

LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
LUT School of Energy Systems
Degree Programme in Environmental Technology
Sustainable Technology and Business

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COMPARISON OF THE TURKISH AND THE FINNISH MUNICIPAL SOLID WASTE MANAGEMENT SYSTEMS WITH A REGARD TO WASTE TO ENERGY POSSIBILITIES IN TURKEY

Examiners: Prof. Mika Horttanainen
Junior Researcher, M.Sc. (Tech.) Miia Liikanen

ABSTRACT

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This thesis represents a comparison of Turkey's and Finland's municipal solid waste management systems in order to provide pathways to improve Turkish municipal solid waste management system and to provide information on it. Comparison of municipal solid waste management systems was conducted under the categories of legislation, finance, collection, transport and treatment of municipal solid waste, and the performance of municipal solid waste management systems. It was found that the current Turkish municipal solid waste management system is not in line with the European Union standards. The main reasons behind this include the inadequacy of legislation surrounding the finance of municipal solid waste management system, the predominance of landfilling, the lack of source separation and mismanagement. The study also provided waste to energy scenarios for Turkey. According to these scenarios, 4,2 to 4,9 TWh of electricity per year can be theoretically generated from the co-combustion of Turkish municipal solid waste with coal addition while using only the waste collected from the five biggest cities. These amounts are equal to 5% and 5,8% of the renewable electricity generation in Turkey in 2015. Additionally, 22,1 Mt CO₂ eq. of greenhouse gas emissions can be avoided.

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ACRONYMS

EU	European Union
EC	European Commission
EP	European Parliament
EPR	Extended Producer Responsibility
GDP	Gross domestic product
HHV	Higher Heating Value
LFG	Landfill gas
LHV	Lower Heating Value
MSW	Municipal solid waste
OECD	The Organisation for Economic Co-operation and Development
RDF	Refuse-derived-fuel
TPES	Total primary energy supply
WFD	Waste Framework Directive
WTE	Waste to Energy

CHEMICAL COMPONENTS

CO ₂	Carbon dioxide
CH ₄	Methane
NO ₂	Nitrogen dioxide
NO	Nitrogen oxide
NO _x	Nitrogen oxide derivatives
SO _x	Sulphur oxide derivatives
SO ₂	Sulphur dioxide



1 INTRODUCTION

While striving to become a member of the European Union (EU), Turkey decided to improve its waste management situation since it was one of the sensitive political points during the accession negotiations. Still, today Turkey is far behind from the modern waste management principles of EU. European Environment Agency's 4-year-old report on Turkish Municipal Waste Management clearly states existing shortcomings of the system. Limited and outdated infrastructure, inadequate fees and taxes, insufficient coordination and cooperation among organizations that are responsible with municipal solid waste (MSW) management and the fact that the development of MSW management system is not a priority policy area are the major shortcomings mentioned in the report. (Bakas & Milios, 2013.)

This master's thesis presents comparative information about the waste management systems of Finland and Turkey. The aim is to explore the Turkish MSW management system and compare it to an already established, modern one, like Finnish MSW management system. The thesis also explores Turkish waste to energy (WTE) environment for determining its potential. The goals of the study are to locate areas for improving the current system, provide pathways for a developed system and to present solutions for the problems in Turkey. The topic is important for conserving and improving the Turkish environment as well as improving the life quality of Turkish citizens.

1.1 Background Information on Turkey

The Republic of Turkey is a country situated in Eurasia. As of 2016, Turkey has a population of 79,8 million and annual population growth rate between 2007 and 2016 was 1,3% on average (Turkish Statistical Institute, 2017a). With the recent refugee crisis, there are now over 3 million refugees in Turkey which will provide additional population and population growth in the future (European Commission, 2017).

Since 2013, Turkey's yearly gross domestic product (GDP) has been decreasing and is at USD 717,9 billion as of 2015 while the country's GDP per capita is at USD 9 125 (The World Bank, 2017a). Turkey is classified as a middle-income country and based on GDP, it is the 17th largest economy in the world (The World Bank, 2017b). Household consumption

distribution data shows that in 2015, Turkish households spent 20,2% of their expenditure to food and non-alcoholic beverages which contributes directly to MSW production in terms of food and packaging waste. In 2015, Turkish municipalities spent EUR 2 046 million for waste management services while governmental organizations and private provincial administrations spent about EUR 2,03 million (2015 currency rate: 1 EUR = 3,02 TRY) (Turkish Statistical Institute, 2017b).

Since 1964, Turkey has been in an Association Agreement with the EU, and since 1999 Turkey has held the status of a candidate country (European Commission, 2016a). Considering the 17 years passed under the potential candidate status, past Turkish governments did not create the effective regulations needed for a proper MSW management system as the problems associated with it continue. Despite the tension between EU and Turkey during the refugee crisis, Turkey has retained its candidate country status and current government shows efforts to become a full member. EU directives are goals that all EU members must achieve (European Union, 2017a). Therefore, Turkey should follow EU directives on waste management to become a full member. To achieve goals that are set in the EU waste directive, Turkey needs reshape its waste management policies and the application practices of them.

In Turkey, municipalities collected 28 million tonnes of MSW in 2014, equating to 394 kg/capita, year. In Figure 1, MSW collected by municipalities and MSW collected per capita per day is presented. MSW collected per capita in Figure 1 is calculated with the division of the amount of MSW collected by the number of inhabitants receiving MSW collection services. During the economic crisis in 2007-2008, collected MSW amounts declined remarkably. With the economic improvements after the crisis, MSW generation increased and the total amount of MSW collected reached 28 000 kt in 2014. MSW collected per capita per day decreased through years 2001 and 2014. Waste generation per capita is strongly correlated with the income levels of a country (United Nations Environment Programme, 2015). In this case, the decrease in waste generation per capita can be explained with the migration of rural population to populated cities and the change in their lifestyle. Between 2008 and 2014, MSW collected by municipalities increased by 3,6 Mt but the MSW collected per capita between those years continued to decrease. During this period, the population receiving MSW collection services in Turkey increased from 57,8 million to 70,8 million, which

is an increase of more than 22%. Because of this, even when the total amount of MSW collected increased rapidly, MSW collected per capita continued to decrease. (Turkish Statistical Institute, 2017b.)

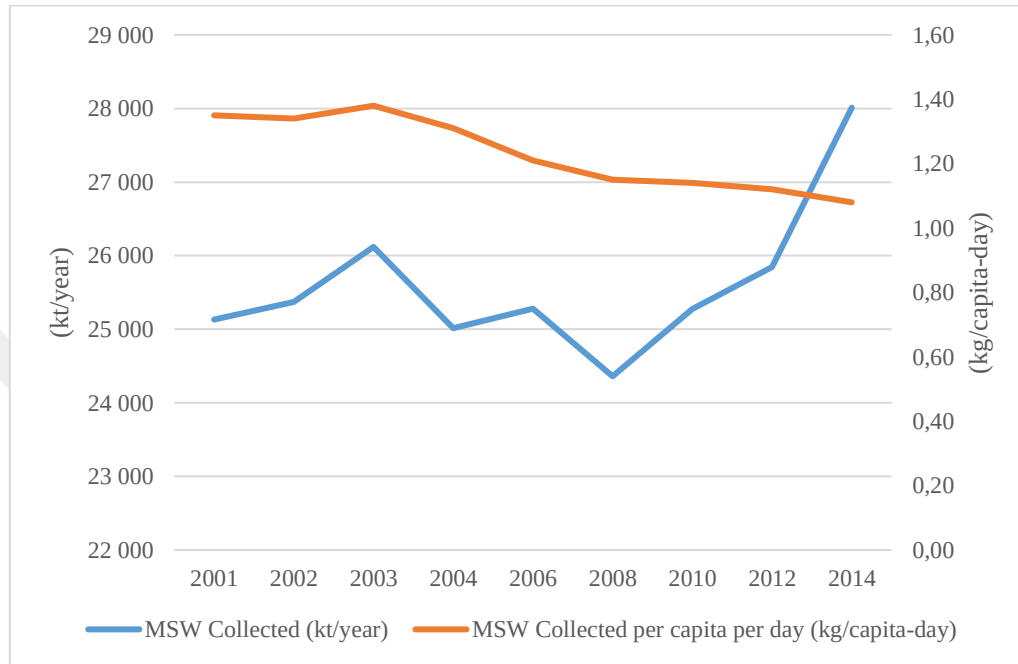


Figure 1. MSW collected and MSW collected per capita per day through year 2001-2014 in Turkey (Turkish Statistical Institute, 2017b)

Waste characterization and waste composition studies in Turkey indicate different results from different sources. There is a need for a standard to categorize the streams in Turkish MSW. To show the differences between waste composition studies, the results of multiple studies were included in this thesis.

In 1993, State Institute of Statistics (name changed to Turkish Statistical Institute in 2005) conducted a nationwide study to determine Turkish household waste composition (ÇEVKO Foundation, 2003). The study reported waste fractions of Turkish household waste and the fractions within the “regainable” category. In this study, “regain” is defined as the process of chemical, biochemical and physical conversion of waste materials into other products or energy. The term includes waste streams that are recyclable or reusable. The results of this study are presented below in Figure 2. In Figure 2, dross category refers to ash and dross materials. Dross is defined as a mass of solid impurities that floats on molten metals. (LÜY, et al., 2007.)

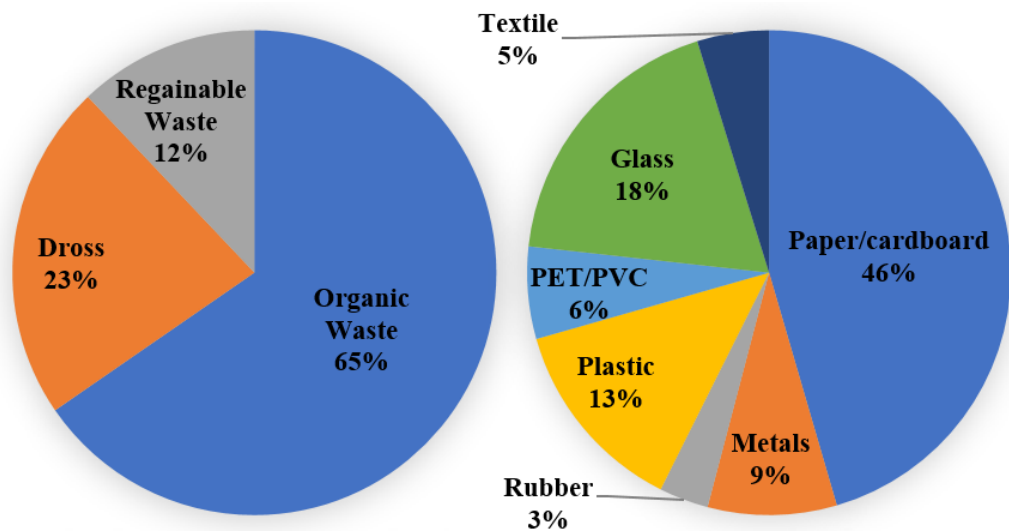


Figure 2. Turkish household waste fractions (left), fractions of regainable waste (right) (ÇEVKO Foundation, 2003)

Figure 3 represents the results of the MSW characterization project which was carried out by Ministry of Environment and Forestry in 2006 (Ministry of Science, Industry and Technology, 2014). The study was called “Solid Waste Master Plan Project”. Clarifications for the figure:

- Kitchen waste category includes only food waste.
- Other, combustible category includes textiles, diapers, various clothing and other types of materials that can be combusted.
- Other, non-combustible includes non-combustible materials like rock, sand dirt, ceramics, non-ferrous and non-aluminum metals.

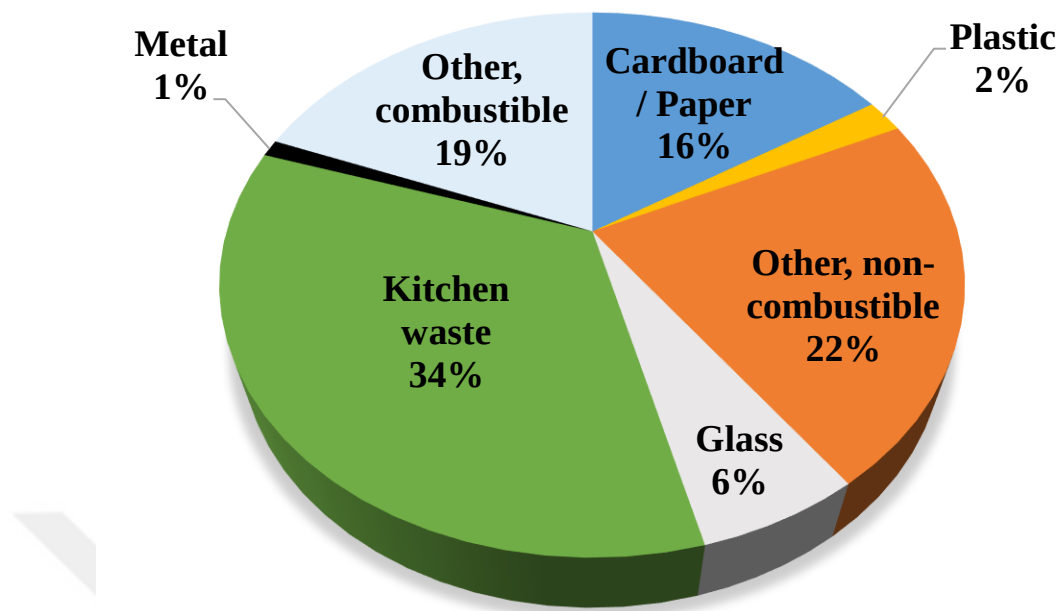


Figure 3. Turkish MSW composition in Solid Waste Master Plan Project (Ministry of Science, Industry and Technology, 2014)

A notable difference between the study conducted by State Institute of Statistics in 1993 and the study of Ministry of the Environment and Forestry in 2006 is the classification of waste fractions. These different classifications indicate the preferred potential treatment options of MSW during 1993 and 2006. In the older study, waste fractions were classified to emphasize the recyclable and the reusable fractions under the term “regain able”. In the newer study by Ministry of the Environment and Forestry, the classification “combustible” or “non-combustible” was included. The inclusion of “combustible” and “non-combustible” categories represent that waste incineration was started to be considered as a potential treatment option for MSW.

Union of Municipalities of Turkey reported the difference of MSW composition between different types of settlements in Turkey within the Solid Waste Recycling and Treatment Technologies handbook. The differences of MSW compositions between settlement types are presented in Figure 4. In Figure 4, non-combustible waste streams include dross, ash, dust and soil. For Figure 4, towns are defined as settlements with a population between 2 000 and 20 000 while cities are defined as settlements with a population greater than 20 000. (Union of Municipalities of Turkey, 2015, p. 19.)

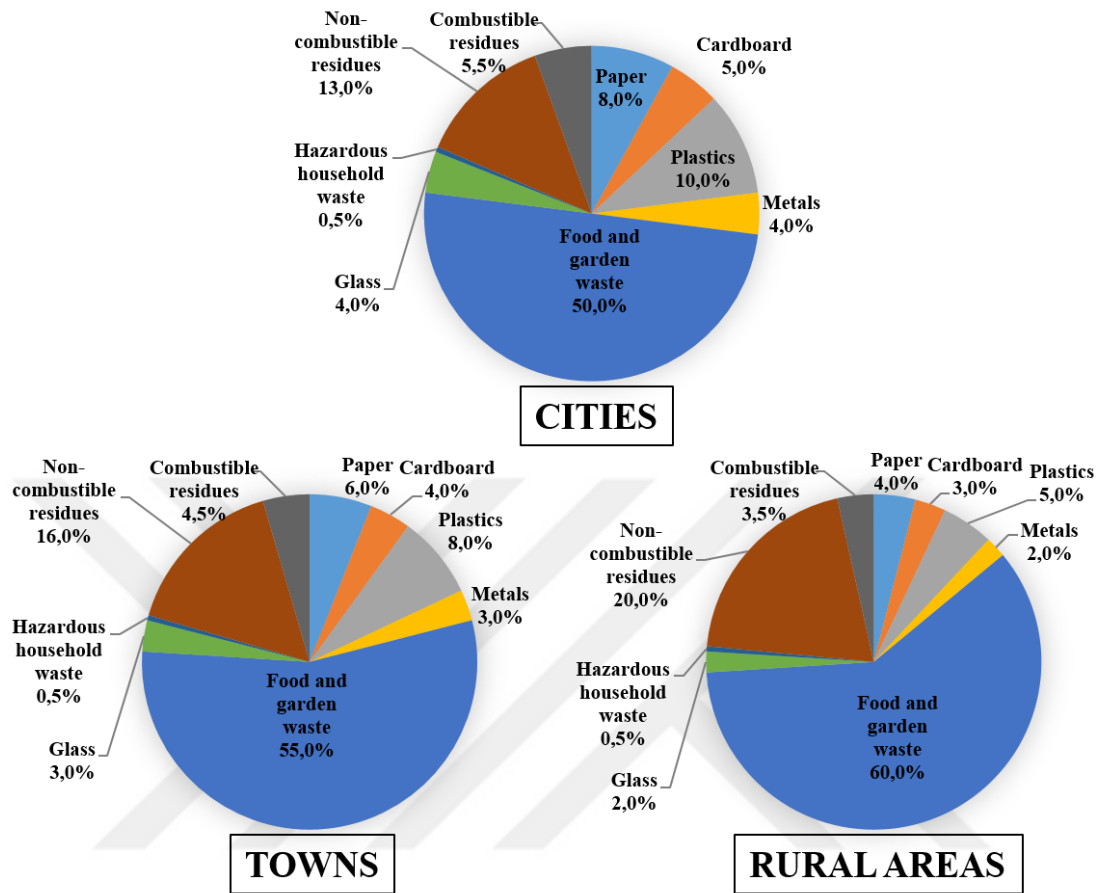


Figure 4. Turkish MSW compositions from different types of settlements (Union of Municipalities of Turkey, 2015, p. 19)

The share of food and garden waste and non-combustible residues increases with the increased rurality of Turkish settlements. Correspondingly, the share of combustible residues, cardboard, plastics, metals, paper and glass decreases with the increased rurality. From these points, it can be said that MSW from metropolitan cities are more suitable for waste to energy applications.

Table 1 shows the general MSW composition in Turkey by Sarptaş and Ergin (2015). The components marked as “Others” include hazardous waste, construction or demolition debris and coal ash. As it can be seen from Table 1, organic compounds or biowaste constitute the majority of Turkish MSW. The organic waste component is higher in rural areas because of the vegetable dominance in the diet corresponding to these areas. Another reason is that the

food supply in these areas are not packaged and premanufactured. Ash content is also higher due to the utilization of coal and waste burning stoves. (Sarptaş & Erdin, 2015.)

Table 1. MSW Composition of Turkey (Sarptaş & Erdin, 2015)

Components	% Range
Organic	40-65
Paper/cardboard	7-18
Plastics	5-14
Metals	1-6
Glass	2-6
Others	7-24

Overall, the composition percentage range given in Table 1 by Serptaş & Erdin (2015) shows an accurate portrayal of various Turkish MSW composition studies. As explained in Figure 4, there are variations in the composition of mixed MSW between different settlement types. These variations are crucial for defining waste to energy possibilities in different settlements and in Turkey as a whole.

Turkish Statistical Institute data shows that in 2014, 3,4% of Turkish greenhouse gas emissions, which is 16,1 million tonnes CO₂ equivalent, was caused by the waste management sector (Turkish Statistical Institute, 2017b). In comparison, waste management sector constituted 3,3% of all greenhouse gas emissions generated in EU in 2014 (Eurostat, 2016a). Since the adoption of Environmental Law in 1983, Turkey is striving to improve its environmental status. Although the progress towards an established MSW management system is moderate, with the adoption of EU targets, Turkey is progressing faster than ever. (Sarptaş & Erdin, 2015.)

1.2 Background Information on Finland

The Republic of Finland is a country situated in Northern Europe. As of January 2017, Finland has a population of 5,5 million people (Statistics Finland, 2017a). Finland has a relatively low population growth compared to Turkey. Statistics Finland projects that by 2050, Finland will have a population of 5,9 million (Statistics Finland, 2017b).

In 2015, Finland had a GDP of USD 231,95 billion. Finland saw its highest GDP growth rate in 2008 and it saw negative growth rates in years 2012-2015. Finland's GDP per capita was USD 42 311 in 2015. (The World Bank, 2017c.) Finnish households spent 12,1% of their household incomes to food and non-alcoholic beverages in 2012 which is significantly lower than Turkish households' share of 20,2% (Statistics Finland, 2017c). While constituting only 3% of total waste, money spent on MSW management in Finland was 36% of total spending on waste management which was estimated to be EUR 1 148 million per year in 2010 (Piippo, 2013).

Finland became a member state of the EU in 1995 (European Union, 2017b). This makes Finland responsible to uphold the EU Waste Framework Directive (WFD) and EU regulations on waste management. In past years, Finland succeeded in realizing some of the EU's MSW targets. Finland's share of landfilling in biodegradable waste treatment can be given as an example to these successful targets. The target amount for 2016 was 735 000 tonnes. This amount equates to 35% of the amount of biodegradable waste generated in 1995. (European Environment Agency, 2013a.) By 2013, Finland achieved this target by reducing landfilled biodegradable waste amount to 672 000 tonnes (Statistics Finland, 2016a). MSW recycling target of 50% by 2020 and construction waste recovery target of 70% by 2020 can be given as examples for targets that have not yet been reached in Finland (Salmenperä, et al., 2016).

In 2015, Finland treated all of its MSW. Figure 5 shows types of treatment methods and their shares in 2015. From Figure 5, the total recycling rate of MSW in Finland can be given as 41% in 2015 since composting and anaerobic digestion are regarded as recycling in waste statistics. (Eurostat, 2016b.) In Finland, between 1995 and 2015, MSW generation per capita increased by 21,1% and reached 500 kg per capita per year in 2015 (Eurostat, 2017).

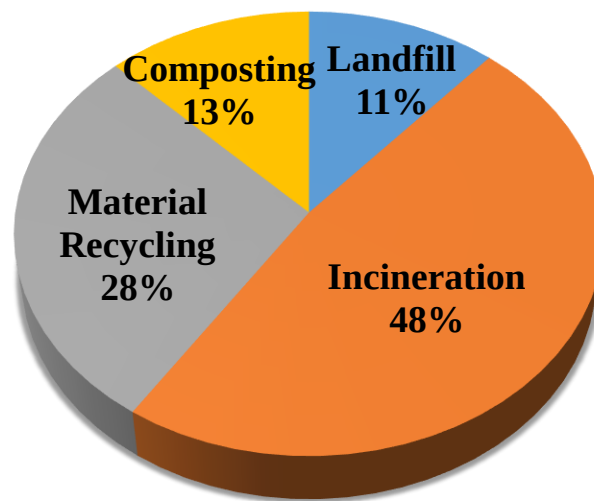


Figure 5. Share of municipal solid waste treatment methods in Finland, in 2015 (Eurostat, 2016b)

In 2015, the average MSW generation rate was 500 kg/capita per year in Finland, which makes 1,37 kg of waste per person per day (Eurostat, 2016b). Since 2000, the amount of MSW generated in Finland was between 2,4 to 2,8 million tonnes per year. Statistics Finland points out that total MSW generation is neither increasing nor decreasing. In Figure 6, total MSW generation in Finland and the MSW generation per capita per day are presented (Statistics Finland, 2017a). MSW generated and MSW generated per capita are strongly related due to the relatively stable population of Finland. In Figure 6 the effect of the 2007-2008 economic crisis can be seen with the reduced MSW generation during the following years. (Statistics Finland, 2016a.)

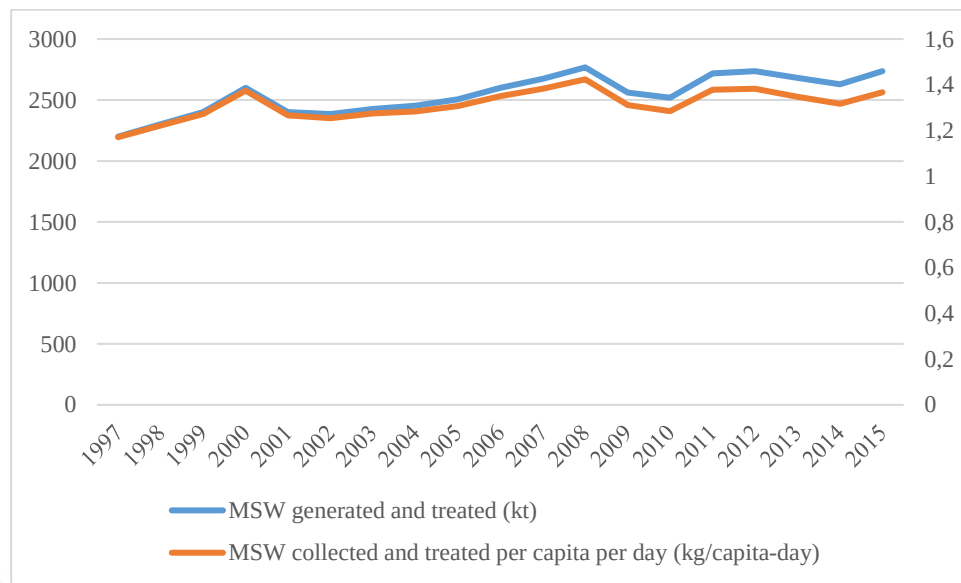


Figure 6. MSW collected and MSW collected per capita per day in Finland through years 1997-2015 (Statistics Finland, 2017a) (Statistics Finland, 2016b)

In Figure 7, Finland's volumes of different MSW streams and the composition of separately collected MSW are presented (Statistics Finland, 2013). In Figure 8, Finnish mixed MSW composition is presented (JLY - Finnish Solid Waste Association, 2017). In Figure 7 and Figure 8 the term “mixed waste” is used for the remaining part of MSW after the source separation process.

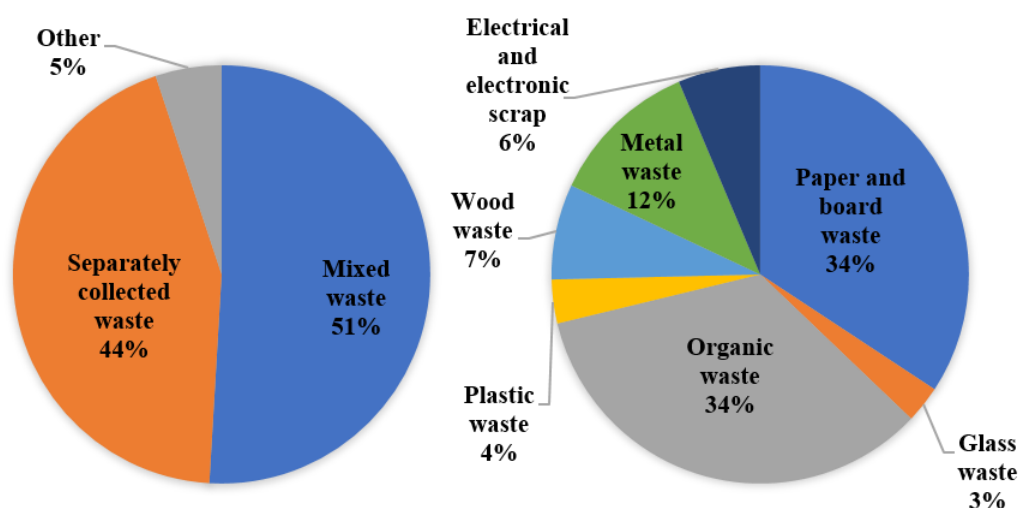


Figure 7. Volumes of different MSW streams (left), Composition of separately collected waste (right) (Statistics Finland, 2013)

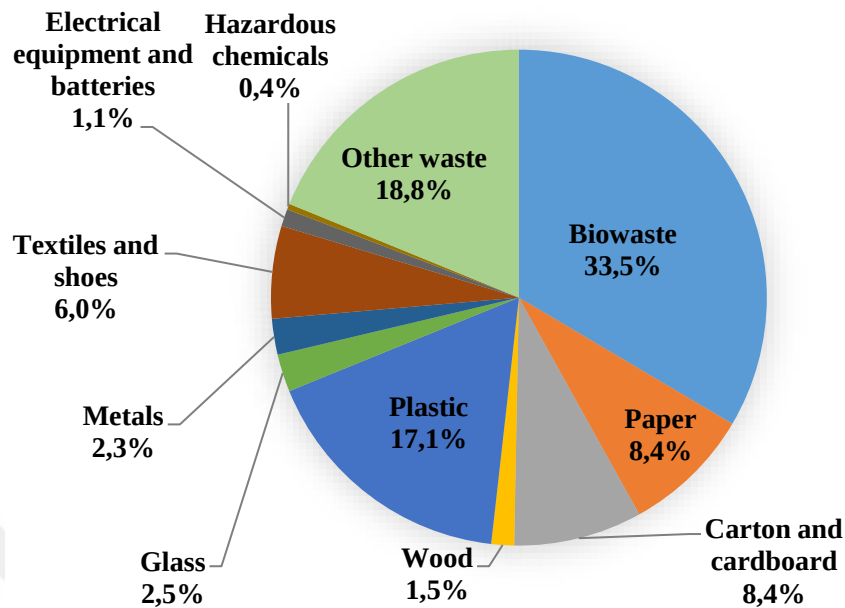


Figure 8. Mixed MSW composition in Finland (JLY - Finnish Solid Waste Association, 2017)

Direct comparison between Turkish and Finnish MSW compositions is not possible due to the availability of source separation in Finland. However, it can be said that organic waste has a higher share in Turkish MSW compositions. Both in mixed and source separated MSW compositions in Finland, organic waste has a maximum share of 34% while the lower limit in Turkish MSW compositions is 40%. Source separation process enables effective material and energy recovery options for MSW in Finland.

2 134 kt CO₂ equivalent greenhouse gas was emitted through waste management in Finland in 2015. This amount represents a share of 3,8% in all greenhouse gas emissions in Finland in 2015. (Statistics Finland, 2016c.) Although Turkey has a similar share of 3,3% while the amount of greenhouse gas emitted from waste management is more than 7 times higher.

2 MSW MANAGEMENT SYSTEMS

MSW management is a challenging task due to the amount of cooperation, infrastructure and citizen compliance needed to implement a successful system. Developing countries, especially those with high population and population growth are having difficulties to establish a modern MSW management system due to the increasing amounts of MSW and the burden it poses on municipal budgets to manage it (Guerrero, et al., 2013). Another difficulty for establishing a MSW management system arises from its nature that requires cooperation between communities, businesses, individuals and the government (Schwarz-Herion, et al., 2008). A successful MSW management system should incorporate said cooperation and waste treatment technologies to minimize environmental burdens of waste while causing minimal amount of burden to a municipal budget.

MSW generation per capita is correlated with national income level. The amount of MSW generated per capita is increasing in countries that are economically developing. For the countries that are at the highest levels of economic development, MSW per capita amounts are stabilizing and even decreasing. Estimations from Global Waste Management Outlook shows that 2 billion people are lacking access to MSW collection. National reporting systems on MSW is often lacking or incomplete. The lack of information makes research on MSW management systems difficult. In this chapter, information on MSW management systems of Finland and Turkey will be provided. (United Nations Environment Programme, 2015.)

2.1 Turkish MSW Management System

2.1.1 Regulations on MSW Management

In Turkey, the main authorities responsible for MSW management are municipalities. According to Solid Waste Control (1991) Regulation, each municipality is responsible to collect, transport and dispose MSW generated within their jurisdiction while preferring controlled storage disposal and separating assessable portion of the waste. (Union of Municipalities of Turkey, 2015, 33.) This regulation was updated through the years and received its final update on 2005 (Sarptaş & Erdin, 2015). The regulations on MSW management in

Turkey are shown in Table 2 with their respective dates and official gazette issue number (General Directorate of Development of Legislation and Publication, 2017).

Table 2. Regulations on MSW in Turkey (General Directorate of Development of Legislation and Publication, 2017) (Modified from Sarptaş & Erdin, 2015)

Year	Regulation (Official Gazette Issue No.)
2004	Regulation on the Control of Used Batteries and Accumulators (25569)
	Regulation on Excavation Soil, Construction Waste and Debris (25406)
2005	Regulation for Control of Medical Waste (25883)
	Regulation on Control of Hazardous Waste (25755)
2006	Regulation for Control of the Tire that Completed Their Life-Cycles (26357)
2007	Regulation on Control of Waste Oils (26952)
2008	Regulation Based on General Principles on Waste Management (26927)
2010	Regulation on Sanitary Landfilling of Waste (27533)
	Regulation on the Incineration of Waste (27721)
	Regulation for to Determining Tariffs for Waste Water Infrastructure and MSW Disposal (27742)
2011	Regulation on the Control of Packaging and Packaging Waste (28035)
2012	Regulation on Control of Waste Electrical and Electronic Equipment (WEEE) (28300)
2014	Communique of RDF, Additional Fuel and Alternative Raw Material (29036)
2015	Regulation on Waste Transportation on (29301)
	Regulation on Waste Management (29314)
	Regulation on Vegetable Oil Control (29378)

In 2005, Hazardous Waste Control Regulation was established and introduced disposal options for hazardous waste such as incineration and landfilling while setting standards for collection, storage and transport of the said type of waste (Sarptaş & Erdin, 2015). Control of Packaging and Packaging Waste Regulation which was introduced in 2011, provided a disincentive for manufacturers to produce products with packaging (Union of Municipalities

of Turkey, 2015, 34). According to this legislation, producers are responsible with the financing of the treatment for their products' packaging. Any damage done on the environment by packaging materials are fined to the responsible person or legal entity. This directive gave the responsibility of coordinating companies and other entities for providing source separation infrastructure to municipalities. The "Control of Packaging and Packaging Waste" regulation is one of the most important regulative decisions in terms of MSW management in Turkey as it provided regain targets for some materials which are set to increase until 2020 and can be seen from Figure 9. (Ministry of Environment and Urbanization, 2011.) These targets are set to comply with EU standards in the future (Union of Municipalities of Turkey, 2015, 35).

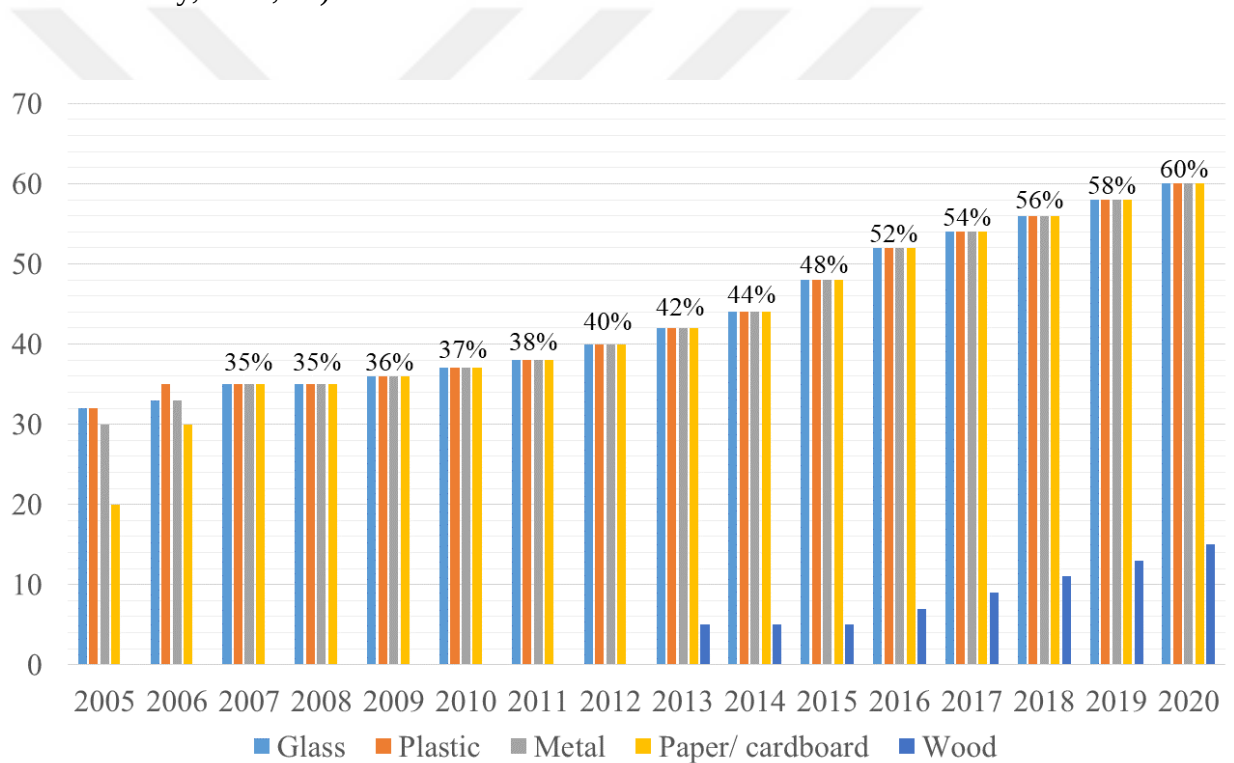


Figure 9. Regain percentage targets for materials according to "Control of Packaging Wastes" directive (Ministry of Environment and Urbanization, 2011)

Another important legislation concerning MSW management is Regulation for Sanitary Landfilling of Waste (2010). The legislation provided rules and laws related to:

- preventing leakage of liquid and gaseous substances that are harmful for the environment,
- construction of waste storage flooring that is suitable for the stored waste and building new landfills,

- applying control and maintenance practices before, during and after landfill operations,
- maintenance operations for the usage, expiration and after expiration of already existing landfills,
- the procedure for accepting waste to landfills.

Regulation for Sanitary Landfilling is particularly important because of the targets that it introduces to reduce the amount of biodegradable MSW that is accepted to landfills. According to the regulation, by 2025, the amount of biodegradable MSW disposed of in landfills should be reduced to 35% of the total amount of the biodegradable MSW generated in 2005 (Union of Municipalities of Turkey, 2015, 35-36). The regulation also states intermediate targets for the amount of biodegradable MSW disposed of in landfills. By 2015, the amount of biodegradable MSW disposed of in landfills should be reduced to 75% of the total amount of biodegradable MSW generated in 2005 and it should be 50% of that by 2018 (Öztürk, 2014). The target is applied to reduce food waste and utilize biodegradable materials for beneficial purposes instead of the conventional dumping preference which is currently the dominant practice in Turkey (Ministry of Environment and Forestry, 2010). Similarly, EU's Landfill Directive obliges its member states to reduce the amount of biodegradable MSW that they landfill to 35% of 1995 levels by 2020 (European Commission, 2016b).

The Regulation Based on General Principles of Waste Management which is the equivalent of Directive 2008/98/EC on waste of European Parliament (EP) was set in 2008. This regulation classified waste streams into 20 detailed groups for differentiating their potential hazards and determining their method of disposal or storage. (Union of Municipalities of Turkey, 2015, 33.)

Regulation on Waste Management (2015) set the ideal methods of waste management within regulations as recycling and energy recovery (Ministry of Environment and Urbanization, 2015). The regulation's main goal is to set methods and principles related to;

- introducing applications to manage waste from its creation until its disposal,
- reducing waste formation and reducing natural resource usage with methods like recycling, reusing and regaining waste,
- market auditing and surveillance of products that are related to this regulation.

The perspective change on waste management from disposal to recovery will diminish the negative effects of waste by providing tangible profit for the country. Also, the regulation obliges Ministry of Environment and Urbanization to prepare National Waste Management Plan with a duration of 5 years (Ministry of Environment and Urbanization, 2017).

2.1.2 Finance of MSW Management System

In Turkey, local authorities (municipalities) are responsible for financing of waste management services within their jurisdiction. Financial support from central authorities are restricted to projects on locations that are under the protection of said authorities and locations that provide external benefit. The main financial instrument to fulfil the financial needs of Turkish waste sector is Sanitation Tax which is collected via water bills. However, Sanitation Tax is not on the levels required by waste management services (0,7% of household expenditures). Currently, the revenue generated by the sanitation tax can only cover 20 to 30% of EU compatible MSW management tariffs that are prepared for Turkey. This means that the current sanitation tax cannot create the financial means for Turkey to introduce EU level MSW management services. The other problem about the Sanitation Tax arises with the inability to collect the tax in situations where water bills cannot be collected. Municipalities spend up to 40% of their revenues to subsidize waste collection and disposal services. The amount of Sanitation Tax collected is even less than the turnover of street collectors or scavengers. More information about street collectors are presented on chapter 2.1.3 Collection, Transport and Treatment of MSW. The problems with Sanitation Tax force municipalities to spend funding reserved for other purposes to waste management services. (Union of Municipalities of Turkey, 2015, 54-55.)

In 2014, Sanitation Tax for households was set to be calculated from the amount of water consumption in households. It was set to EUR 8,3 cents per m³ for metropolitan areas and EUR 6,5 cents per m³ in other municipalities (2014 currency rate: 1 EUR = 2,91 TRY). Industrial and commercial waste producers pay a fixed amount per year according to their type and scale of operations. The buildings used by these producers are assigned into groups and degrees. The annual Sanitation tax for industrial and commercial buildings are given in

Table 3. In Table 3, the first values, the values on left side on each column, are for metropolitan municipalities and the second values are for other municipalities. (Union of Municipalities of Turkey, 2015, 57.) In Table 3, building degrees are defined according to the purpose of the building; e.g. dormitories, schools and venues. Groups for these degree levels are defined from a quantified property of this purpose; e.g. number of students and amount of utilized area. Detailed group and degree selection criteria for Table 3 can be found in Appendix 1.

Table 3. Yearly Sanitation Tax amounts for buildings (2014 currency rate: 1 EUR = 2,91 TRY) (Union of Municipalities of Turkey, 2015, 57)

Building Groups / Degrees	1st Degree		2nd Degree		3rd Degree		4th Degree		5th Degree	
1st Group	990 €	792 €	775 €	620 €	646 €	517 €	517 €	413 €	431 €	344 €
2nd Group	646 €	517 €	474 €	379 €	383 €	307 €	301 €	241 €	258 €	207 €
3rd Group	431 €	344 €	331 €	265 €	258 €	207 €	207 €	165 €	164 €	131 €
4th Group	207 €	165 €	164 €	131 €	125 €	100 €	99 €	79 €	78 €	62 €
5th Group	125 €	100 €	131 €	79 €	69 €	55 €	64 €	52 €	52 €	41 €
6th Group	64 €	52 €	99 €	41 €	34 €	28 €	30 €	24 €	21 €	17 €
7th Group	21 €	17 €	52 €	14 €	12 €	10 €	10 €	8 €	8 €	7 €

As it is with households, the current levels of Sanitation Tax on buildings is not enough to cover modern MSW management costs. Categorizations of Sanitation Tax for buildings is not fully compatible with the polluter pays principle. For example, with the current categorization system, two schools with the same number of students but with different amounts of MSW generation pays the same amount of tax. With this categorization system, there is no incentive for users of these buildings to reduce their MSW generation because the tax levels are not adjusted according to the generated amount of waste and it is static. An adequate tax group categorization system which considers the amount of MSW generated as well as the type of MSW generated in buildings should be introduced to adjust the tax levels on MSW.

The two major disposal methods for MSW in Turkey are landfilling and dumping. Here, landfilling refers to the systematic burial of waste within landfill sites with adequate infrastructure while dumping refers to dumping waste to open pre-determined sites. Currently, there is no landfill tax in Turkey (Bakas & Milios, 2013). Landfilling is encouraged instead of dumping practices. Fees vary on each landfill site. For example, landfill fee for non-hazardous industrial waste in Izmir is 14,9 EUR/tonne while in Bursa, it is 22,4 EUR/tonne (Izmir Metropolitan Municipality, 2017; Bursa Metropolitan Municipality, 2017).

In 2005, under the Environmental Heavy-Cost Investment Planning (EHCIP) project, the investment need for environmental protection in Turkey was defined with the FEASIBLE model in accordance with the EU standards. FEASIBLE model is a software tool which is used for environmental financing and it is widely used in The Organisation for Economic Co-operation and Development (OECD) (Cowi, 2017). EHCIP project was prepared with the funding support by EU. The project's results show that the investment needed to "update" the MSW management sector in accordance with the EU standards in Turkey for the duration between 2007 and 2023 is EUR 9 560 million, (2005 currency rate: 1 EUR = 1,858 TRY) which makes 16% of the total investment required for environmental protection. Public sector is expected to provide 80% of these investments while private sector is expected to cover 20% of it. (Union of Municipalities of Turkey, 2015, 52.)

Union of Municipalities' Solid Waste Recycling and Treatment Technologies Handbook presents possible finance providers for environmental protection which are defined under the analysis Investment Plans in Accordance with EU Directives. These possible finance providers are represented in Figure 10. (Union of Municipalities of Turkey, 2015, 54.)

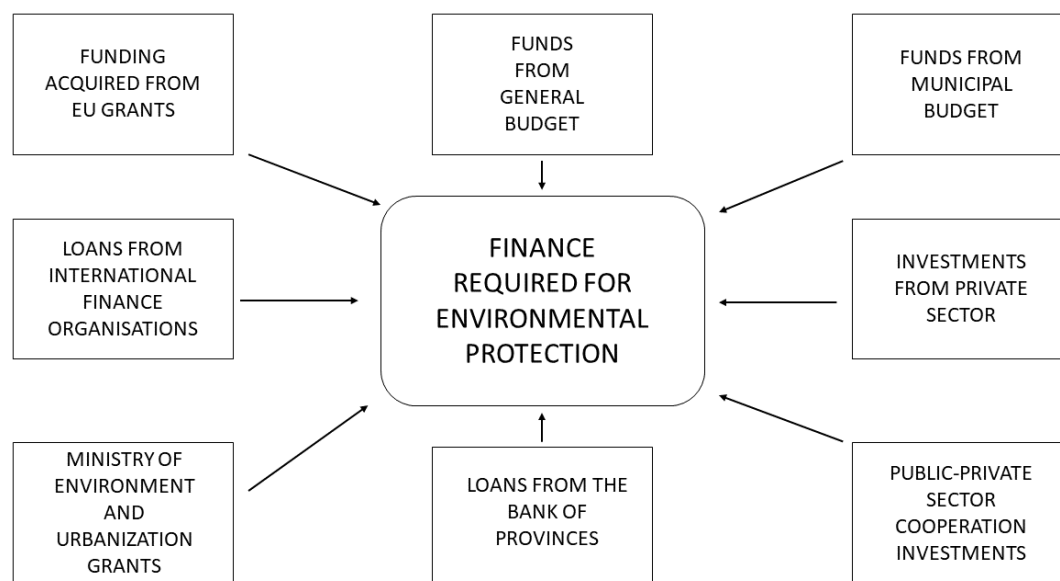


Figure 10. Possible finance providers for environmental protection (Union of Municipalities of Turkey, 2015, 54)

Overall, current economic instruments for MSW management are not effective in Turkey. The main revenue instrument, Sanitation Tax does not provide enough resources for municipalities to handle waste in accordance with EU legislation. New finance opportunities for enabling waste-to-energy infrastructure should be investigated.

2.1.3 Collection, Transport and Treatment of MSW

Municipalities are responsible for MSW management services throughout Turkey. Collection methods of MSW tend to change according to the characteristics of a given jurisdiction or area of service. Curbside collection trucks, trucks that collect and transport MSW with dedicated personnel are the main collection solution, especially in cities and large towns. These trucks collect MSW daily or twice a day. For areas with less population and less amount of waste, such as urban areas, community bin system is applied with various bin models fitting to the demand. The vehicles used by municipalities for MSW transportation are owned by the respective municipalities. It should be noted that municipalities spend a

large portion of their budget on MSW management services. MSW management expenditures constituted 7,96% of all municipal expenditures in 2014 (Turkish Statistical Institute, 2017b). (Sarptaş & Erdin, 2015.)

Another side of the Turkish MSW collection situation are scavengers. MSW recycling is the livelihood of these individuals. These individuals collect and transport recyclable MSW materials to sell them by weight to factories and various processing facilities. Scavengers are very common in developing countries. Large number of scavengers are apparent in China, India, Brazil, Columbia and Turkey. (Medina, 2008.) According to Union of Recycling Workers, there are around half million scavengers in Turkey (BBC, 2016). Ministry of Environment and Urbanization arranged fines to the companies that are purchasing materials from these unofficial workers and fined EUR 41 827 to 27 such companies (2016 currency rate: 1 EUR = 3,347 TRY) (BBC, 2016). These workers are estimated to provide recycling of 10-15% of the MSW in Turkey. (Sarptaş & Erdin, 2015). Currently, as it can be understood from the fines that the government issued, street collectors are seen as a problem. However, providing 10-15% of MSW recycling is no task that can be disregarded. According to Wilson et al. (2006), governments should investigate opportunities to engage these street collectors and provide them with legal mechanisms to support them. Ignoring these informal recycling systems and trying to establish a new waste recycling system can be highly counterproductive. Instead, integration of these street collectors to the MSW management system, building on their experience and providing them with improved living and working conditions can be much more effective. Some municipalities, like Municipality of Bolu, established pilot applications for separate MSW collection at source to enable efficient collection of recyclable MSW (KÖSE, et al., 2011).

According to Turan et al. (2009), instead of being collected separately by dedicated trucks, medical waste from healthcare facilities are commonly dumped into community bins. Nonetheless, some municipalities, especially municipalities with large populations organize separate collection of medical waste.

In 2014, 91% of the population was living within a municipality that offers MSW disposal services. Figure 11 shows the increase of this rate through 1994-2014 (Turkish Statistical Institute, 2017b). Only in 13 years, percentage of population within a municipality with

MSW services increased by 16%. This shows a major development of municipal services on waste management in Turkey.

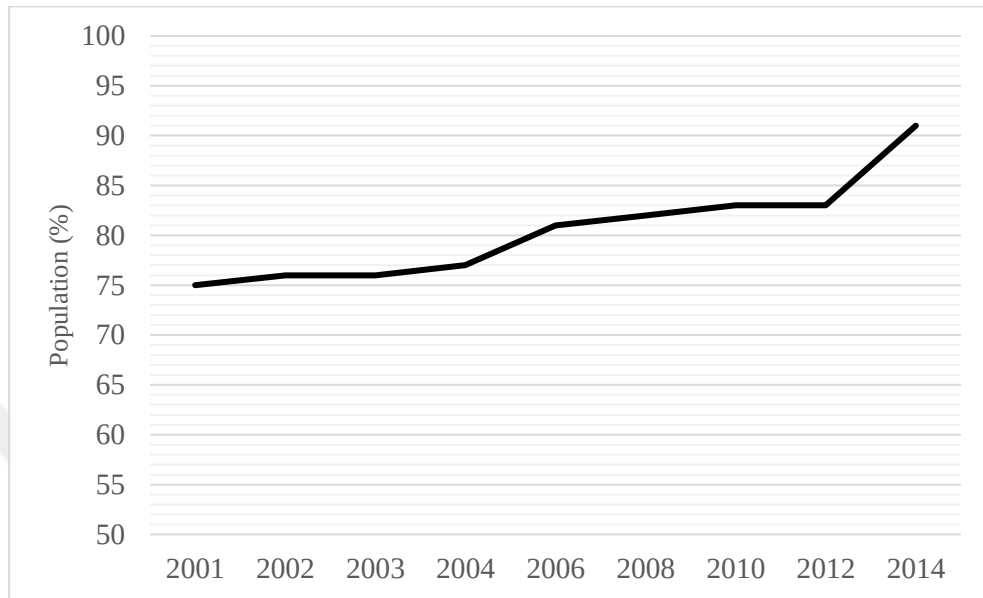


Figure 11. Percentage of population within a municipality with MSW services (Turkish Statistical Institute, 2017b)

Table 4 shows waste disposal methods that were applied by Turkish municipalities in 2014 (Turkish Statistical Institute, 2017b). The table includes the amount of waste collected only by the municipalities. Figure 12 represents the disposal method preference of municipalities through 1994-2014 (Turkish Statistical Institute, 2017b).

Table 4. Waste disposal methods and amounts in Turkey, 2014 (Turkish Statistical Institute, 2017b)

Amount of municipal waste collected (kt)	28 011	100%
Municipality's dumping site	9 936	35,47%
Waste delivered to controlled landfill site	17 807	63,57%
Waste delivered to composting plant	126	0,45%
Burning in an open area	4	0,01%
Lake and river disposal	16	0,06%
Burial	7	0,02%
Others	114	0,41%

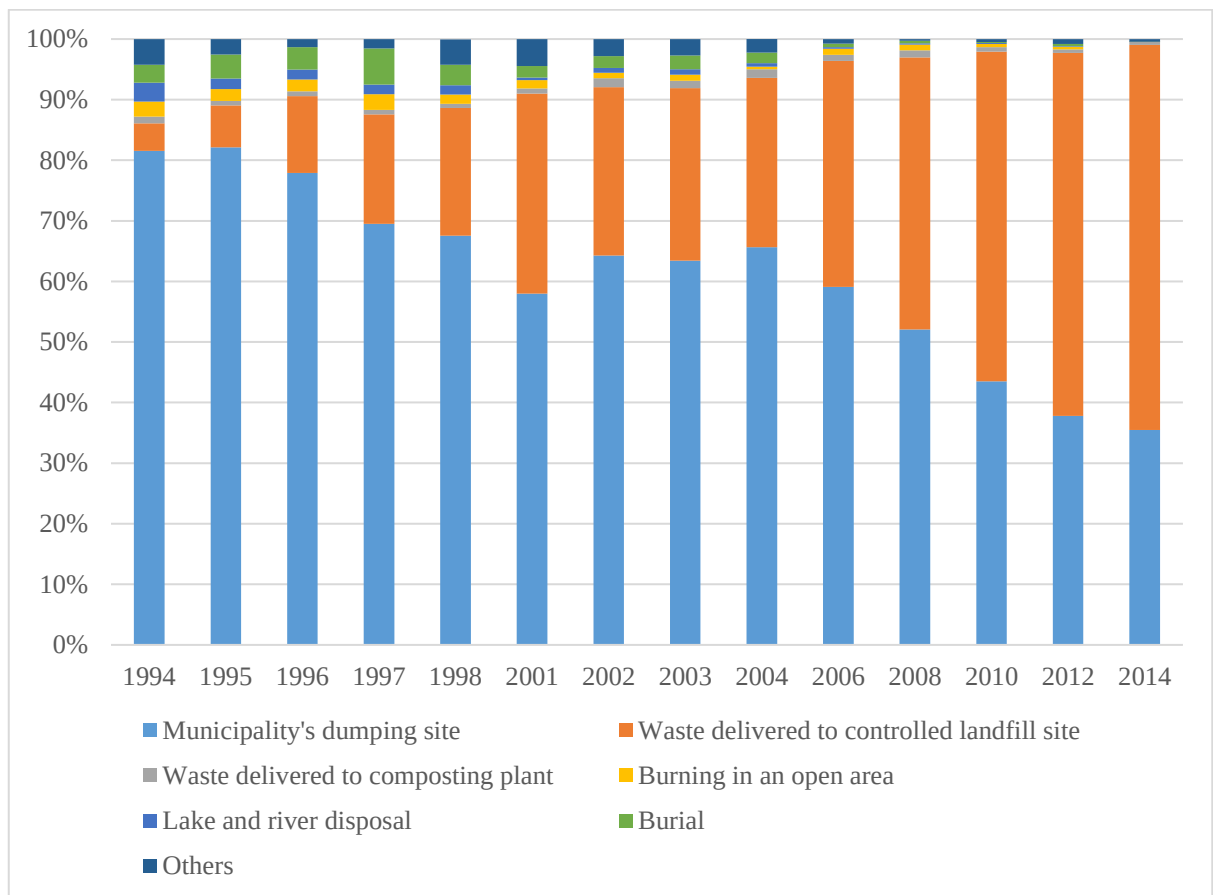


Figure 12. MSW Disposal method preference of municipalities between 1994-2014 (Turkish Statistical Institute, 2017b)

In Figure 12, municipality's dumping site refers to predetermined areas where waste is simply dumped and not processed. These dumping sites are prone to explosions and other dangerous situations like disease spreading via stray animals. Controlled landfills are sites with the appropriate infrastructure to contain waste safely and with minimal environmental consequences. Burial refers to uncontrolled burial of waste without a regard for consequences. Between 1994 and 2014, dumping site practices evolved into controlled sanitary landfills. Dominant disposal method became landfilling and environmentally harmful practices such as lake and river disposal and burning in open areas are close to be abandoned.

2.1.4 Performance of MSW Management System

MSW management practices that are considered illegal in many countries are still applied in Turkey. In 2015, 0,06% of MSW collected by municipal services were disposed to lakes

or rivers and 0,01% of the waste collected was openly burned in Turkey (Turkish Statistical Institute, 2017b). It should be noted that these are official statistics and the disposal act was documented by municipalities. On the other hand, there are many instances of uncontrollable catastrophes or acts done by unknown individuals that are caused by inappropriate MSW management practices. As an example, Bandırma dumping site which receives 170 tonnes of MSW each day, exploded and burned because of methane deposition in December 2016 (Hürriyet, 2016).

Turkish waste management sector causes negative effects to its air quality. The sectors' effect on air pollution as reported by the European Environmental Agency was minimal and was in the form of NMVOCs (non-methane volatile organic compounds) (European Environmental Agency, 2013b). However, the report did not consider the open burning of waste. Composed of many different materials, MSW, when burned openly and without control can cause many harmful emissions such as dioxins, particulate matters, CO, SO_x, NO_x, heavy metals and acidic compounds (Consonni, et al., 2005). The problem with the open or uncontrolled burning of waste is that the emissions from such events and their contribution to the air pollution of a country is hard to estimate as their composition, size and burning duration as well as their location affect the amount of emissions. Emissions from open burning are not included in many emission inventories. (Wiedinmyer, et al., 2014.)

9% of Turkish population does not have access to MSW management services (Turkish Statistical Institute, 2017b). These citizens are mostly living in rural countryside and they are managing their waste themselves, usually through openly burning, disorganized dumping or burning in stoves for their heating needs.

Ministry of the environment and urbanization released a report containing the regain amounts for some waste materials. According to the report, in 2013, all of the regain targets set in 2011 with the Control of Packaging Wastes directive were achieved. This example shows that with effective regulations, targets on waste can be reached in Turkey. Waste production amounts, waste amounts that are introduced to the market, amounts of waste regained, waste regain rate and their respective targets for the year 2013 are presented in Table 5. (Ministry of Environment and Urbanization, 2011; Ministry of Environment and Urbanization, 2016.)

Table 5. 2013 regain amounts and rates for waste types that are targeted in Control of Packaging Waste regulation (Ministry of Environment and Urbanization, 2011; Ministry of Environment and Urbanization, 2016)

Packaging Waste Type	Produced Amount in 2013 (t)	Amount introduced to the market in 2013 (t)	Amount regained in 2013 (t)	Regain rate in 2013 (%)	2013 regain target (%)
Plastics	1 566 809	904 579	472 890	52	42
Metals	279 177	156 879	82 187	52	42
Paper/card-board	2 358 591	1 271 906	1 429 091	112	42
Glass	899 596	641 520	183 053	29	42
Wood	655 477	456 057	61 600	14	5

It should be noted that regain rate is calculated from the share of regained amount in the amount of waste that is introduced to the market. Paper and cardboard regain rate of 112% can be explained by the behaviour of the companies that are reporting regain amounts. The amount of paper and cardboard introduced to the market is lower than the regained amount for the year 2013. This means that companies included in their reports the paper and cardboard amounts that are not introduced to the market in 2013 or the amounts that were already available but not regained in previous years. Organizations or companies that introduce the types of waste that are presented in Table 5 to the market are responsible to reach the regain rates according to the Control of Packaging Waste regulation (Ministry of Environment and Urbanization, 2011). It should also be noted that the amounts that are presented in Table 5 represents only the waste streams from organizations and companies that produce these waste streams. Since they are not collected and processed by municipalities, these waste statistics are not included in the collection and disposal statistics of municipalities. Government's approach to the recycling problem in Turkey was to regulate waste producing organizations or companies for increasing recycling rates of waste packaging materials. However, MSW collected by municipalities are not recycled because of the lack of municipal infrastructure and appropriate regulations. (Ministry of Environment and Urbanization, 2016.)

2.2 Finnish MSW Management System

2.2.1 Regulations on MSW Management System

In 1967, through the Sanitary Law, Finland gained its first law on waste. Sanitary Law stated that waste may not cause harm to human health. The first Waste Act was created in 1979 and it introduced legislation on administration, enforcement and financing of waste management. The latest Waste Act came in force in 2011 and amended until 2014. (Piippo, 2013.)

Finnish waste legislation is largely based on EU waste legislation. However, Finnish waste legislation incorporates some stricter standards or limits and some issues about waste that are not part of EU legislation (Ministry of the Environment, 2016a). Inclusion of tyres, graphic papers, medical wastes and agricultural films to the extended producer responsibility scheme in Finland can be given as an example to these differences. In Finland, The Ministry of the Environment is responsible with the supervision and the execution of waste legislation (Piippo, 2013).

As it is required by the EU, Finnish government issued National Waste Plan for 2016 in 2008. It contains waste management principles, objectives and actions required for these objectives. Finland's waste policy defines reducing the harmful health and environmental impacts of waste as the central objective. The other objective of the waste policy is to reduce greenhouse gas emissions, especially those that are emitted from landfills. The National Waste Plan for 2016 is in force until the next plan is ready. (Ministry of the Environment, 2009.) The new waste plan is in preparation and expected to be ready in 2017 (Ministry of the Environment, 2016b).

Since Finland is a member of the EU, directive 2008/98/EC or the Waste Framework Directive is followed in Finnish waste management systems. This framework defines a waste management hierarchy. This hierarchy is represented in Figure 13. (European Commission, 2008.)

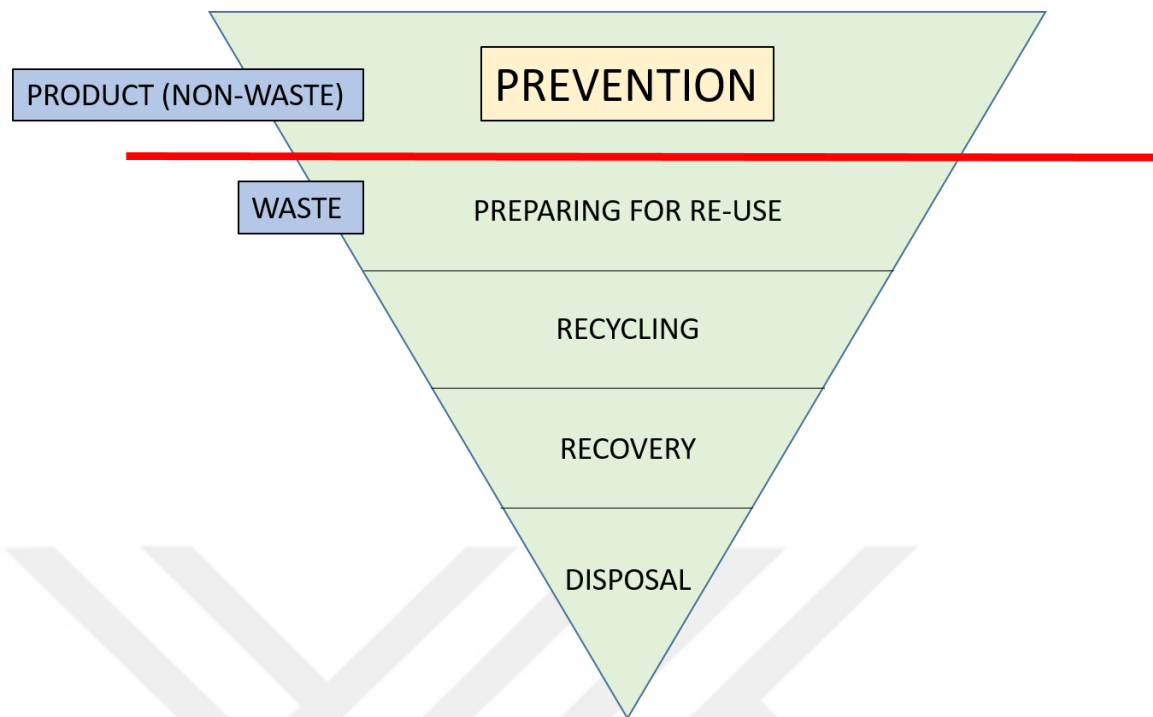


Figure 13. Waste management hierarchy (European Commission, 2016c)

The hierarchy presents prevention as the main priority followed by preparing for re-use, recycling, recovery and disposal. All regulations and policies related to waste management should follow waste management hierarchy set by European Commission (EC). The principle of this hierarchy is to minimize environmental impacts of waste. This hierarchy rule may be overrun if it is justified by better environmental performance (European Commission, 2008).

In Finland and in the EU, waste policies follow some key principles that have been adopted to the Finnish waste legislation. The principle of prevention suggests that production of waste should be reduced and if possible, it should be prevented. Polluter pays principle suggests that producers of waste should be responsible with the economic burden of managing it. Producer responsibility suggests that producers or importers of products are responsible with the management of waste materials that are created by their actions. The precautionary principle includes the anticipation of potential risks associated with waste and its management. The proximity principle implies that waste should be disposed near its source. Finally, self-sufficiency principle suggests that the EU and its members should remain self-sufficient with their disposal of waste. (Ministry of the Environment, 2016c.)

Extended Producer Responsibility (EPR) is an important part of the Finnish waste legislation. EPR introduced some obligations to producers for recovering the waste that occurred from their products. Producers must finance and organize the collection, pre-processing, recycling, utilization and management of their products that have finished their use. EPR covers batteries, accumulators, tyres of various vehicles, electrical appliances, cars, vans and other vehicles, newspapers, magazines, paper products and all types of packaging. The goal of EPR is to instate life-cycle thinking into producers and force them to think about the consequences of their product design decisions. (Piippo, 2013.)

Finnish government is aiming to increase the recycling rate of municipal waste from 33% to 50% and the recovery rate of construction waste from 58% to 70% to meet 2020 targets set in WDF (Salmenperä, et al., 2016). Another important regulation on MSW management is the landfill ban on all organic waste which started at the beginning of 2016 (CEWEP, 2017).

2.2.2 Financing of MSW Management System

Compared to Turkey, Finland's financial mechanisms that are supporting MSW management are highly developed. Finnish society is guided to environmentally better performing waste recovery solutions via economic instruments. The main economic instruments for the finance of waste management are municipal waste charges, waste tax, drinks packaging tax and oil waste charges (Piippo, 2013).

MSW charges are used to cover all costs associated with MSW management. It includes costs from collection to final disposal or recovery of MSW. These charges are applied to encourage waste reduction, waste utilization and to make waste less harmful. The amount of waste charge is set by municipalities and private companies that partake in MSW management activities. MSW charges are reduced if MSW is being sorted. (Piippo, 2013; Ministry of the Environment, 2016d.)

Waste tax is applied to all landfill sites if their utilization is technically feasible, environmentally good performing and allows increased commercial exploitation of waste with the tax. Waste tax amount was 40 EUR/t in 2011, 50 EUR/t in 2013 and since the beginning of

2016, it is 70 EUR/t. This progressive increase in waste tax amount shows Finland's commitment to reduce the amount landfilled waste. (Piippo, 2013; Ministry of the Environment, 2016d.)

To encourage reuse of drinks packaging and to reduce landfilled waste amount, drinks packaging tax is applied in Finland. The amount of tax is set to 0,51 EUR/litre. Finland has deposit-based return systems for beverage packages. Beverage manufacturers can be exempt from drinks packaging tax by participating in approved returnable deposit systems or organizing new return systems in accordance with Waste Act. (PALPA, 2017.) Oil waste charges is included in lubrication oil prices with the amount 5,75 EUR cents/litre. It is applied for covering costs associated with oil waste and its effects on the environment. (Ministry of the Environment, 2016d.)

Also in Finland, producer responsibility is highly important as an economic instrument for MSW management. The producers and importers of cars, tyres, electronic and electrical appliances, batteries and accumulators, and paper are considered applicable for producer responsibility. Producers are also responsible with the packaging of their products under producer responsibility. The producers of these products must cover the finance of the waste management for their products. Usual solution for this is to include the costs associated with the waste management products into the selling price. (Ministry of the Environment, 2017.)

Landfill gate fees in Finland are on average 99,6 EUR/ton (changing between 70 to 150 EUR/ton, waste tax amount = 60 EUR/ton) (CEWEP, 2017). Due to the increasing requirements and the increasing gate fees, the amount of landfill sites in Finland decreased from about 2000 to less than 100 (YLE, 2015). Compared to Turkish landfill gate fees (15-20 EUR/ton), Finland's landfill fees are extremely high. The great difference between landfill gate fees shows how different are MSW management approaches of these countries. While Turkey is aiming to increase the landfilling of MSW, Finland is trying to decrease it. The average gate fee for waste incineration in 2014 was 75 €/t in Finland (CEWEP, 2016).

2.2.3 Collection, Transport and Treatment of MSW

As in Turkey, municipalities are under obligation to organize their MSW management in Finland. To promote efficiency, municipalities can cooperate with other municipalities. Co-operation between municipalities is established by instating a waste management authority that is responsible on the decisions regarding MSW management regulations and fees within the participating municipalities. It is common that municipalities form a company for their MSW management needs. For example, Etelä-Karjalan Jätehuolto Oy is a waste management company owned by 9 municipalities in Finland. The company is responsible with the transportation, reception and processing of MSW. (Etelä-Karjalan Jätehuolto Oy, 2017; Piippo, 2013.)

In Finland, MSW management begins with waste sorting in households and companies. Waste producers are responsible with sorting their waste by waste types such as biowaste, mixed waste, metals, hazardous waste, glass, paper and carton. Waste producers are also responsible with organizing waste collection points within their property and the transport of their waste to these collection points. (Piippo, 2013.)

To make handling and treatment of waste easier, different types of waste are collected separately. If it is environmentally and economically reasonable, separate collection activities can be organized. Almost all Finnish citizens have access to separate collection of paper, glass, hazardous waste, metals and cardboard. Biowaste collection from households is also very common. Containers used for collection changes in capacity and type according to the waste production amounts and the type of households. Deep collection containers and surface collection containers are both widely used. Containers for different types of waste are usually marked or coloured differently in a way to distinguish their respective waste type. Apartments and apartment blocks usually have their own collection containers for paper, cardboard, metal and glass while single family houses usually have containers for biowaste and dry waste only. Collection of MSW is usually done once a week with garbage trucks. In the case of deep collection containers, time between collections can be as high as 6 weeks. (Piippo, 2013.)

Most municipalities in Finland do not own waste collection trucks and outsource their MSW transportation needs to private waste management companies. Usually, these waste companies are selected through competitive bidding. Waste generators can also arrange direct contracts with collecting companies. (Piippo, 2013.)

The next step in MSW management is waste treatment. Waste treatment refers to recovery or disposal of waste to transform it into a useful or a less harmful form of itself. Municipalities must choose and organize waste treatment for the waste that they are responsible for. In Finland, waste treatment is often done in centralized treatment facilities to promote efficiency. These facilities have the means for processes required for different waste treatment methods. Due to the lack of local treatment facilities waste is often transported long distances for treatment, e.g. incineration. This is especially evident in northern municipalities where finding investments for new treatment facilities is harder due to low population. (Piippo, 2013.)

MSW treatment methods are classified as material recovery, energy recovery and landfilling. Municipalities treat their MSW according to regulations and budget limits. In Figure 14, Finland's preferred MSW treatment methods are shown (Statistics Finland, 2016b).

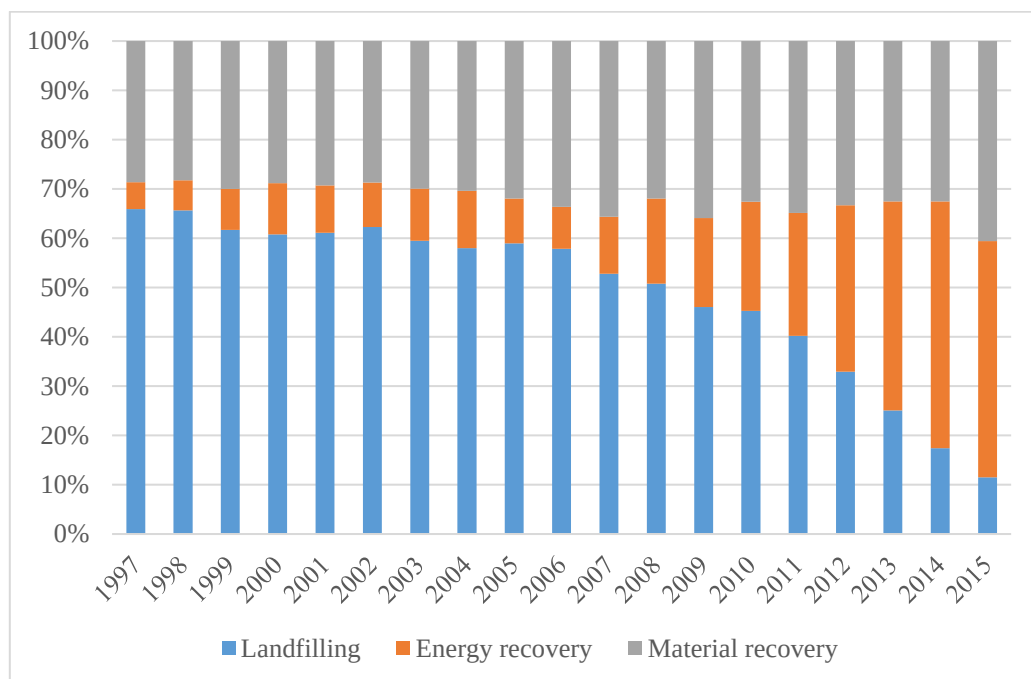


Figure 14. Realized MSW treatment method shares in Finland through 1997-2015 (Statistics Finland, 2016b)

In Figure 14, the effect of landfill ban on organic waste and the gradual increase of landfill fees can be seen as a reduction of landfill preference percentage over the years. Municipalities had to avoid landfilling options due to both regulation and economic constraints. (Statistics Finland, 2016b.)

Finland has a total of 9 waste-to-energy facilities including dedicated RDF plants. However, there are also energy plants with waste incineration permissions. Generally, these plants receive commercial and construction waste and utilize co-combustion techniques for energy production. There are 23 co-combustion plants in Finland (Horttanainen, 2016a). In 2014, nearly 50% of treated MSW in Finland was incinerated. Approximately 50% of energy recovered from waste is recognized as renewable energy. Currently, there are no subsidies or market based instruments to support waste to energy in Finland. It should be noted that there is no waste incineration tax in Finland which is a desirable situation for private companies willing to invest in waste to energy. (CEWEP, 2016.)

2.2.4 Performance of MSW Management System

Compared to Turkey, Finland has a very successful MSW management system. 100% of Finnish MSW generated in 2015 (2 738 kt) was treated. Of this amount, 11,5% was landfilled and 47,9% was incinerated (Eurostat, 2017). Landfilling is steadily decreasing. The advancement of incineration and recycling options created a competition between these two treatment methods and forces the selection of the best economic performer. In 2015, total recycling rate was 41% (Eurostat, 2016b).

Finnish authorities must continue to implement well performing MSW management practices to reach EU's targets on MSW management for 2030. These targets include recycling 65% of MSW, 75% of packaging waste and reducing landfilling to maximum 10% of MSW (European Commission, 2016d). Finland produced 0,62 TWh of electricity and 2,643 TWh of heat from waste to energy processes in 2014 (CEWEP, 2016).

3 COMPARISON OF MSW MANAGEMENT SYSTEMS

To compare Turkey's and Finland's MSW management systems, the systems are divided into regulations and finance. These are categories that are used in the previous chapters to provide background information on the countries themselves and their MSW management systems. The aim of this chapter is to point out the main differences between the countries' MSW management systems to discover practices that can be adopted by the countries to improve their MSW management systems. In the last part of the chapter, a comparison table composed of quantifiable information on MSW management systems of both countries is provided.

3.1 Regulations

Both Turkey and Finland should comply with EU's framework on waste management since Turkey is a candidate and Finland is a member of the EU. Current regulations on MSW in both countries show that while Finland is trying to fine tune its already established MSW management system, Turkey is trying to upgrade its system to a position where all MSW is treated in a way that doesn't produce any unwanted outcomes. Countries' view on landfilling can be given as an example to this situation. Finland is trying to phase out landfilling altogether while Turkey is trying to establish it as a standard disposal method. The absence of a landfill tax in Turkey is the outcome of its positive view on landfilling.

Municipalities are the responsible authorities on MSW management in both countries. In Finland, all municipalities are obliged to organize the MSW management needs of the population within their jurisdiction. In Turkey, however, not all municipalities provide MSW management services. Out of a total of 3225 municipalities, 96 municipalities do not provide MSW services in Turkey (Ozcan, et al., 2014). New regulations should focus on increasing the percentage of population receiving MSW services to 100%. This percentage through years 2001 and 2014 was shown previously in Figure 11.

Source separation of MSW is an important issue on MSW management. The purpose of source separation is to transform MSW into fractions that can be utilized in a way that generates environmental or economic benefits. Source separation enables better recycling and

energy recovery options. It is especially important for improving the quality of MSW for energy recovery options by removing undesirable fractions of waste for energy production such as fractions with high water content, which increases the heating value of MSW. Source separation also helps with the mechanical separation processes that proceeds it. Effective source separation can reduce mechanical separation duration for recovering recyclables from MSW that is meant for combustion. Source separation enables less contaminated and less costly materials for recycling. It can also improve the quality products derived from MSW. For example, the quality of compost products is increased with reduced glass, metal or plastics content. With source separation, MSW is diverted from reaching landfills. Instead, MSW is reintroduced to the economy. Finland's Waste Act 2011 specifies quality requirements for MSW management services and it mentions separate collection of MSW as a quality requirement (Finlex, 2015). Without source separation regulation in place, waste cannot be collected in sorted form and it can't be processed adequately. Turkey should incorporate separate collection into regulation to enable source separation of MSW. Otherwise, informal collection systems will further develop inside the MSW management system. Street collectors or scavengers in Turkey can be given as an example to this outcome. These people are not to blame for their activities as they are a natural consequence of the current MSW management environment. Their existence shows the industries' need for recyclable materials and the inefficient formal collection methods for these recyclable waste materials.

Currently, Turkey is preparing its regulations on MSW management according to EU directives. However, as it is shown in the performance section of the Turkish MSW system, these regulations are not applied effectively. Turkey should ensure the application of its laws to collect the benefits of them. In terms of MSW management more monitoring should be done, especially on municipalities performance.

To ensure easier transition to a more modern MSW management system that complies with EU's standards, regulations on public education on MSW management should be implemented. Public compliance is a must to operate a successful source separation system which as previously mentioned, provides better MSW management options. Informative posters or flyers can be dispersed through public buildings and schools for education on MSW management. However, education on MSW management should not be limited with informing

the public, it should be supported with economic incentives via regulations to cement public behaviour.

3.2 Finance

In Turkey, the finance need of MSW management systems is mainly supplied from the funds generated from the Sanitation Tax while in Finland, finance around MSW management is highly developed and is supplied with multiple taxes and waste charges. Turkish Sanitation Tax levels are not adequate and enough for modern MSW management applications as municipalities are committing funds from their budgets that are reserved for responsibilities other than MSW management. Another issue about Sanitation tax is its calculation method. Tax amount to be collected is calculated from the water consumption amounts of households. It should be transformed into a measure that takes polluter pays principle into account and it should be adjusted to cover all costs associated with MSW management. Finland's waste charges can be a good example economic instrument. It is dynamic and it changes from municipality to municipality and it is calculated to cover all costs associated with MSW management.

Finland has succeeded in creating an environment for inter-municipality cooperation for MSW services. Combining revenues from MSW management fees enables better MSW treatment options with better environmental and economical outcomes due to the availability of increased capital for investments that can benefit all participating municipalities. Turkey should seek out to establish this cooperation between its municipalities. Regional MSW management budgets that are assigned to multiple municipalities can be a good application for this endeavour.

In terms of landfill taxes, the absence of its application in Turkey is justifiable. Landfill tax applications are avoided to promote landfilling against simple dumping sites that are controlled by municipalities. Again, the low landfill gate fees are also justified with this stance of the government. In Finland, all financial measures relating to landfills are applied to discourage landfilling.

Turkey's great population poses a challenge for transforming its MSW management system. Especially, population density in major cities like Istanbul makes the finance of MSW collection and treatment difficult. For Istanbul, which is a city that contains almost a fifth of the population of Turkey, major investments are needed to finance MSW treatment centres that can meet the demand of MSW treatment. Changing public awareness on MSW management to promote environmentally better outcomes can be also financially challenging for Turkey. Due to high population, the finance need of education on MSW management can be high. Another issue is the income levels of Turkish citizens. Increasing taxation on MSW management can lead to citizens abandoning their support for the government. However, for the long-term benefit, MSW management taxes should be adjusted to accommodate modern MSW management practices.

3.3 Comparison Table of MSW Management Systems

In

Table 6, comparison of various parameters on MSW management are presented for Turkey and Finland.

Table 6 is prepared in order to spot major differences between the MSW management systems of Turkey and Finland. Conclusions on Table 6 can be found after the table.

Table 6. Comparison Table of MSW Management Systems for Turkey and Finland

Compared information	In Turkey	In Finland
Municipal waste generated in 2015 (a)	31 283 kt	2 738 kt
Municipal waste generated per capita, 2015 (b)	400 kg	500 kg
Municipal waste treated per capita, 2015 (b)	352 kg	500 kg
Treated municipal waste share, 2015 (b)	88%	100%
Landfilled municipal waste share, 2015 (b)	87,5%	11,4%
Composted and digested share, 2015 (b)	0,5%	12,4%
Material recycling share, 2015 (b)	N/A	28,2%
Incineration share, 2015 (b)	N/A	47,8%
Total spending on waste management (c) (d)	EUR 2 048 million (c)	EUR 1 148 million (d)
Total spending on waste management per capita (c) (d)	EUR 26,03 (c)	EUR 209,4 (d)
GDP per capita, 2015 (g) (h)	EUR 8 550 (g)	EUR 39 645 (h)
Share of total spending on waste management per capita in GDP per capita, 2015	0,3%	0,5%
Landfill tax (e) (f)	None (e)	70 EUR/ton (f)
MSW Collection Practices (d) (i)	Curbside collection or community bin systems with municipality trucks (i)	Various collection points organized by companies formed by municipalities. Active cooperation between municipalities (d)
Separate collection of MSW (d)	N/A	Paper, glass, hazardous waste, metals and cardboard available for almost all citizens, bio-waste separation widely available (d)

- (a) (Eurostat, 2017)
- (b) (Eurostat, 2016b)
- (c) (Turkish Statistical Institute, 2017b)
- (d) (Piippo, 2013)
- (e) (Bakas & Milios, 2013)
- (f) (Ministry of the Environment, 2016d)
- (g) (The World Bank, 2017a)
- (h) (The World Bank, 2017c)
- (i) (Sarptaş & Erdin, 2015)

The difference between countries' total spending on waste management per capita is striking. Turkey's MSW generation per capita is 100 kg/year lower than Finland's MSW generation per capita. Even when Turkey's total spending on waste management per capita is adjusted due to this difference via direct proportion, it is still EUR 32,5. Finland's share of MSW spending per capita in GDP per capita is 0,5% while Turkey's is 0,3%, which a difference of 60%. The statistics show the financial problems in Turkey's MSW management system and that Finland prioritizes MSW management more than Turkey.

As mentioned before, the practice of landfilling is still supported in Turkey and the statistics on In

Table 6, comparison of various parameters on MSW management are presented for Turkey and Finland.

Table 6 is prepared in order to spot major differences between the MSW management systems of Turkey and Finland. Conclusions on Table 6 can be found after the table.

Table 6 shows this property as well. Even with immense landfilling shares (87,5%), Turkey is still not treating all of its MSW. Efforts should be made to provide municipalities with enough resources to handle their MSW management.

One of the biggest contributors to a MSW management system's performance is the method of MSW collection. In Turkey, there is no developed source separation system to enable

separate collection of MSW. In Finland, almost all citizens have access to separate collection. The lack of source separation severely limits Turkey's MSW management options as it can be seen from the statistics presented in In

Table 6, comparison of various parameters on MSW management are presented for Turkey and Finland.

Table 6 is prepared in order to spot major differences between the MSW management systems of Turkey and Finland. Conclusions on Table 6 can be found after the table.

Table 6. Predominance of landfilling, very low or non-existent recycling rates and the lack of energy recovery options from MSW are all problems derived from the absence of source separation.

4 WASTE TO ENERGY

WTE refers to processes that can derive usable energy from waste materials (Branchini, 2015). There are various technologies for WTE processes. As presented in Figure 15, the technologies for WTE include, incineration of waste, biogas production from biodegradable waste (anaerobic digestion), gas collection from landfills, bio-fuel production with pyrolysis and syngas production from gasification process (Tan, et al., 2014).

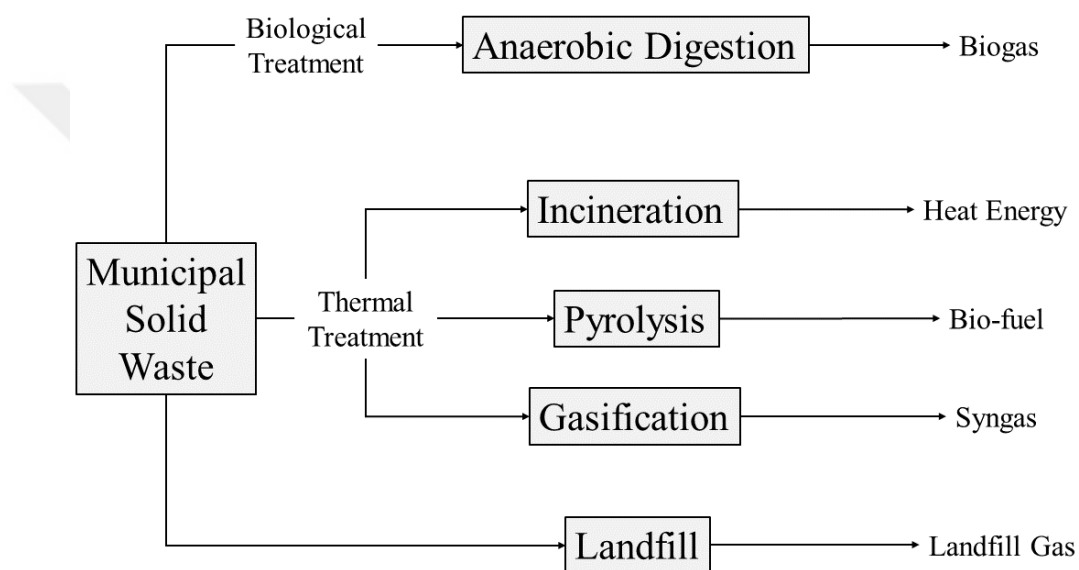


Figure 15. Waste to Energy technologies (Modified from Tan, et al., 2014)

The most common WTE technology is mass burn incineration. The process involves direct combustion of MSW on a moving grate to generate heated steam and then using the steam in processes or in a thermodynamic cycle to generate usable energy. Mass burn incineration facilities include processes for flue gas cleaning and destruction of pathogens is achieved simultaneously with combustion. Mass burn incineration is also used for reducing the volume of MSW. The other combustion technology for WTE is fluidized bed combustion where waste particles are burned in a fluidized sand bed. This process requires pre-treatment of MSW. Recyclables and materials that can be harmful for the boiler such as polyvinyl chloride, aluminium and wet waste are separated. Size of the remaining waste materials is reduced to enable floating motion on the fluidized bed. There is also rotary kiln technology for waste incineration. In this process, waste is placed inside an inclined cylinder that rotates

to ensure effective mixing and drying of waste. This technology is usually used for the destruction of hazardous wastes. (Metso, 2012.) MSW can also be co-combusted with different fuels such as coal. Since MSW is composed of many different materials, energy recovered from it varies with its composition. Parts of MSW that are considered renewable (paper, cardboard, wood, food waste and some parts of textiles) tend to have less energy content while fossil parts of MSW tend to have more energy content. (Branchini, 2015.)

Pyrolysis is the process of thermal degradation of waste in an oxygen or air-free environment and in the temperature range of 200 and 760 °C (The Gasification and Syngas Technologies Council, 2017). The process produces combustible gases, char, oils and waxes. With pyrolysis, MSW is converted into energy fuels and substances that can be safely disposed. (Chen, et al., 2014.) Compared to mass incineration, pyrolysis is significantly less common for waste to energy because currently, it is a new, emerging technology. Pyrolysis is now becoming prominent because of its ability to generate wide range of fuel products and its ability to transform waste materials into high energy density fuels and high value chemicals. While pyrolysis technology is now well understood, it still faces a challenge to be economically viable. (Czajczyńska, et al., 2017.)

Gasification technology is also the process of thermal degradation of waste in an oxygen poor environment. This oxygen poor environment has significantly less oxygen than the oxygen needed for complete combustion and it is about 20 to 40% of stoichiometric oxygen. Gasification occurs at a higher temperature range (480 to 1 650 °C) and it includes the conversion of carbon char into additional syngas. Also, steam can be added to the process for the conversion of carbon to syngas. (The Gasification and Syngas Technologies Council, 2017.) Gasification plants usually require waste with stable properties. There is also plasma gasification that is used for the destruction of contaminated and toxic organic materials. (Sanderson, 2014.) Gasification is still considered as an advanced thermochemical technology and not a conventional one. Although gasification is not as common as mass burn incineration, it is gaining interest due to the benefits it can introduce. These benefits include lower emissions of NO_x, SO₂ and Hg, better overall plant efficiency, wide range of final products and lower dioxin and furan formations. (Maya, et al., 2016.)

Anaerobic digestion refers to the decomposition of organic waste via microbial processes under oxygen-free conditions. The process results in biogas which is composed of CH_4 , CO_2 and some impurities. Another output of anaerobic digestion process is a sludge which contains water, carbon compounds, nutrients and parts of the organic material that entered into the process. Biogas resulted from anaerobic digestion can be used as an energy fuel. This technology is particularly used with “wet” wastes such as food waste, agricultural waste and wastewater sludge. (Jain, et al., 2015.)

Landfilling is the most common MSW disposal method in many countries. Landfilling process is the burial of MSW in pre-determined sites. In oxygen-free and mildly dry conditions, landfills produce landfill gas which is mostly composed of CH_4 and CO_2 . The share of CH_4 and CO_2 can vary between 40 to 60% of dry volume in a typical landfill gas sample. Landfill gas is collected via a collection system which is usually in the form of series of wells drilled and connected with a piping system in the landfill. After some treatments, such as dewatering, and desulphurization, landfill gas can be used for energy generation with many different energy generation techniques such as gas turbines, various engines and fuel cells. (California Energy Commission, 2017.)

WTE is beneficial in terms of providing energy from materials that are considered unwanted and materials that should be disposed. WTE also reduces the environmental impact of MSW management. It is helpful with the reduction of dangerous and toxic material emissions such as dioxins and heavy metals. Energy generated from waste can reduce dependency on fossil fuels and promote better environmental outcomes such as reducing greenhouse gas emissions. In United States, it is observed that the communities that use WTE have 17,8% higher recycling rates than the United States Environmental Protection Agency average. (Psomopoulos, et al., 2009.)

4.1 Turkish Energy System

Turkey had a total primary energy supply (TPES) of 1 498 TWh and a total electricity generation of 261,8 TWh in 2015. 88% of Turkey’s TPES and 68% of Turkey’s electricity generation was produced using fossil fuels. Turkey’s TPES and electricity generation shares by fuel in 2015 is given in Figure 16. (IEA, 2016.) Turkey’s installed electricity generation

capacity by fuel type as of May 2017, is given in Figure 17. There is a total of 80 035 MW of installed power production capacity from 2736 power plants in Turkey. (Turkish Electricity Transmission Company, 2017.)

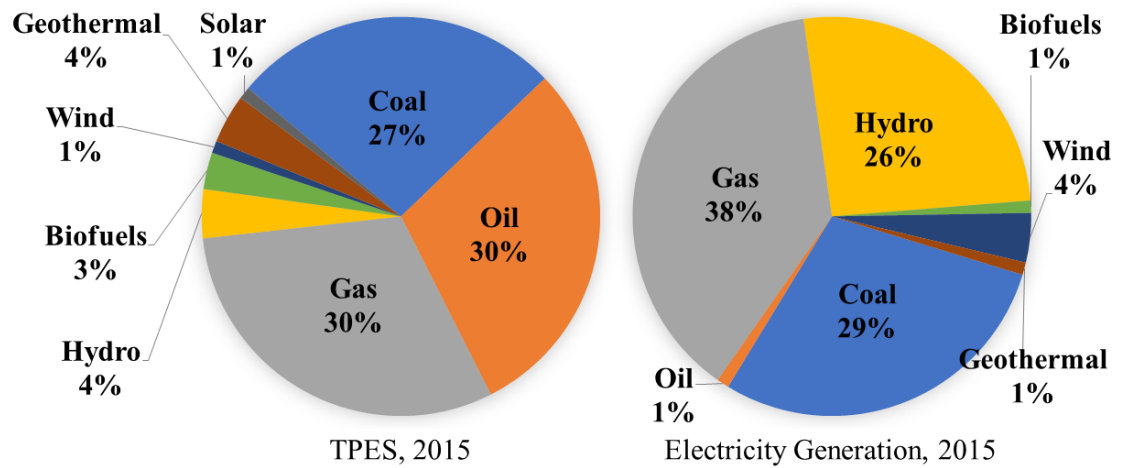


Figure 16. 2015 TPES and electricity generation shares by fuel in Turkey (IEA, 2016)

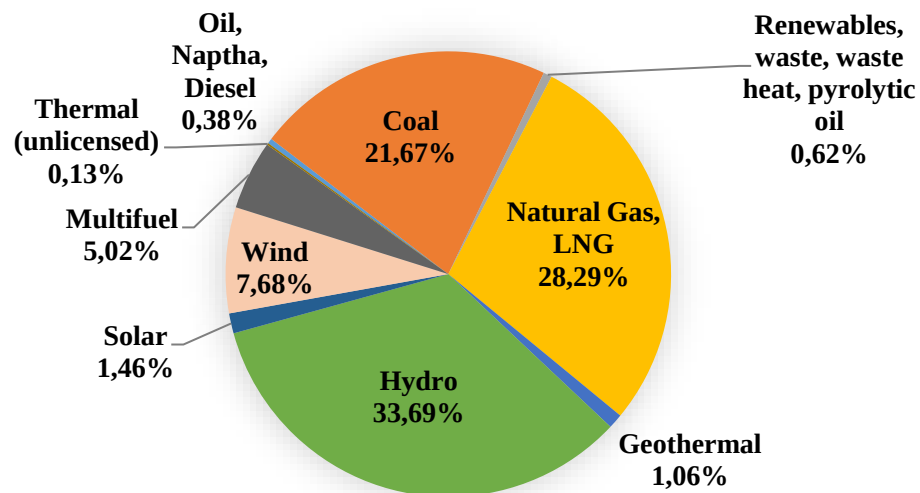


Figure 17. Turkish installed electricity generation capacity by fuel, 2017 (Turkish Electricity Transmission Company, 2017)

Turkey is heavily reliant on foreign countries for its energy fuels. In 2015, Turkey's import dependency was 94,4% for oil, 99,2% for natural gas and 36,9% for coal (IEA, 2016). When combined, these shares show that 68% of Turkish TPES was generated from imported fuels in 2015. Turkey dedicates an immense amount of capital for its energy needs. In 2015, total spending on energy imports was USD 37,8 billion (Anadolu Agency, 2017). This spending and the alarming rate of energy dependency resulted in a search for alternative local resources to replace imported energy fuels.

Currently, the biggest projects dedicated to increase local energy production in Turkey are two nuclear power plants that are under construction. With an estimated total cost of USD 40 billion, Akkuyu and Sinop Nuclear power plants are planned to have a total capacity of 9 280 MW (Ministry of Energy and Natural Resources, 2017a). In the past, accidents caused by human error and natural disasters have made nuclear power known for its potential effects. The risks associated with nuclear power have caused many countries to take actions for phasing out nuclear power. These countries include Germany, Switzerland, Belgium and Spain (World Nuclear Association, 2017). From June 2015 to January 2017, Turkey suffered 19 terror attacks with 423 deaths (Sözcü, 2017). If targeted and damaged by terror attacks, nuclear power facilities can have devastating consequences for Turkey. Instead of relying on nuclear power, Turkey should consider investing on safer energy technologies and energy resources that are already available for usage.

4.2 Current Waste to Energy Situation in Turkey

In Turkey, WTE has a negligible share in the country's total energy mix. The dominant WTE method is energy production from landfill gas (LFG) due to the availability of landfills filled with MSW. The total LFG production capacity is 162,7 million m³/a in Turkey (Serencam, 2016). Installed capacity of licensed facilities that produce energy from landfill gas is 151,7 MW (Çelebi, 2017). In 2011, Turkey approved The Renewable Energy Law and through this law, implemented feed-in tariffs for various renewable energy technologies. Current feed-in tariff for biogas facilities which includes LFG is USD 13,3 cents/kWh. Electricity prices on average were EUR 7,2 cents/kWh for medium size industries and EUR 12,6

cents/kWh for medium size households in 2016 (Eurostat, 2016c). (YURDADOĞ & TOSUNOĞLU, 2017.)

In EU Compatible Municipal Solid Waste Management Strategic Plan, the amount of MSW that should be thermally treated to comply with the EU standards for Turkey was calculated and the amount of energy that can be recovered from this MSW amount was presented. The project focused on biodegradable fractions of MSW to comply with EU landfilling directive. In the project, 75% of 18 municipalities' MSW generation was taken into account. The project was presented in 2005 and Turkey's population was 68,8 million in that year (Turkish Statistical Institute, 2017a). The project assumed that 500 kWh of electrical energy can be recovered from 1000 kg of MSW with a lower heating value (LHV) greater or equal than 6 MJ/kg. In Table 7, the results of the project are presented. It must be noted that in Table 7, renewable share of incinerated or gasified waste was assumed to be 100%. (Union of Municipalities of Turkey, 2015, pp. 225-226.)

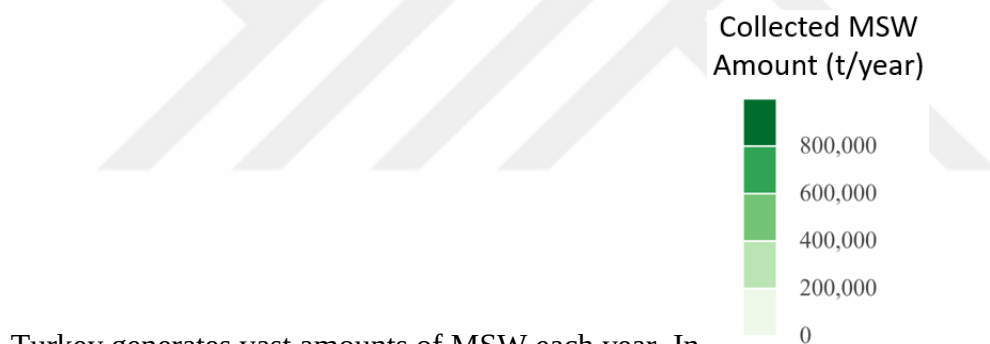
Table 7. EU Compatible Municipal Solid Waste Management Strategic Plan results (Union of Municipalities of Turkey, 2015, pp. 225-226)

Targets / Year	2013	2023	2033
Population that will receive thermal treatment for their MSW (in millions)	33	36,8	39,5
Amount of incinerated/gasified MSW (kt/day)	36,3	49,3	64,4
Amount of renewable electrical energy (MWh/day)	18 150	24 560	32 200
Installed power capacity required for the project (MW)	~ 755	~ 1025	~ 1340

Unfortunately, the targets foreseen by the project were never realized. Current installed electricity generation capacity for all waste, waste heat and pyrolytic oil is 495,6 MW, which is well under 2013's target of 755 MW (Turkish Electricity Transmission Company, 2017). It should be noted that the project's target capacities are only for thermal treatment facilities.

General Directorate of Renewable Energy issued an atlas that represents Turkish biomass energy potential. In the atlas, there is also a section for MSW. The atlas shows that according to 2012 data, there are 29,6 million tonnes of MSW generation per year in Turkey. The atlas also presents the total energy content of the organic fractions of all MSW in Turkey as 25,4 TWh per year which equates to 1,7% of TPES and 9,7% of electrical energy generation of Turkey in 2015. The atlas assumes that all of the organic fractions of MSW are transported to landfills and then converted into LFG for energy potential calculations. The atlas assumes that organic fractions of MSW has an energy content of 7 MJ/kg if they are collected in landfills and converted into LFG that is utilized for energy production. (General Directorate of Renewable Energy, 2017.)

4.3 Situation of Waste to Energy from Incineration in Turkey



Turkey generates vast amounts of MSW each year. In Figure 18, the amount of MSW collected in each province of Turkey is presented as a map. Exact amounts can be found in Appendix II. (Turkish Statistical Institute, 2017b.)

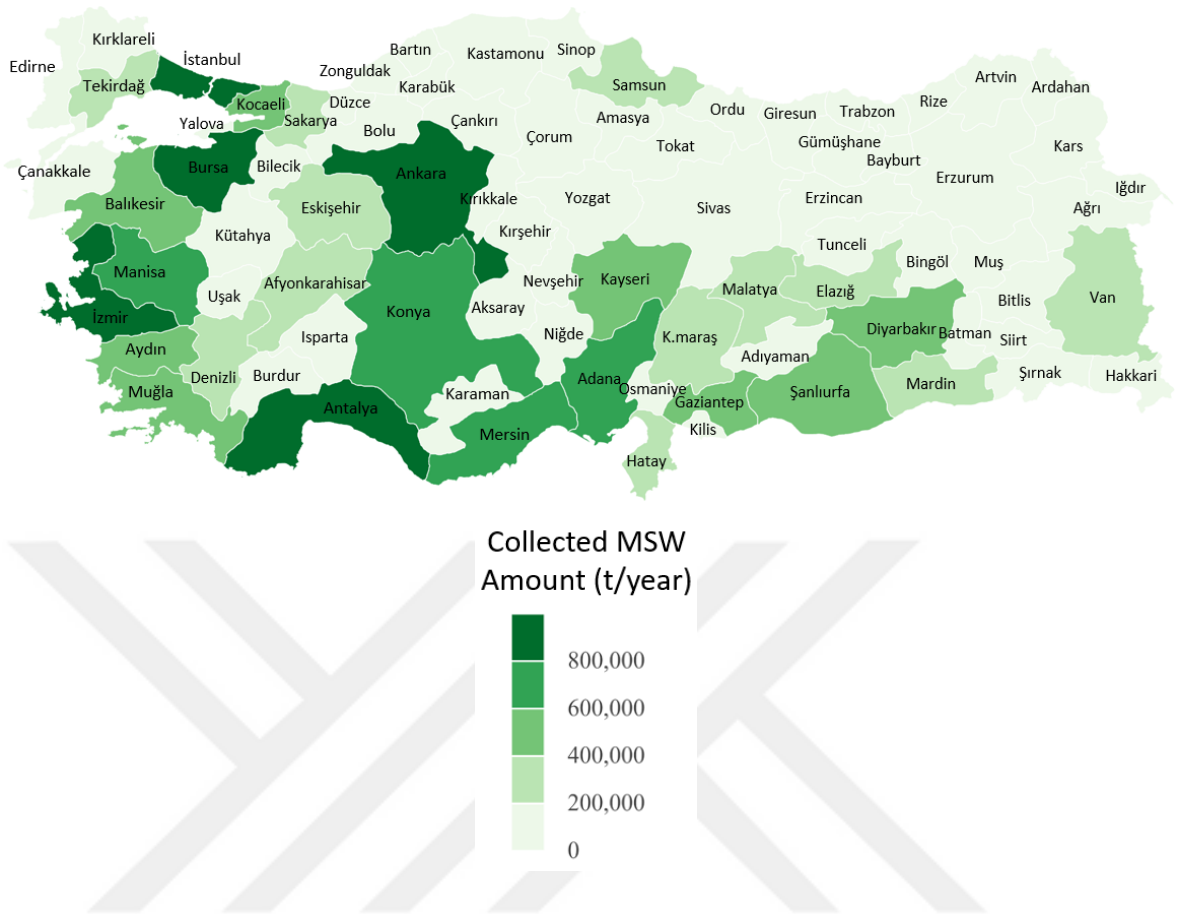


Figure 18. Collected MSW amounts by provinces (Turkish Statistical Institute, 2017b)

In order to calculate WTE potential of Turkey, energy content of Turkish MSW is needed. Currently, there is a lack of sources for definitive MSW characterizations of Turkey. Along with MSW characterizations, more research should be conducted on the energy content of Turkish MSW. There are reports of MSW characterizations for some individual cities in Turkey. The results of these reports are presented in Table 8.

Table 8. Results of MSW characterization studies for different cities in Turkey

Study	Province	Moisture Content	LHV Range (MJ/kg)	LHV Average (MJ/kg)
(Yildiz, et al., 2013)	İstanbul	62,41%	5,26 – 9,51	6
(Dolgen, et al., 2005)	İzmir	46,5% - 57,2%	3,5 – 5,5 (urban) 6 – 7 (industrial)	< 6
(Ağdağ, 2009)	Denizli	65,3%	-	5,15

In Dolgen et al. (2005), LHV results were divided for showing the difference between the MSW's LHV in urban and industrial parts of İzmir. In addition, the study provided calorific values of İzmir's MSW according to the income level. The calorific values for different income areas were as the following:

- Low income: 3,97 MJ/kg,
- Average income: 4,85 MJ/kg,
- High income: 5,65 MJ/kg.

In addition to the studies presented in Table 8, Yay reported Sakarya's MSW's higher heating value (HHV) as 15,7 MJ/kg and Banar & Özkan reported Eskişehir's MSW's HHV as 12,7 MJ/kg (Yay, 2015; Banar & Özkan, 2008).

To sum up, current MSW characterization studies for different cities provided a calorific value range for Turkish MSW. Turkish MSW's LHV range is between a minimum of 3,5 MJ/kg and a maximum of 9,51 MJ/kg. The average MSW calorific values of cities ranged between 5,15 and 6 MJ/kg.

Due to the high moisture content in Turkish MSW, incineration options are not as strong as in Finland. In Finland, as reported by Horttanainen et al., moisture content ranges between 28,5% to 33% and the biowaste fractions can have as low as 9% (Horttanainen, et al., 2013). In Turkey, the lowest moisture content found was in a sample of Yildiz et al. (2013)'s study and it was 46,6%. The lowest organic waste share found in reviewed studies is 40%. The high moisture content of Turkish MSW can be explained with the lack of source separation

of MSW. The absence of source separation causes the mixing of wet parts of MSW with other parts which in turn increases moisture content and decreases the heating value of MSW. In Finland, where source separation of MSW is well applied, average LHV of mixed MSW as received changes between 9,3 and 17 MJ/kg (Horttanainen, et al., 2013).

To achieve a successful waste incineration project, there are some key criteria about the waste that is used as fuel. Average lower calorific value of MSW should be greater or equal to 7 MJ/kg and should not fall below 6 MJ/kg during the year. Annual waste reserved for incineration should not be lower than 50 kt/plant. (Rand., et al., 2000.) Turkish MSW has an average LHV lower than 7 MJ/kg. Without any additional processes to improve its LHV, Turkish MSW is not suitable for direct incineration projects. A way to improve the LHV of Turkish MSW is refuse-derived fuel (RDF) preparation via mechanical treatment. Mechanical treatment options require investments for different kinds of treatment equipments such as screens, separators, sorters and shredders. A benefit of RDF is that it could be burned in coal furnaces. Due to investment requirement for equipment and possible risks that can occur in coal furnaces, this option was not explored in this report. Another option for MSW incineration in Turkey is co-incineration with fossil fuels (e.g. coal) for raising temperatures to needed levels. As shown before in Figure 16, 27% of Turkish TPES in 2015 was supplied with coal. There are 54 coal fired power plants in Turkey (Ministry of Energy and Natural Resources, 2017b). This means that coal supply is already available in Turkey. With this process, the amount of coal burned for energy purposes can decrease, energy can be recovered from MSW and landfilling shares of MSW can be reduced. Additionally, replacing coal with MSW as an energy fuel can result in lower GHG emissions.

4.4 Waste to Energy from combustion of MSW and coal

There are some technical issues regarding burning MSW with coal in coal burning furnaces. Since MSW particles are not uniform, different feeding and conveying equipment can be needed for burning MSW in coal power plants. Another issue that also arises from MSW particles is that, big MSW particles require longer residence times for complete combustion. Since MSW is very heterogeneous, higher excess air rates are needed for combustion. MSW can lower overall thermal efficiency due to stack losses such as thermal losses with flue gas.

As explained before, due to the low LHV of Turkish MSW, direct combustion of MSW by itself is not reasonable. However, another possibility arises from the abundance of coal fired power plants in Turkey. RDF, when prepared, can be co-combusted with coal in coal burning furnaces. There are demonstrations of RDF combustion in cyclone, stoker and wall fired furnaces. RDF firing can bring the same benefits discussed for combusting MSW with coal addition including reduced landfilling, reduced GHG emissions, reduced fossil fuel usage and increased energy recovery from waste. However, RDF combustion brings potential problems as well. These problems include slagging and fouling, corrosion and erosion of boiler piping, increased maintenance costs, decrease in particulate collection efficiency in electrostatic precipitators and derating of the boiler. It can also bring tighter air pollution control measures and emission monitoring. Some of these problems can have lasting consequences on plant equipment. RDF preparation requires many specialized equipment for physically altering MSW. These equipment include crushers, magnets, screen for filtering and air classifiers for separating heavy and light fractions. On the other hand, Turkish MSW is mostly composed of organic and non-combustible waste fractions, meaning that RDF yield would be very low. (Ruth, 1998.)

In this section, multiple scenarios with different assumptions were created to provide reasonable amounts for energy potential from MSW in Turkey. In these scenarios, MSW is burned in MSW burning plants with a small share of coal as a support fuel. For combustion of MSW with coal, 25% electric efficiency is reasonable since it is already realized within Lvneng waste incineration plant in Hangzhou, China where MSW is burned with coal as a support fuel. This plant uses MSW with a LHV of 3,9 MJ/kg and a moisture content of 72,1%. The plant burned 210 kt MSW with 779 t of coal while producing 59 GWh of electricity. In 2014 only 2 to 7% of energy was from coal in this plant. (Horttanainen, 2016.)

For the LHV of Turkish MSW, the lower and higher values of average results were presented in Table 8 and they were, 5,15 MJ/kg for lower and 6 MJ/kg for higher LHV. For the volumes of MSW, Turkish Statistical Institute's database on MSW collected from each municipality is used (Turkish Statistical Institute, 2017b). The other assumptions are scenario specific. The scenarios are created in a way to introduce more realistic assumptions as their suffix number increases. For all scenarios, MSW is assumed to be combusted with coal as

support fuel. Energy values presented in scenarios only account for the energy derived from MSW and does not include energy received from coal.

Scenario 1 uses 100% of the MSW produced in Turkey, meaning a 100% incineration rate. Scenario 2 leaves out provinces that produce less than 50 kt of MSW as suggested by Rand., et al. (2000). Scenario 3 takes into account only metropolitan municipalities which are municipalities with higher access to investments. These municipalities are more likely to invest in the transport of collected MSW to coal burning facilities. Scenario 4 only includes provinces with yearly MSW generation higher than 1 million tonnes which are also the 5 biggest cities of Turkey. The results for the scenarios can be found in Table 9. The results of Scenario 4 show that only with the participation of the 5 biggest cities, Turkey can theoretically produce 4,2 to 4,9 TWh of electrical energy from MSW by combusting it with coal. These amounts constitute 1,6% to 1,9% of all electricity generated in 2015.

Turkey is reliant on both foreign and domestic coal for electricity production. For Table 9, it is assumed that the energy generated from MSW replace energy normally generated from coal in Turkey. For the calculation of the amount of coal that is substituted by MSW, coal's LHV is assumed to be 25 kg/MJ as suggested by IEA (IEA Bioenergy, 2003).

Replacing coal with MSW brings environmental benefits. According to IEA's study, the life cycle based total emissions of MSW for conventional MSW to energy technologies are 1833 g CO₂ per kWh of energy derived from MSW (IEA Bioenergy, 2003). This number includes emissions from the biogenic part of MSW which includes organic waste, paper and cardboard. Biogenic emissions are considered carbon-neutral due to them belonging to the natural carbon cycle. For this reason, only fossil derived emissions from the amount 1833 g CO₂ per kWh should be taken into account. IEA's assessments on MSW show that about 20 to 40% of the carbon in MSW is derived from fossil parts of MSW. However, Turkey's MSW composition is different. It also varies widely throughout the country. Since there is no extensive research on waste compositions and already available compositions have great shares on "Others" category (between 7% and 24%), assumptions on Turkish waste compositions should be made in order to determine approximate greenhouse gas reductions. It can be assumed that on average, 10% of Turkish MSW is composed of plastics and 65% of Turkish MSW is of organic origin (biowaste, paper and cardboard). The rest are metals, glass and

others. With these information in mind, IEA's lower assumption on fossil derived carbon shares of MSW, which is 20% can be used as a rough assumption for Turkey. With 20% fossil carbon share, only 20% of CO₂ emissions from MSW which is 367 g CO₂ per kWh should be taken into account for CO₂ emission approximations. IEA also states life cycle CO₂ emissions for coal as 987 g CO₂ per kWh of electricity. For each kWh of electricity that is generated with MSW instead of coal, 620 g of CO₂ emissions is avoided. From this assumption, in Scenario 4, only with the participation of the 5 biggest cities, Turkey can reduce up to 3 Mt of CO₂ emissions per year from incinerating MSW instead of coal. This amount is equal to 18,7% of GHG emissions from waste sector in 2014 (Turkish Statistical Institute, 2017b). Another component of CO₂ emissions of MSW management is emissions from landfills. In 2014, 87,5% of MSW collected by Turkish municipalities were landfilled. According to IEA, landfills emit 1610 kg CO₂ eq. of GHG per tonne of MSW, due to high global warming potential of methane that is generated in landfills. Due to the lack of data, the amount of LFG that is extracted from Turkish landfills appear to be negligible. That is why IEA's amount for GHG emissions from landfills can be used. With the inclusion of the effect of avoided landfilling and with previous assumptions, Turkey can reduce 22 Mt CO₂ eq. GHG emissions by incinerating its MSW via co-combustion. This amount is equal to 137% of all emissions from waste management in 2014. The reduction percentage higher than 100% can be explained with the inclusion of GHG reduction from energy production from MSW. It also raises the question of accuracy about Turkish Statistical Institute's greenhouse gas inventory calculation on waste management. (IEA Bioenergy, 2003.)

Table 9. Results for Waste to Energy Scenarios (1-4)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Waste incinerated (Mt)	28	27,7	22,7	11,8
Lower Electricity Production Potential (TWh)	10	9,2	8,1	4,2
Higher Electricity Production Potential (TWh)	11,7	11,6	9,4	4,9
Number of Provinces participating	81	73	30	5
Amount of coal substituted with MSW (kt)	1 443 to 1 681	1 429 to 1 665	1 168 to 1 361	608 to 709
Avoided CO ₂ emissions (Mt)	6,21 to 7,24	6,15 to 7,17	5,03 to 5,86	2,62 to 3,05
Avoided CO ₂ emissions, including the effect of avoided landfilling (Mt)	51,3 to 52,3	50,8 to 51,8	41,5 to 42,4	21,6 to 22,1

5 CONCLUSION

Turkish MSW management system can incorporate a lot from Finnish MSW management on finance, legislation and active practices. Current situation of Turkish MSW management is far from the standards of EU. A major finding of this thesis is the lack of and the disorganization of information on Turkish MSW and MSW management situation. More research should be done on defining the energy potential of Turkish MSW. In order to provide an accurate estimation on benefits of potential MSW management systems, new MSW characterizations should be conducted throughout the country. More emphasis should be given to the effects of government's policies on MSW management and they should be regularly updated to provide the most benefit. Currently, Turkey doesn't utilize its MSW in a beneficial way and suffer negative outcomes due to the short-term solution approaches on MSW management. A comprehensive life-cycle assessment of MSW disposal and recovery options of Turkey can provide a lot of benefit and it can set the stage for long term planning of MSW management. Turkey generates vast amounts of MSW and Turkey is a country that depends on foreign resources for energy generation. Converting domestic MSW to energy can be a great benefit for Turkey. It can provide better environmental outcomes as well as economic ones. This thesis shows a rough potential of waste to energy from MSW in Turkey as 4,9 TWh per year and this amount can have a great positive impact on the Turkish energy system. Separate collection systems for MSW should be introduced in Turkey to enable different and better performing MSW disposal, treatment and recovery options. Authorities that are responsible with MSW management should be informed and they should be convinced that the current MSW management system needs major changes to start providing benefit to the country.

6 SUMMARY

The aim of this thesis is to compare Turkish and Finnish MSW management systems to locate improvement areas and to provide information on Turkish MSW management system. Another task of the thesis is to explore Turkish waste to energy environment. Finland is the exemplary country in this thesis. The reason behind this is the success of Finnish MSW management system which continues to improve. Finland's MSW management system can effectively recover materials or energy from MSW. Many performance issues with the Turkish MSW management system are mentioned in this thesis. To compare the MSW management systems, MSW management systems are divided into four categories and these are Finance, Legislation, Collection and Transport and finally, Performance. Turkish MSW management system can take some elements from the Finnish one to improve. The main issue with Turkish system found out to be the inadequacy of the legislation surrounding the finance of the MSW management system. Municipalities need more funds to convert their MSW management systems to a complete, EU compatible one. The lack of source separation severely limits recycling and energy recovery options for MSW and causes extra problems like street collectors that are looking for recyclables. With the current policies, the dominance of landfilling as a waste treatment method in Turkey will continue if no changes are made in the legislation surrounding it. After a study of reports on MSW characteristics of various cities in Turkey, MSW composition of Turkey was determined to be not suitable for direct combustion. Combustion of MSW with coal as support fuel has potential in Turkey due to the availability of great waste amounts. 4,2 to 4,9 TWh of electricity can be generated from combustion of Turkish MSW with coal as support fuel while using only the MSW collected from the five biggest cities.

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APPENDICES

Appendix I, 1

Group and degree categorization criteria for determining Sanitation Tax for buildings
(Council of Ministers, 2005)

Building Groups	1 st Degree: Number of Students	2 nd Degree: Total bed amount	3 rd Degree (a): Amount of Utilized Area (m ²)	3 rd Degree (b): Permanent activity areas (m ²)	4 th Degree: Number of seats	5 th Degree: Number of Personnel
1 st Group	> 750	> 500	> 1000	> 5000	> 2000	> 300
2 nd Group	750 – 500	500 – 300	1000 – 500	5000 – 4000	2000 – 1500	300 - 200
3 rd Group	499 – 250	299 – 150	499 – 250	3999 – 3000	1499 – 1000	199 – 100
4 th Group	249 – 100	149 – 50	249 – 100	2999 – 2000	999 – 500	99 – 50
5 th Group	99 – 50	49 – 20	99 – 50	1999 – 1000	499 – 250	49 – 10
6 th Group	49 – 20	< 20	< 50	999 – 500	249 – 100	9 – 4
7 th Group	< 20	-	-	< 500	< 100	< 9 and households

Explanations for the table:

1st Degree: Number of students in schools, dormitories, kindergarten, private teaching institutions, education centres, day-care facilities and buildings dedicated to education and teaching.

2nd Degree: Total bed amounts in accommodation facilities, hospitals and other healthcare facilities that contain beds.

3rd Degree (a): Total amount of area utilized in all kinds of venues, food and drink serving buildings and buildings used for entertainment business purposes.

3rd Degree (b): Total amount of area utilized in permanent activity areas such as amusement parks, fairs, expositions, stadiums, hippodromes, racetracks, gyms and permanent warehouses.

4th Degree: Number of seats in theatres, cinemas, opera houses, ballet halls and venues that require a ticket for entry.

5th Degree: Amount of personnel in commercial, industrial, agricultural and professional buildings all buildings excluding these activities. (Excluding 1st, 2nd, 3rd, and 4th rows)

Appendix II, I

MSW Collected by municipalities in 2014 (Turkish Statistical Institute, 2017b)

Province	MSW Collected in 2014 (t)	Province	MSW Collected in 2014 (t)
İstanbul	6 064 688	Şırnak	139 255
Ankara	2 059 306	Ağrı	137 350
İzmir	1 659 986	Batman	131 505
Antalya	1 015 827	Tokat	131 210
Bursa	1 010 853	Kastamonu	129 901
Konya	788 506	Kırklareli	129 801
Adana	667 480	Yozgat	126 632
Mersin	637 356	Düzce	122 298
Manisa	619 131	Bolu	117 244
Gaziantep	584 017	Giresun	112 929
Şanlıurfa	574 972	Nevşehir	110 382
Kocaeli	573 414	Uşak	110 021
Diyarbakır	566 687	Aksaray	107 865
Muğla	536 462	Niğde	102 848
Balıkesir	536 379	Erzincan	96 570
Aydın	431 480	Yalova	86 490
Kayseri	416 541	Amasya	82 132
Tekirdağ	396 813	Karaman	82 025
Hatay	392 670	Rize	78 516
Van	380 983	Kırşehir	77 864
Samsun	369 816	Kars	77 272
Denizli	360 924	Bilecik	75 666
Sakarya	339 826	Karabük	74 868
Kahramanmaraş	308 752	Burdur	74 206
Mardin	300 087	Siirt	74 059
Eskişehir	271 520	Kırıkkale	73 515
Elazığ	268 759	Bingöl	71 195
Malatya	263 673	Çankırı	64 809
Afyonkarahisar	238 118	Muş	64 140
Edirne	198 657	Sinop	57 692
Trabzon	186 260	Bitlis	57 578
Ordu	186 064	Iğdır	57 396
Sivas	185 401	Hakkari	43 655
Zonguldak	183 989	Bartın	41 393
Erzurum	178 669	Kilis	41 300
Çanakkale	175 303	Artvin	37 501
Kütahya	175 257	Gümüşhane	35 375
Çorum	167 737	Tunceli	23 944
Adıyaman	150 412	Ardahan	22 065
Osmaniye	143 354	Bayburt	21 045
Isparta	143 079	TOTAL	28 010 720

Appendix III, I

Currency rates used for converting Turkish lira to euros. (EUR to TRY)

	2005	2014	2015	2016
EUR	1,857	2,91	3,02	3,347

