kilometers each truck travels calculated. Based on our evaluation shown below, the lubricant oil usage per functional unit has been decided.

$$\frac{15000}{D} = N.O$$

N.O: number of days that oil needs changing

D: the roundtrip traveled each day for collection services

$$\frac{MSW\left(\frac{ton}{year}\right)}{365days} * N.O = L.O$$

L.O= the amount of MSW collected for the lubricant oil to change

Every 5 liter of Lubricant oil is approximately 4.45 kg

$$\frac{4.45\ kg}{L.O} = kg\ lubricant\ oil\ that\ will\ be\ use\ per\ functional\ unit$$

3. Steel product manufacturing:

Based on the reports of each district, the number of solid waste containers was given. As a calculated approach, we assumed that 80% of the containers were in use, and the other

20% might be at maintenance or due to the object's lifetime going through the replacement processes. The lifetime of each container is estimated as ten years of service. The steel used in every 1 ton of functional unit was calculated with that information.

$$\frac{(the\ weight\ of\ MSW containers) * 80\% *\ the\ number\ of\ containers}{MSW generated\ in\ 10\ years}$$

4. Water at use in both Door to container and Transfer station stages:

The amount of water used to wash the trucks was calculated based on the type of the truck, and it was constant in all scenarios. Based on the previous studies, the average was assumed and calculated based on the weekly schedule of the cleaning processes.

5. Polythene bags

The packaging was defined as polythene bags that the household uses to pack the waste and remove it from the containers. The amount of plastic garbage bags was defined as kg per FU; the average bag has a capacity of 50 lt the density of waste is 313. We calculated the volume as 3.19 $m^{3,}$ and based on our capacity, the number of bags per functional unit was calculated as 63.8. With market research mass of the plastic bags was decided as 93 g; hence the amount set in our model is considered as 5.93 kg per functional unit. The summary of the raw materials entered in the CCalC2 tool was presented in Table 3.1.

$$\frac{FU}{density} = volume \qquad \frac{volume}{capacity} = the\ number\ of\ plastic\ bags\ used$$

$$The\ number\ of\ bags * the\ mass = amount\ of\ plastic\ garbage\ bag$$

Table 3.1 Raw materials used in the calculations.

Scenarios	Alkylbenzene sulfonate, Kg/f.u	Lubricant oil Kg/f.u	Steel product manufacturing Kg/f.u	Water use in "door to container" stage	Water use in transfer stations	Polythene bags
Karaburun S0	1.00	0.00038	1.08	12.3	20	5.93
Karaburun S1	1.00	0.00038	1.08	12.3	20	5.80
Karaburun S2	1.00	0.00038	1.08	12.3	20	4.7
Çeşme S0	1.00	0.00067	0.816	12.3	20	5.93
Çeşme S1	1.00	0.00067	0.816	12.3	20	5.85
Çeşme S2	1.00	0.00067	0.816	12.3	20	4.4
Urla S0	1.00	0.00038	0.539	12.3	20	5.93
Urla S1	1.00	0.00038	0.539	12.3	20	5.84
Urla S2	1.00	0.00038	0.539	12.3	20	4.81

3.4 Scenarios

Each district includes a business as usual scenario (Scenario 0) that we thoroughly constructed on CCalC2 based on the research we conducted and the characterization of each district. In the first phase, we defined system details. For instance, the functional unit based on the waste generation in this research chosen as 1 ton, the mass units are based on kilograms, the energy unit is kWh, the distance in kilometers, and the volume unit is a meter cube. Then we defined the raw materials such as lubricant oil, steel product for the container material, water usage, and detergent for cleaning the trucks and transfer stations. Based on our market studies and analysis, the trucks' use of lubricant oil is calculated based on the kilometers they travel in the collection and transportation processes; thus, we calculated the day-to-day trips and based on the waste generation, obtained the oil lifetime. We also have the water usage in the raw material phase for cleaning the trucks and transfer stations. Based on the previous studies, the average was assumed and calculated based on the weekly schedule of the cleaning processes.

The next step in the baseline scenario was production. The stage we had was "Door to container". This is where the waste generated at the source will dump in the containers for the collection services to gather them. The packaging was defined as polythene bags that the household use to pack the waste and remove it to the containers. The amount of plastic garbage bags was defined as kg per FU, the average bag has the capacity of 50lt the density of waste is 313 we calculated the volume as 3.19 m^3 and base on the capacity that we have the number of bags per functional unit calculated as 63.8. With market research mass of the plastic bags decided as 93 g, hence the amount set in our model considered as 5.93 kg per functional unit

$$\frac{FU}{density} = volume \qquad \frac{volume}{capacity} = the\ number\ of\ plastic\ bags\ used$$

$$The\ number\ of\ bags * the\ mass = amount\ of\ plastic\ garbage\ bag$$

The output of "door to container" stage is MSW that is collected and ready to move to the transfer stations. In Urla base scenario, the data shows that the collection services were divided into two categories:

1. Nine trucks with 8 tons of capacity

2. Five trucks with 5 tons of capacity

Thus in this district, the MSW would have different service trucks to transport them to the Zeytinalani transfer station. As a result, we defined two material outputs named MSW1 and MSW2 so that each truck's capacity will be considered. While we had waste generation per month for Urla based on the municipality data, we calculated the average amount transported with each truck capacity to have a more accurate scenario.

The focus of this study was the collection and transportation of waste; therefore, for the next step, we defined the transportation from the containers of the district to the Zeytinalani transfer station. Each day the collection trucks of Urla district did a 120km roundtrip for the collection process. This data was provided from our official correspondence e-mails with Urla municipality. CCaLC2 contains three databases: CCaLC, Ecoinvent, and User database. The CCaLC database consists of publicly available data and data generated during tool development. The Ecoinvent database is a proprietary database included in the CCaLC2 tool with kind permission of Ecoinvent. The user database is created and populated by the user, as explained in the subsequent sections (The University of Manchester, 2013). Based on the Ecoinvent database in the related stage, the transportation is defined as "Lorry 3.5-7.5t, EURO4" for our 5 ton trucks and "Lorry 7.5-16 t, EURO4" for the 8ton trucks for Urla's collection services since they have different capacities and numbers. The density of waste calculated and determined as 313kg/m^3 (Palanivel & Sulaiman, 2014) for packing density of the transport.

Storage in our model was assumed to be the transfer station in which the collected waste would transfer and be gathered to send to the Harmandali landfill. The other transportation stage that defined was “22-ton truck” that gathered around the total amount of the MSW that had been collected in the related transfer station and transferred to the Harmandali landfill.

3.4.1 Scenario 0: A baseline scenario (business as usual)

The business as usual scenario showed the baseline of each district’s current state from the given data, research, or corresponding from the related municipality. To better compare each district's scenarios, we defined a functional unit. The current municipal solid waste management system in Izmir, which lacks a source separation or sorting facility, is described in the scenario. Additionally, all MSW gathered from the containers will be delivered to the district's transfer station before being dumped at the Harmandali landfill. The transfer stations will collect the entire 1 ton of the assumed functional unit, which will then be transported to the landfill. Because there was no information or report on how each district was characterized, the description of Izmir MSW was based on "the master plan report Izmir"(Ve, 2020). The weights of composition were calculated with the given percentage of the characterization. The density of each item was determined based on FU, and used the related density for the changes in each scenario.

Production was the next stage in the scenario model. Polythene bags will be used as garbage disposal bags in the production step, and MSW will be an output of this process that is dumped from households into containers.

The first analysis of transportation was from the stage of production to storage, which in this study was assumed to be the transfer stations. On the basis of the provided information, truck models, and capacity, we constructed the daily waste collection routes from containers to transfer stations.

The next step was storage; for this step, we added the energy consumption, which was based on an assumption that the transfer stations' average electricity usage. The lighting and hypothetical offices there were considered to be only energy consumers because the entire process is manual. Once more, the output of this step is waste that will be disposed of in the Harmandali landfill.

The final transportation was defined from storage to use, which we assume to be the Harmandali landfill. The distance and waste density were calculated based on each scenario. The 22-ton truck with the empty return trip was chosen because it would return from the landfill with no waste.

3.4.2 Scenario 1: 50% of plastics segregated at the source

In this scenario, we used a new waste management approach and assumed that 50 % of plastic waste had been separated at the source before transportation. The density and volume of waste will change with this proposal because we will reduce the plastic waste weight by 50%, and density will also change in the given models. As a result, the functional unit were adjusted, indicating that there will be less municipal solid waste to transport when compared to the BAU scenario.

3.4.3 Scenario 2: 50% of all renewables segregated at the source

Based on the research and the other two scenarios, an alternative future scenario is proposed that further improves transportation systems. This scenario was formed to reduce transportation and, as a result, the global warming potential. It suggests plastic and a 50% separation of all renewables at the source therefore the composition by weight of the renewables waste characterization was reduced by 50%. The functional unit was decided as 1 ton = 1000kg so the weight and volume of each item adjust based on the f.u.

3.5 Life Cycle Assessment (LCA)

This study aims to quantify and compare the three scenarios that indicate the environmental and energy impacts of different MSWM scenarios and assess the most optimum system for collection and transportation for the Karaburun Peninsula region through the life cycle assessment. The software we used in this study is CCaLC2. The functional unit was chosen as 1 ton based on the rate of MSW generation, and the system's lifetime was considered ten years. System boundary consists of collection and transportation of MSWs, and reduction of plastic waste based on the scenarios.

Researchers at The University of Manchester have started a project called CCaLC software to promote environmental sustainability. A variety of tools for calculating and reducing the carbon footprint have been created by the CCaLC team. (Ccalc2 @ Www.Ccalc.Org.Uk, n.d.) The CCaLC2 tools, which allow quick and simple estimations of environmental impacts and value-added along supply chains, are the second generation of the CCaLC tools. It adopts a life cycle perspective and allows for analysis of a variety of environmental effects, including carbon footprint, water footprint, acidification potential, eutrophication potential, ozone layer depletion potential, photochemical smog, and human toxicity potential (Azapagic, 2016). With the help of CCaLC2, users can quickly and effectively calculate their carbon footprint and other environmental effects while adhering to widely recognized LCA standards like ISO 14044 and PAS 2050. (Azapagic, 2016).

We have cooperated and successfully gathered the related data with the help of district municipalities on the waste generation and related information during the past few years. Furthermore, we have calculated the projection of the specific population's regarded in our research, waste generation, and waste per capita in the next ten years in the aim districts (Urla, Cesme, Karaburun). In this section of the study, we compared projection calculations using a variety of methods, including the provincial bank, forecasting, linear regression, trend, and equations based on the provided data. We then compared the results and chose the provincial bank as the best projection method.

CHAPTER 4

RESULTS AND DISCUSSION

Unfortunately, waste management is one of the most significant environmental issues in Turkey's cities, and Izmir is no exception. It is a crucial strategic issue as well, one that is especially important at the regional level. The current solid waste landfill in Izmir has reached its maximum capacity. In addition to adopting a model, cutting-edge, and environmentally friendly urban infrastructure approach, the new facility will offer Izmir high-quality integrated solid waste management at a crucial time.

In order to collect the data that is needed to conduct this study, we adopted a tiered approach, going from city scale to district scale. As a first approach, we investigated the MSW generated in Izmir Metropolitan City, which is collected without or minimal separation at the source. Consequently, 8000 tons of MSW is transferred and disposal of to landfill sites on a daily basis (Figure 4.1). Therefore, selecting a new and integrated waste management strategy that aims to divert MSW from landfilling areas to meet legal requirements is crucial for the city (Bölükbaş & Akıncı, 2018).

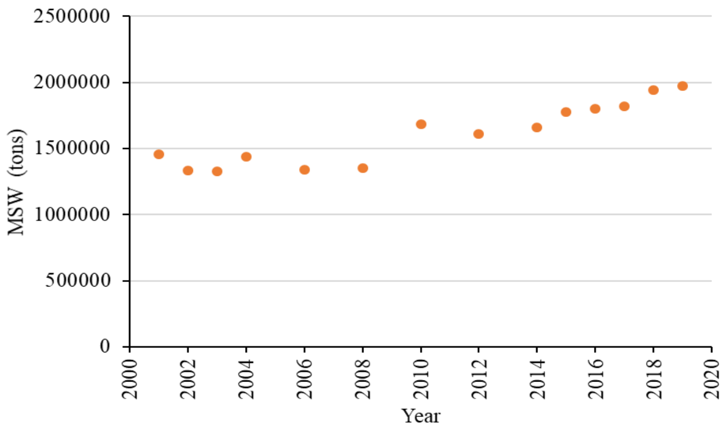


Figure 4.1 İzmir municipal waste collection data

The amount of municipal waste collected throughout the province in 2019 was 1,971,903 tons (Figure 4.1). More than 93 % of the total waste (1,839,064 tons) was sent to Harmandali Solid Waste Landfill. Only 3.49 % of the total waste (68,760 tons) was sent to Bergama Solid Waste Landfill, and the rest (64,080 tons) was sent to Tire Irregular

Landfill. The results from the waste characterization study by the İzmir Metropolitan Municipality was presented in Table 4.1.

Table 4.1 Waste characterization of İzmir.

Waste Group	**Waste Type**	**Percentage**
Recyclable waste	Glass	10.60%
	Metal	0.81%
	Paper/cardboard	7.27%
	Plastic	7.36%
	Total	26.04%
Other wastes	Hazardous Waste (waste medicine, waste battery, waste battery paint cans, detergent cans, etc.)	2.02%
	Other Combustibles (textile waste, diapers, shoes, carpets, bags, foam, wood, etc.)	6.75%
	Other Non-Combustibles (Ash, Sand, Dust, Stone, Ceramic, Rubble, etc.)	4.20%
	Electrical and Electronic Goods	0.10%
	Voluminous Wastes	6.53%
	Total	19.6
Biodegradable Waste	Kitchen waste, garden waste	54.36%
TOTAL	-	100%

The collection included the process from where the waste was produced to the collection vehicle, then transported to the desired location and discharged from the collection vehicle. According to the Metropolitan Municipality Law No. 5416, the collection and transportation of solid wastes were done by district municipalities; services regarding storage and disposal were the responsibility of the metropolitan municipality. District municipalities or contractor companies carried out the waste collection in İzmir. The frequency of municipal waste collection throughout the province varied depending on the season and tourism. In the summer months, at least two times a day were collected in the district centers. The collection days were generally the same as in the summer months in the winter months, but the number of trips decreased. In 30 districts, municipal wastes were transported by 569 compressed vehicles with capacities ranging from 7 to 20 m^3, and 141,233 containers with capacities ranging from 400 lt to 1100 lt are used to collect wastes. While Konak and Bornova were the districts that contained the most waste in the summer and winter periods, the communities with the least waste are Beydağ and Karaburun. (Ve, E. 2020).

Transfer stations are used to reduce the number of trips required for transportation, reduce the costs of waste services, and increase their efficiency. Although transfer stations add extra charges (initial investment and large tonnage vehicle) to the system, they are often more convenient as they lower transportation costs. The transfer center may become necessary in cases where topography or road conditions are not suitable, such as in mountainous areas. A transfer station is a facility where waste is transferred from small-volume garbage collection vehicles to large-volume vehicles such as trucks, boats, or freight cars. (Ve, E. 2020).

There are 10 transfer stations in total in the districts of Buca (Gediz), Bornova, Konak (Halkapınar), Menemen (Türkelli), Urla, Menderes (Kınık, Gümüldür), Kınık, Selçuk and Seferihisar in İzmir; There are 8 transfer ramps in total in Torbalı, Karşıyaka, Çeşme, Kemalpaşa, Foça, Karaburun, Dikili and Ödemiş districts. The capacity of the transfer vehicles is 27 tons and has a walking-based semi-trailer system. (Ve, E. 2020). For the purposes of this thesis study, we are interested in the locations of the Alaçatı, Mordoğan and Zeytinalanı waste transfer stations (Figure 4.2), since that will be determinative in calculating the fuel consumption and hence associated emissions.

The last stage in the defined MSWM operation was Harmandalı Solid Waste Landfill Facility, which was located in the Çiğli district. It has been operating since 1992 as Turkey's first modern landfill site. During the process, it was aimed to reduce the waste load going to the landfill facility with regional facilities to be established within the scope of Izmir Province Integrated Solid Waste Management Plan at different points of the city and to rehabilitate and control the site in stages. It is approximately 8 km from Çiğli city center. The municipal wastes coming from the districts are disposed of with the regular landfill method. (Ve, E. 2020). Over the past few years, Harmandali has been the main landfill for discarding Municipal solid waste (MSW) in İzmir. However, the need for land due to population growth and the damage done to the environment has driven the decision-makers to think of alternatives, which will result in the reduction of waste being transferred to Harmandali. Depending upon the sizes of the municipalities, location of the waste transfer station and the location of Harmandali Landfill site the approximate travel distances of the garbage trucks were calculated (Figure 4.3).

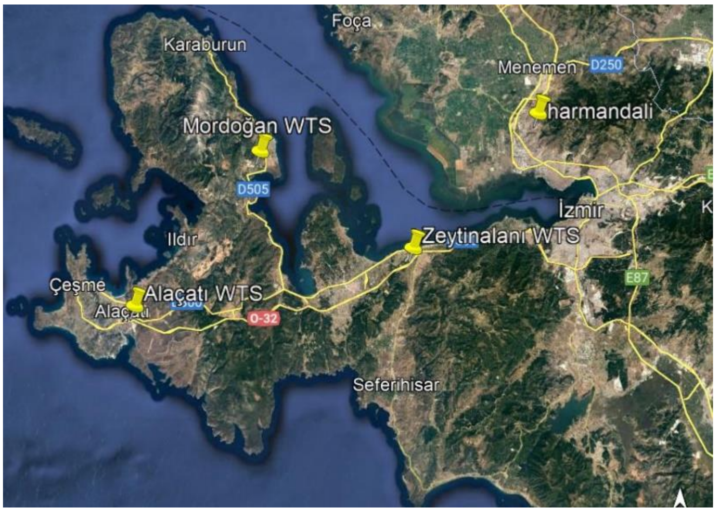


Figure 4.2 Waste transfer station locations serving Çeşme, Karaburun and Urla Districts (Source: Google Earth, 03.07.2022)

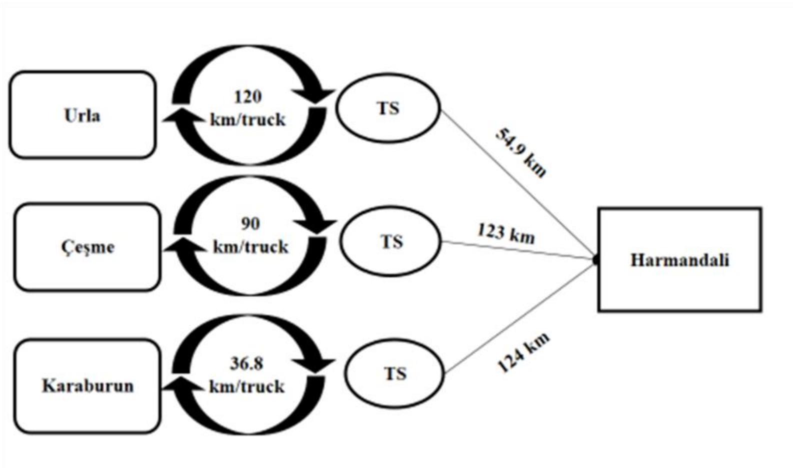


Figure 4.3 Travel distances for one truck within districts, from district to transfer station and from transfer station to Harmandali Landfill Site.

4.1 Population and MSW Projections

The Bank of Provinces method was taken into consideration based on the methodology's explanation for the projection processes since this method had been widely used in the projects of the public sector. The trend of each method for the following ten years is shown in Figures 4.4, 4.5, and 4.6 for all three districts.

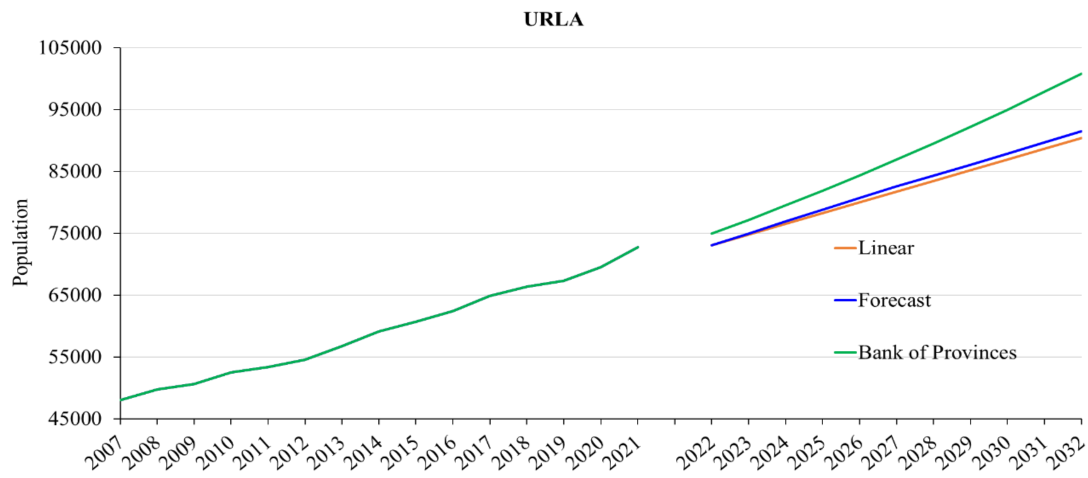


Figure 4.4 Population data (2007-2021) and projection (2022-2032) for Urla.

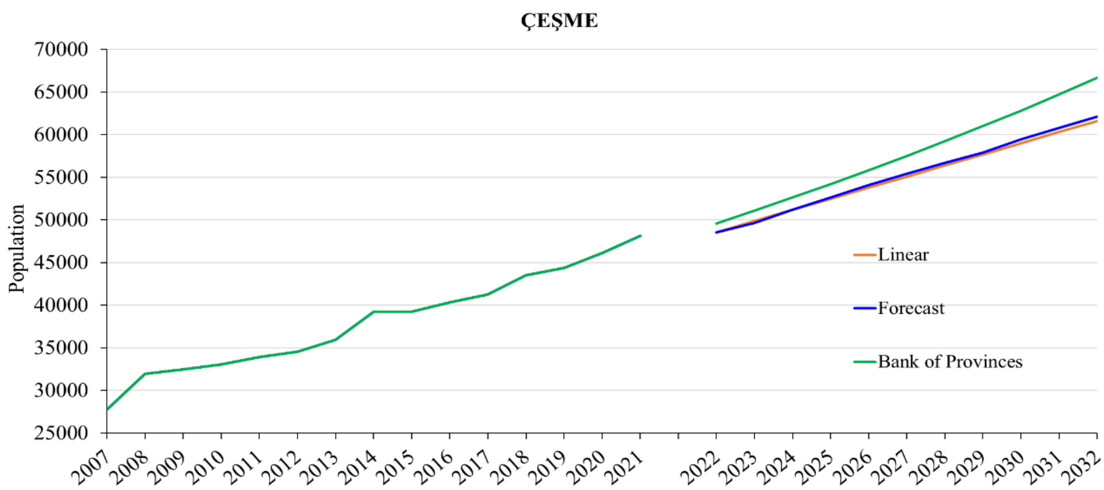


Figure 4.5 Population data (2007-2021) and projection (2022-2032) for Çeşme.

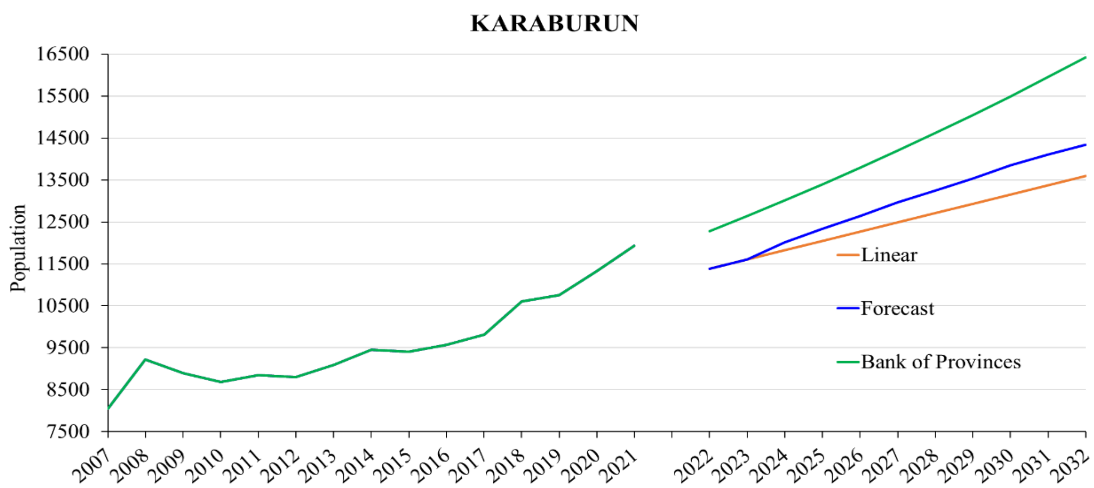


Figure 4.6 Population data (2007-2021) and projection (2022-2032) for Karaburun.

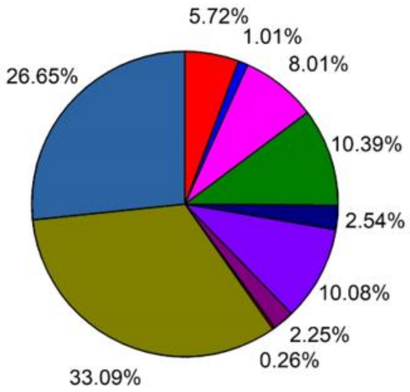
The per capita amount that we used for Çeşme and Karaburun was based on the Izmir report's waste generation, which is 1.27 kg/day because the numbers in the related reports were so utterly out of accordance. Based on the projected population and waste generation per capita, a ten-year comparison of waste generation has been done as part of the scenario analysis. The next 10 years' total estimated waste generation values were 1,526,683.5 tons for Urla, 806,984 tons for Çeşme and 199,213,9 tons for Karaburun.

4.2 MSW Density Changes for Scenarios

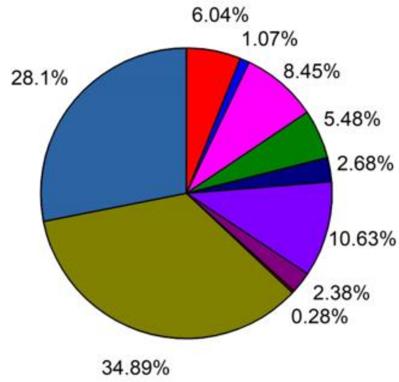
The composition of the waste handled in Scenario 0 was given in Table 4.2 (a-c). The density of waste was calculated to be 313.1 kg/m^3. As a result of the composition changes in Scenarios 1 and 2, the density values of the total waste were updated to 318.1 kg/m^3 and 385.15 kg/m^3, respectively.

Table 4.2 Waste composition by volume for different scenarios.

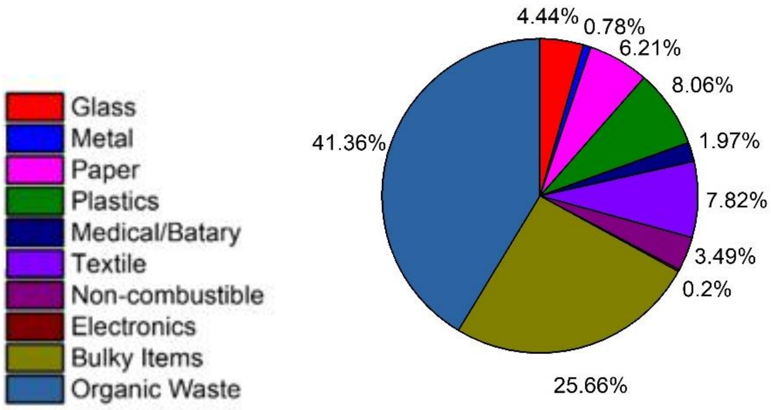
a. S0 Waste Composition by volume (%)



b. S1 Waste Composition by volume (%)



c. S2 Waste Composition by volume (%)



4.3 LCA Results

In each baseline scenario, we have the current MSW management of assumed districts. The environmental impact values were calculated with CCalC2, and over the 10 years of the system lifetime, the carbon dioxide equivalent was calculated for each district's scenarios. In scenario 1 of three districts the numbers decreased on the environmental impacts. Based on changes in the characterization of the waste that was collected, scenario 1's environmental impacts per ton of MSW have significantly changed. Since bulky items, like plastic bottles, have now been separated from waste, it has a direct impact on the collection and transportation. Because of the 50% separation of waste from all renewables, scenario 2 showed the greatest changes in the impacts. For instance, Urla's data in the transportation sector changed from 39.8 kg/f.u. of CO_2 in the base scenario to 31.49 kg/f.u. in the final scenario. By 2032, the indicated number will result in a reduction in GHG emission of 12,670.4 kg/waste generation. The following results are provided in Tables 4.3-4.11 based on each district.

Scenario 0 is the baseline and current practice in Urla (Table 4.3). Due to the type of fuel and engine that is diesel the given impacts on Carbon footprint and Acidification were closely monitored in scenarios. We had carbon footprint impact in raw material section, packaging of waste in door to container stage and transport sector. Segregation of plastic in scenario 1 has reduced the amount of plastic waste and affected transportation for Urla (Table 4.4). In scenarios 0 and 1, the carbon footprint decreased from 60,761.9 tons to 58,471.9 tons, a reduction of 3.7 percent. In Scenario 2 case, where 50% of the renewable waste was separated at the source, the transportation sector's carbon footprint was reduced the most (Table 4.5). The total amount of CO_2 equivalent decreases by 21% (48,090.5 tons) compared to Urla's current waste management strategy.

Table 4.3 Results for environmental indicators for Urla-Scenario 0.

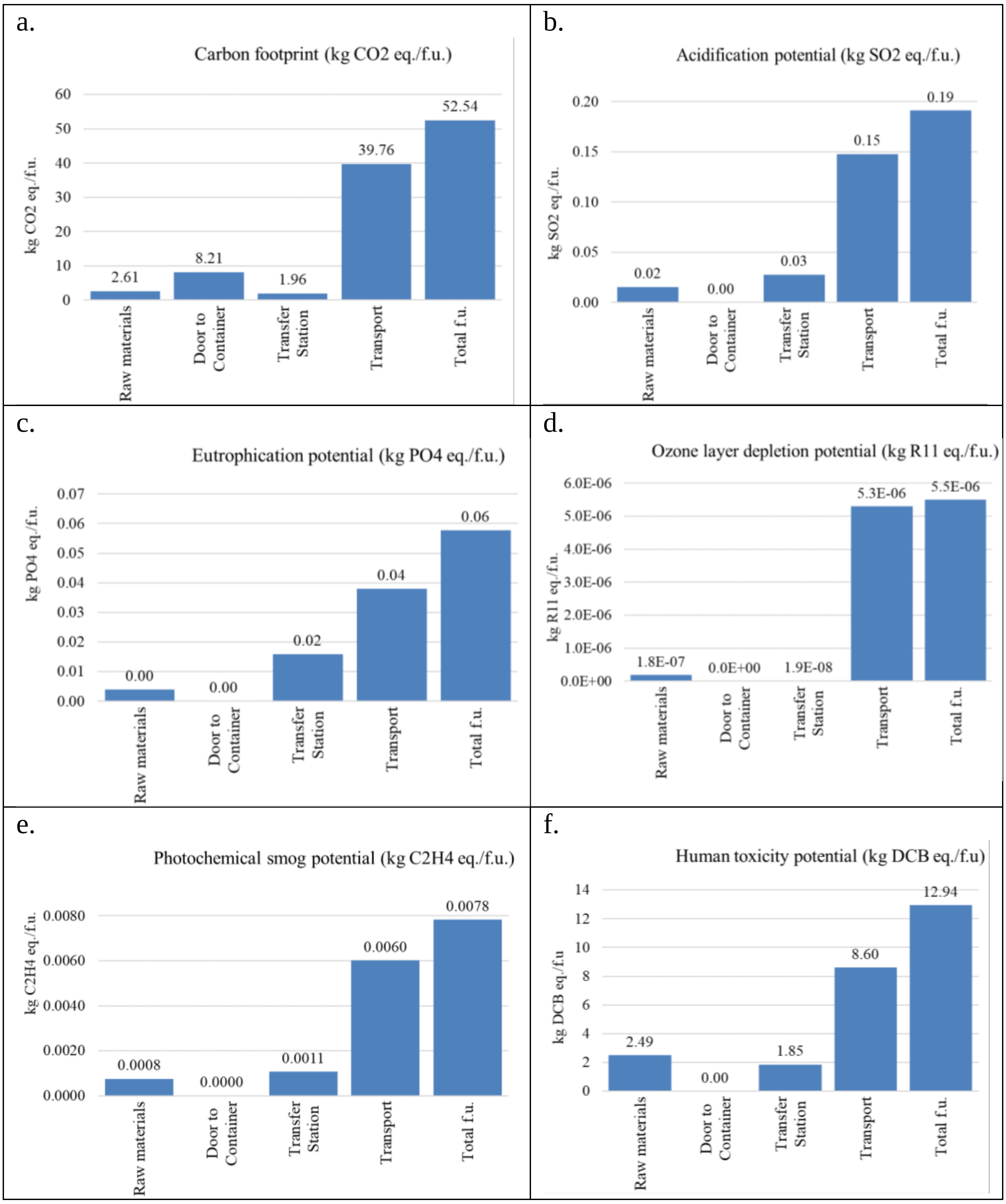


Table 4.4 Results for environmental indicators for Urla-Scenario 1.

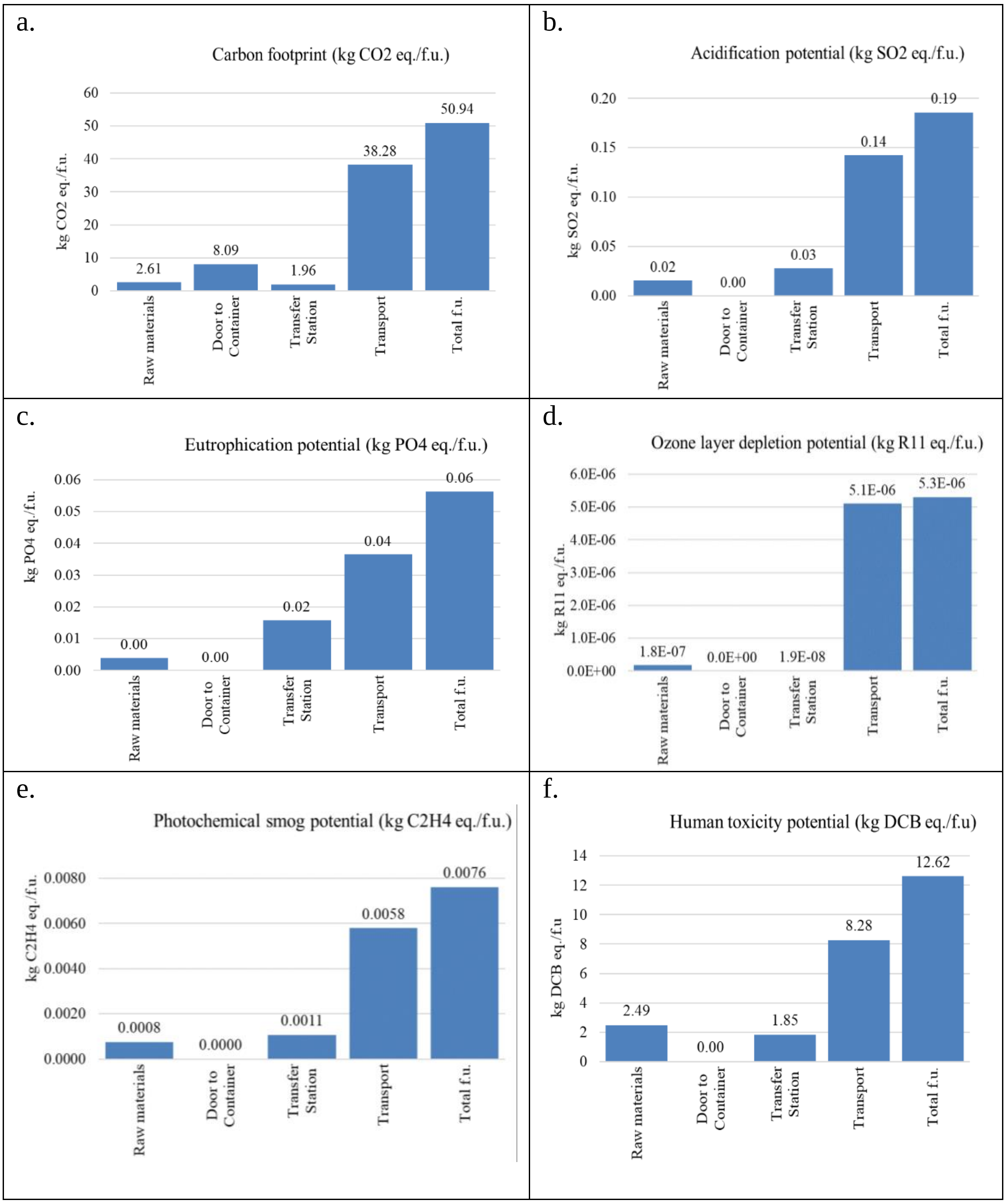
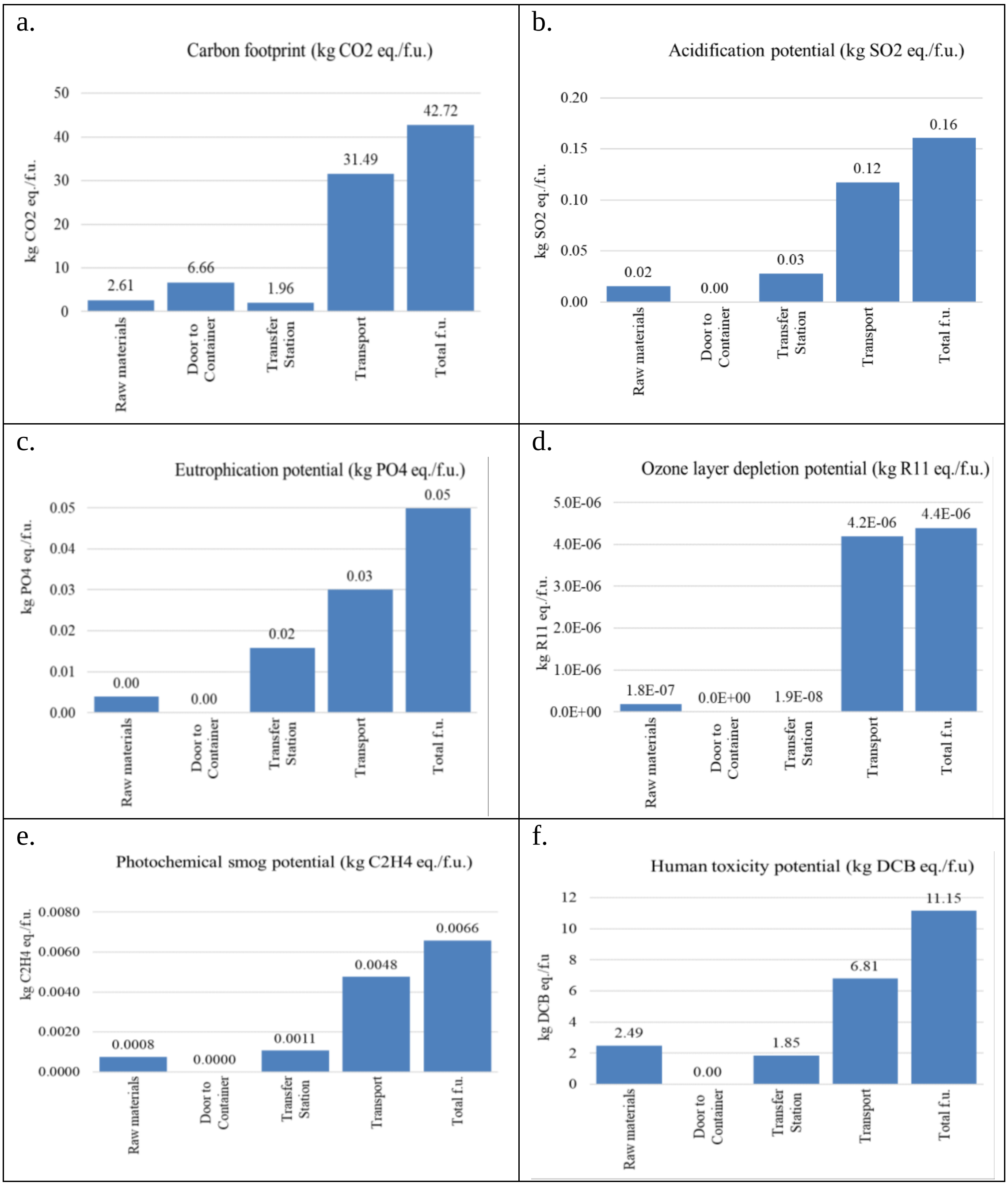


Table 4.5 Results for environmental indicators for Urla-Scenario 2.



For Çeşme Scenario 1, the changes were similar to Urla Scenario 1 on transportation sector. Carbon footprint has decreased by 3.7% with reduction from 26,146.3 tons of CO_2-eq to 25,177.9 tons of CO_2-eq. Results from Scenario 2 was even more significant, with a 20% reduction calculated in carbon footprint.

Table 4.6 Results for environmental indicators for Çeşme-Scenario 0.

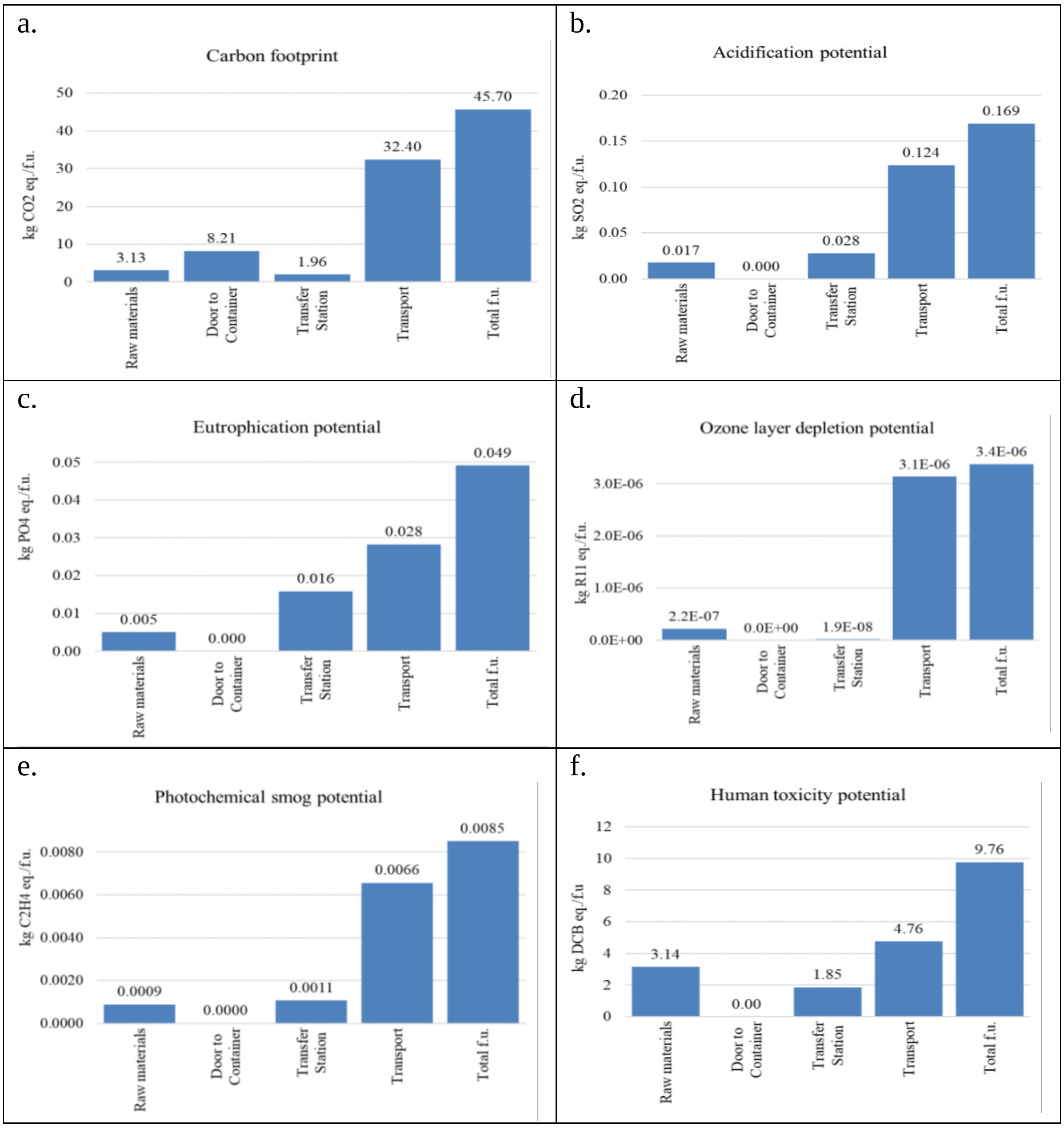


Table 4.7 Results for environmental indicators for Çeşme-Scenario 1.

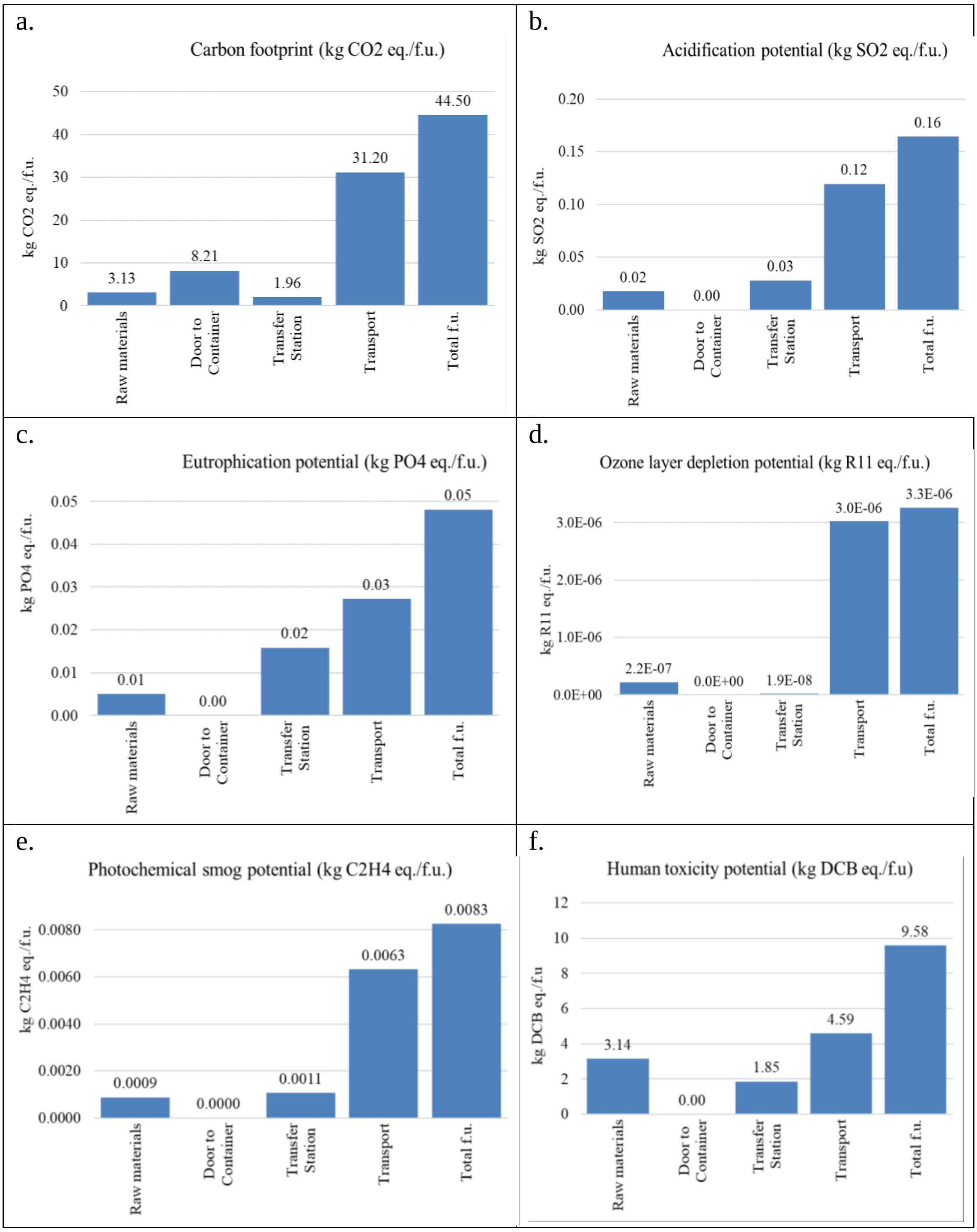
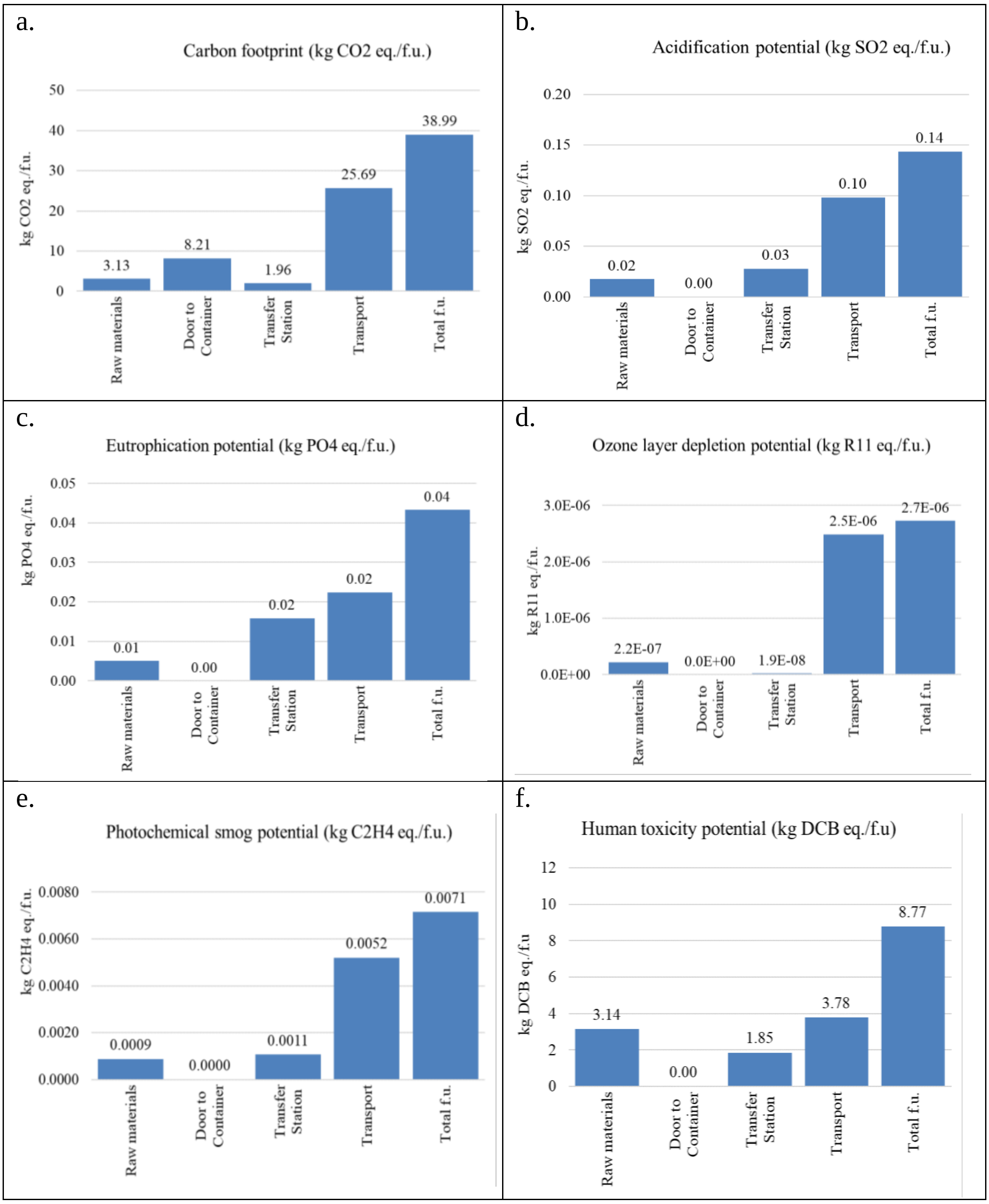


Table 4.8 Results for environmental indicators for Çeşme-Scenario 2.



Based on the information that the municipality provided, the Karaburun district base scenario was described. Scenario 1's characterization change resulted in a deduction of 219,13 tons of CO_2 being produced. The second scenario, which includes a reduction of 1,195.3 tons of CO_2, has the greatest impact on the numbers.

Table 4.9 Results for environmental indicators for Karaburun-Scenario 0.

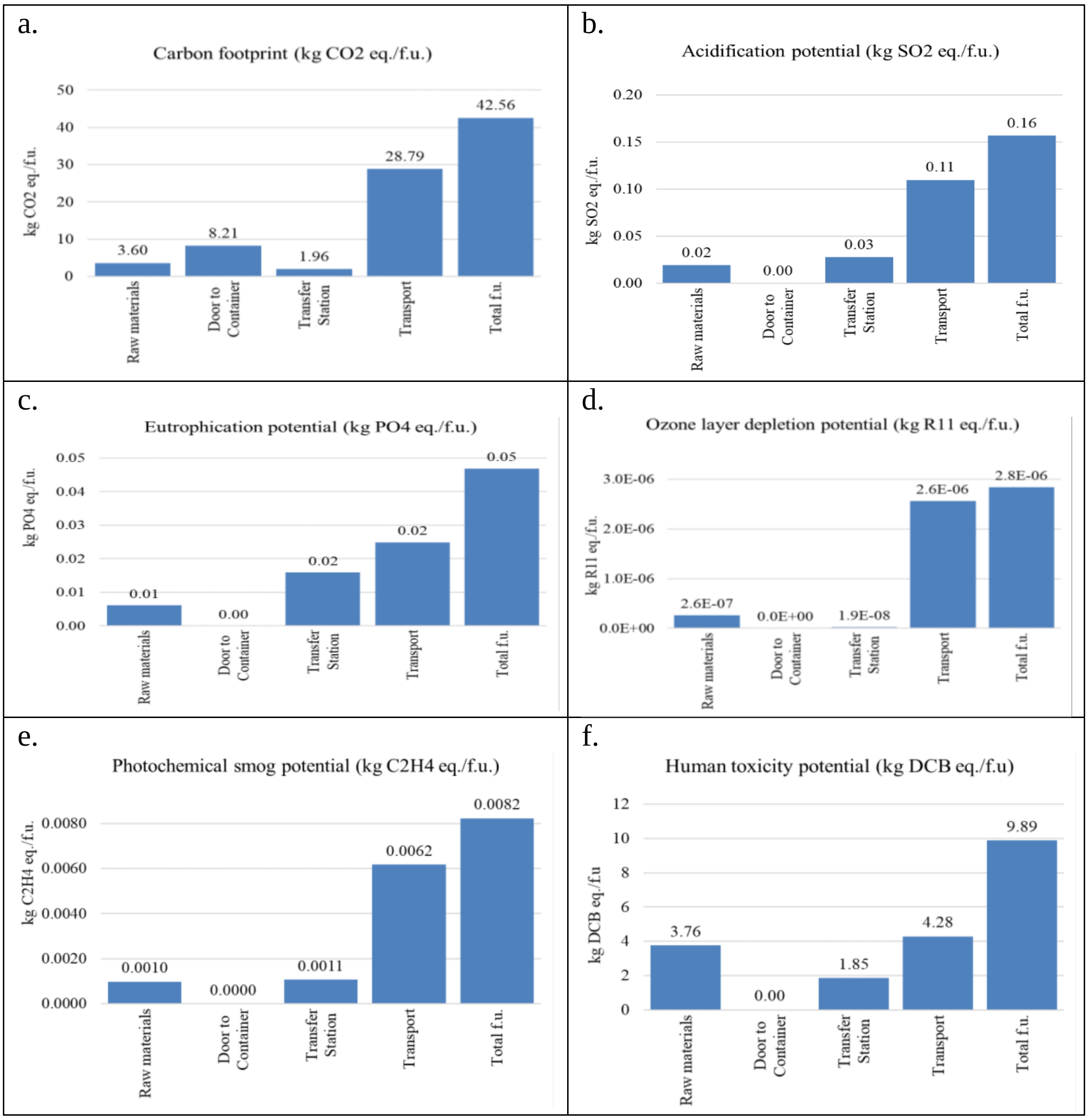


Table 4.10 Results for environmental indicators for Karaburun-Scenario 1.

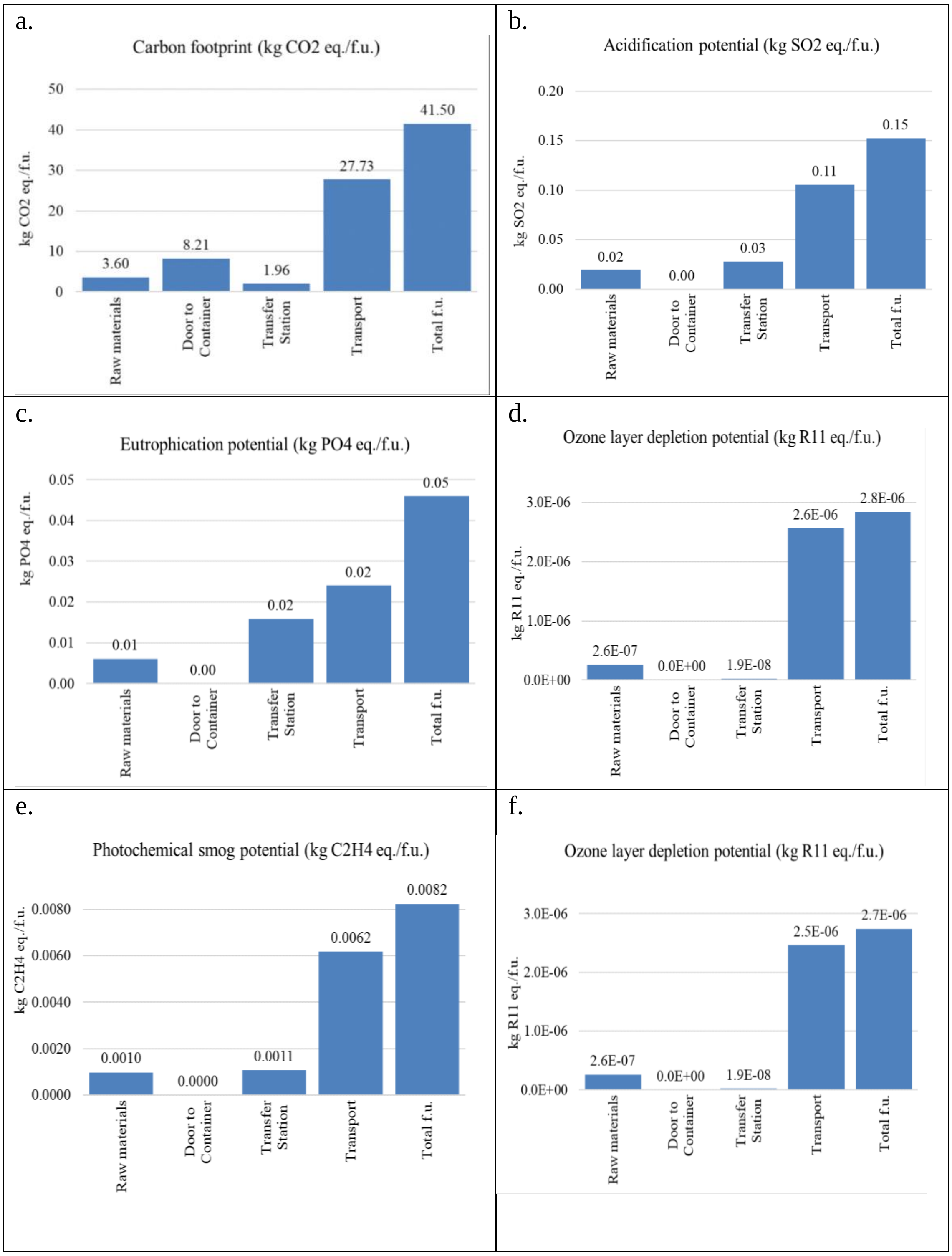
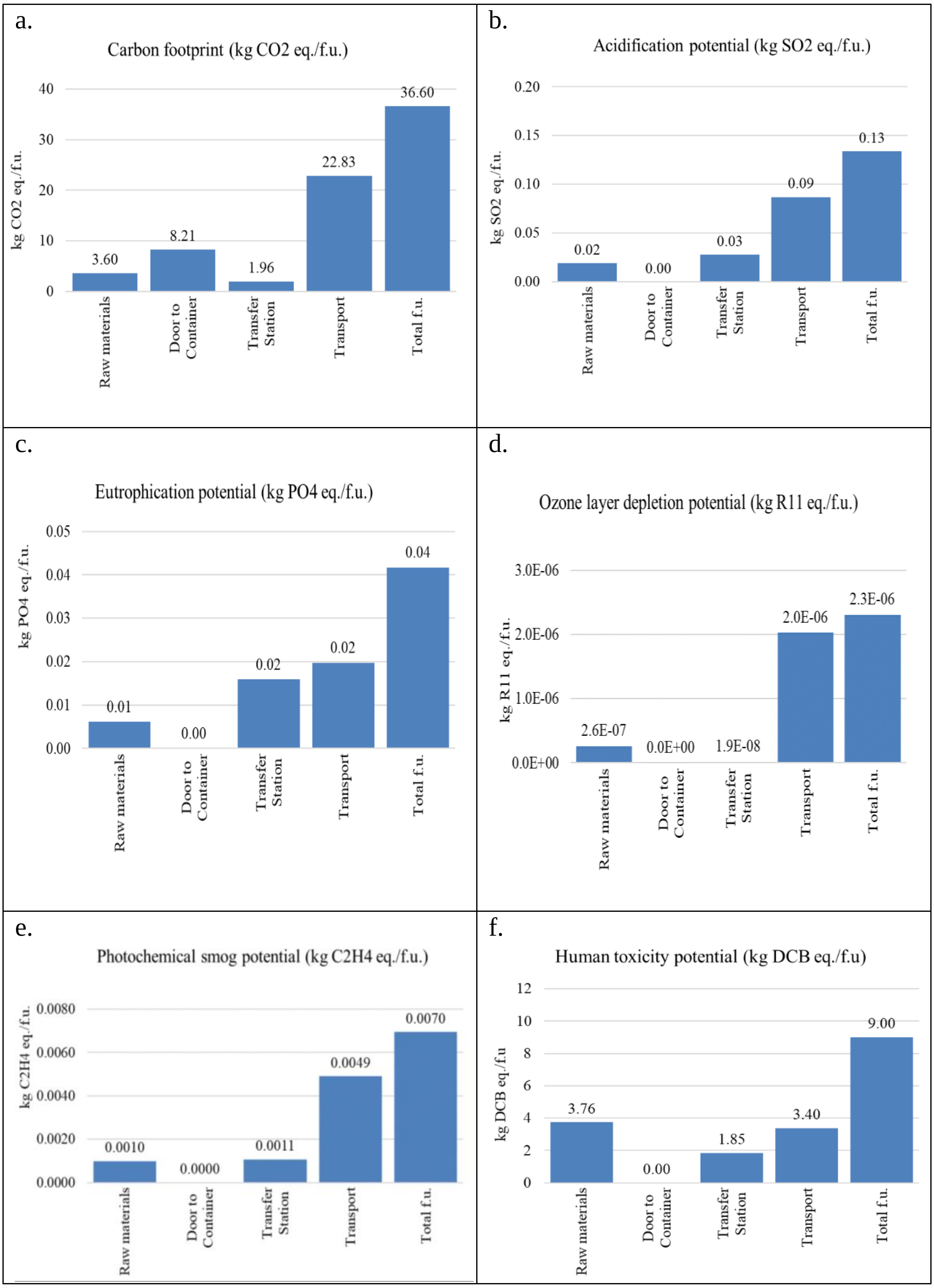


Table 4.11 Results for environmental indicators for Karaburun-Scenario 2.



Based on the given figures and analysis, scenario 2 in all three districts has the most significant effect on the environmental impacts of MSW transportation. The table below compares each district's differences regarding the effect of changing scenarios on the Carbon footprint impact and shows that the alteration and reduction of only 50% of all renewable can effect radically on the environmental impacts. The results were summarized in Table 4.12.

Table 4.12 Environmental indicator values for different scenarios.

Scenarios	**Carbon footprint (kg CO_2 eq./f.u.)**	**Acidification potential (kg SO_2 eq./f.u.)**	**Eutrophication potential (kg PO_4 eq./f.u.)**	**Ozone layer depletion potential (kg R11 eq./f.u.)**	**Photochemical smog potential (kg C_2H_4 eq./f.u.)**	**Human toxicity potential (kg DCB eq./f.u)**
Karaburun S0	42.56	0.16	0.047	2.84E-06	0.0082	9.89
Karaburun S1	41.50	0.15	0.046	2.74E-06	0.0080	9.73
Karaburun S2	36.60	0.13	0.042	2.31E-06	0.0070	9.00
Çeşme S0	45.70	0.17	0.049	3.38E-06	0.0085	9.76
Çeşme S1	44.50	0.16	0.048	3.26E-06	0.0083	9.58
Çeşme S2	38.99	0.14	0.043	2.73E-06	0.0071	8.77
Urla S0	52.54	0.19	0.058	5.50E-06	0.0078	12.94
Urla S1	50.94	0.19	0.056	5.30E-06	0.0076	12.62
Urla S2	42.72	0.16	0.050	4.39E-06	0.0066	11.15

CHAPTER 5

CONCLUSION

The findings suggest that only separating plastic waste is insufficient and that the carbon emission reduction will be significantly impacted by separating all renewable waste at the source. This paper evaluated the transportation sector's environmental impacts on MSW management with LCA modeling of the Karaburun Peninsula. Three scenarios were suggested with different approaches for the reduction of Carbon footprint and also acidification due to the truck types and diesel consumption. The first scenario in all three districts was the current municipal solid waste management approach implemented in the Karaburun peninsula. The following scenario assumes that source segregation will reduce plastic waste by 50%. Furthermore, the last scenario is that all renewable waste reduction by 50% at the source. All three scenarios were modeled on CCalC2. The results show that the transportation of MSW in scenario 1 with 50% plastic at source separation shows around a 3% CO2 decrease while scenario 2 has about a 20% reduction of CO2 eq with only 50% assumed segregation of renewable waste characterization. For a more sustainable municipal solid waste management plan, the municipality can use LCA for decision-making processes and evaluation of each sector's environmental impacts. During this research, there were some limitations regarding the data collection, such as the lack of district waste characterization; therefore, we assumed Izmir characterization for all the districts.

Karaburun Peninsula, due to its touristic nature, has significant waste generation differences during summer and winter; however, the data provided by the municipality did not add up to this description of the peninsula, and the communication with the related municipality was challenging and time-consuming. The accuracy of this project or future research on the management of MSW in this area can be improved with the related waste characterization district. The results of this study showed that despite the importance attributed to the plastics recycling in recent years, only plastics recycling did not cause significant carbon footprint reduction. On the other hand, recycling of all renewables caused significant savings in the carbon footprint. On the policy-making level, awareness raising activities shall be organized for all renewables and efforts and resources shall be allocated to recycle all types of renewables.

REFERENCES

“Ccalc2 @ Www.Ccalc.Org.Uk.” n.d. http://www.ccalc.org.uk/ccalc2.php.

“General MSW.” n.d. https://data.tuik.gov.tr/Search/Search?text=atık.

ESRI. n.d. “ArcGIS Online.” Accessed July 3, 2022. https://www.arcgis.com/index.html.

“National Environment Action Plan of Turkey Ankara, 1999 Table of Contents.” 1999. *Environment*.

“Plastic Weight.” n.d. Https://Www.Avansas.Com/Avansas-Cop-Torbasi-Buyuk-Boy-65-Cm-x-80-Cm-Siyah-Tek-Rulo-p-64158#:~:Text=Avansas%20b%C3%BCy%C3%BCk%20boy%20%C3%A7%C3%B6p%20torbas%C4%B1,Sadece%2093%20gram%20a%C4%9F%C4%B1rl%C4%B1%C4%9Fa%20sahiptir. https://www.avansas.com/avansas-cop-torbasi-buyuk-boy-65-cm-x-80-cm-siyah-tek-rulo-p-64158#:~:text=Avansas büyük boy çöp torbası,sadece 93 gram ağırlığa sahiptir.

“World Carbon Emission.” n.d. https://www.iea.org/topics/transport.

Akinci, Gorkem, Elif Duyusen Guven, and Gulden Gok. 2012. “Evaluation of Waste Management Options and Resource Conservation Potentials According to the Waste Characteristics and Household Income: A Case Study in Aegean Region, Turkey.” *Resources, Conservation and Recycling* 58: 114–24. https://doi.org/10.1016/j.resconrec.2011.11.005.

Andersen, J K, A Boldrin, T H Christensen, and C Scheutz. 2012. “Home Composting as an Alternative Treatment Option for Organic Household Waste in Denmark : An Environmental Assessment Using Life Cycle Assessment-Modelling.” *Waste Management* 32 (1): 31–40. https://doi.org/10.1016/j.wasman.2011.09.014.

Azapagic, Adisa. 2016. “CCaLC2 © for Windows Manual (V1.1),” no. November.

Damgaard, Anders, Christian Riber, Thilde Fruergaard, Tore Hulgaard, and Thomas H. Christensen. 2010. “Life-Cycle-Assessment of the Historical Development of Air Pollution Control and Energy Recovery in Waste Incineration.” *Waste Management* 30 (7): 1244–50. https://doi.org/10.1016/j.wasman.2010.03.025.

Das, Subhasish, S. H. Lee, Pawan Kumar, Ki Hyun Kim, Sang Soo Lee, and Satya Sundar Bhattacharya. 2019. “Solid Waste Management: Scope and the Challenge of Sustainability.” Journal of Cleaner Production 228: 658–78. https://doi.org/10.1016/j.jclepro.2019.04.323.

Dastjerdi, Behnam, Vladimir Strezov, Ravinder Kumar, Jing He, and Masud Behnia. 2021. “Science of the Total Environment Comparative Life Cycle Assessment of System Solution Scenarios for Residual Municipal Solid Waste Management in NSW, Australia” 767. https://doi.org/10.1016/j.scitotenv.2020.144355.

EPA. Environmental Protection Agency (2010) US Environmental Protection Agency. WARM Waste Reduction Model. https://www.epa.gov/warm. Accessed 24 January 2011

Evangelisti, Sara, Carla Tagliaferri, Roland Clift, Paola Lettieri, Richard Taylor, and Chris Chapman. 2015. “Life Cycle Assessment of Conventional and Two-Stage Advanced Energy-from-Waste Technologies for Municipal Solid Waste Treatment.” Journal of Cleaner Production 100: 212–23. https://doi.org/10.1016/j.jclepro.2015.03.062.

Hoornweg D, Bhada-Tata P. What a Waste: A Global Review of Solid Waste Management. Urban Development Series; Knowledge Papers No.15, World Bank, vol. 116; 2012. https://doi.org/10.1111/ febs.13058.

Kayhanian, M., and G. Tchobanoglous. 1993. “Innovative Two-Stage Process for the Recovery of Energy and Compost from the Organic Fraction of Municipal Solid Waste (MSW).” *Water Science and Technology* 27 (2): 133–43. https://doi.org/10.2166/wst.1993.0091.

Kaza, Silpa; Yao, Lisa C.; Bhada-Tata, Perinaz; Van Woerden, Frank. 2018. *What a Waste 2.0 : A Global Snapshot of Solid Waste Management to 2050. Urban*

Development;. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/30317 License: CC BY 3.0 IGO."

Köse, Ömer, Sait Ayaz, and Burak Köroglu. 2007. "Waste Management in Turkey." *Performance Audit Report* 1 (January): 82.

Laurent, Alexis, Ioannis Bakas, Julie Clavreul, Anna Bernstad, Monia Niero, Emmanuel Gentil, Michael Z. Hauschild, and Thomas H. Christensen. 2014. "Review of LCA Studies of Solid Waste Management Systems – Part I: Lessons Learned and Perspectives." *Waste Management* 34 (3): 573–88. https://doi.org/10.1016/J.WASMAN.2013.10.045.

OECD (n.d.). https://stats.oecd.org/index.aspx?DataSetCode=MUNW

Palanivel, Thenmozhi Murugaian, and Hameed Sulaiman. 2014. "Generation and Composition of Municipal Solid Waste (MSW) in Muscat, Sultanate of Oman." *APCBEE Procedia* 10: 96–102. https://doi.org/10.1016/j.apcbee.2014.10.024.

Pérez, Javier, Julio Lumbreras, and Encarnación Rodríguez. 2020. "Life Cycle Assessment as a Decision-Making Tool for the Design of Urban Solid Waste Pre-Collection and Collection/Transport Systems." *Resources, Conservation and Recycling* 161 (June): 104988. https://doi.org/10.1016/j.resconrec.2020.104988.

Rajput, R, G Prasad, and Chopra A.K. 2009. "Scenario of Solid Waste Management in Present Indian Context." *Caspian Journal of Environmental Sciences* 7 (1): 45–53. https://cjes.guilan.ac.ir/article_1016.html.

Ravi, Venkata, Sankar Cheela, Michele John, and Wahidul K Biswas. 2021. "Environmental Impact Evaluation of Current Municipal Solid Waste Treatments in India Using Life Cycle Assessment," 1–23.

RDC Environment SA. 2019. "Life Cycle Assessment of Aluminium Beverage Cans in Europe Methodological Report Metal Packaging Europe" 32 (0): 87. https://metalpackagingeurope.org/sites/default/files/2020-01/20190723_Metal Packaging Europe_Alu Bev Cans LCA_Methodological report.pdf.

Republic of Turkey Ministry of Environment and Urbanization. (2018). *Turkey's Third Biennal Report*.

Schübeler, Peter. 1997. "A Conceptual Framework for Municipal Solid Waste Management in Developing Countries." *Waste Management and Research* 15 (4): 437–46. https://doi.org/10.1006/wmre.1997.0098.

Taşkın, Akif, and Nesrin Demir. 2020. "Life Cycle Environmental and Energy Impact Assessment of Sustainable Urban Municipal Solid Waste Collection and Transportation Strategies." Sustainable Cities and Society 61 (October). https://doi.org/10.1016/j.scs.2020.102339.

The University of Manchester. 2013. "CCaLC © Manual (V3.1)," no. August: 74. http://www.ccalc.org.uk/downloads/Manual_CCaLC_V3.1.pdf.

The University of Manchester. 2013. "CCaLC © Manual (V3.1)," no. August: 74. http://www.ccalc.org.uk/downloads/Manual_CCaLC_V3.1.pdf.

TURKSTAT. (n.d.). https://data.tuik.gov.tr/Search/Search?text=atık

Wang, Dan, Jun He, Yu Ting Tang, David Higgitt, and Darren Robinson. 2020. "Life Cycle Assessment of Municipal Solid Waste Management in Nottingham, England: Past and Future Perspectives." *Journal of Cleaner Production* 251: 119636. https://doi.org/10.1016/j.jclepro.2019.119636.

Zhang, Li, Lihua Wu, Feng Tian, and Zheng Wang. 2016. "Retrospection-Simulation-Revision: Approach to the Analysis of the Composition and Characteristics of Medical Waste at a Disaster Relief Site." *PLoS ONE* 11 (7). https://doi.org/10.1371/JOURNAL.PONE.0159261.