MSc Program
Engineering Management

Efficient Use of Community Waste

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supervised by
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Affidavit

I, **BURCAK BICER, BSC**, hereby declare

1. that I am the sole author of the present Master's Thesis, "EFFICIENT USE OF COMMUNITY WASTE", 69 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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ABSTRACT

Waste management and its impact on the environment is currently a topic that is present everywhere. It is important that people become familiar with the consequences that their actions have on the environment and possible solutions how to turn waste into energy. Waste is certainly something that we cannot avoid, however, we could find different ways to make the most of it, and that is something that people should bear in mind when it comes to waste. In this paper, it will be talked about the reason why we need better waste management and efficient use of community waste. Afterwards, waste and waste categorization will be presented. After that, waste management methods will be discussed and some methods will be recommended. Possible solutions how to transfer waste into energy will be analyzed. Finally global situation of the waste management in the world will be carefully considered and different solutions will be compared.

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1 INTRODUCTION

Environmental problems are currently one of the biggest problems of the modern world. However, people are still not aware enough of the importance of keeping the environment safe. One of the solutions is to raise the awareness among people about the consequences of their actions. Therefore, it is important that people become familiar with the problems they may be facing in the future, and start thinking about possible solutions. One of the things they should focus on should be waste management. Of course, waste is not something that can be avoided, it is part of our daily lives, however, it can be managed in a way that does not leave a bad impact on the environment.

However, in order for people to change their behavior, they should first be faced with the consequences, that not managing the waste in a correct manner would bring them. First of all, waste is causing air pollution, land pollution, human health problems, global warming. Waste is a major threat to the environment and human health, since a large part of it is not fragmented in nature. Therefore, special efforts are needed to remove waste from the environment. One other issue is reduction of the natural resources which is related waste and waste management. Since the natural resources are not unlimited, they should be consumed carefully. Increasing demand, rapid industrialization and increasing population lead to rapid resource consumption. For that reason, environmental problems become progressively important issue in the world. Protecting natural resources should be a priority. First step should be the reduction of consumption. That will also automatically influence the waste generation. Since the income level of developed countries is much higher than the other countries, the most of waste is generated in the high level countries. Therefore, those countries can have important impact on the environment and resources. Nevertheless, in the countries with a high level of income, nowadays it is very usual to have advanced waste treatment systems and plants. That render possible to decrease of total waste generation. One hand they are responsible for big amount of waste generation. As a result of rapidly developing technology and globalization in the world, people buy more electronic devices which contain many important elements, but unfortunately they use the technological devices very shortly and they replace it rapidly with new ones. That is causing too much source consumption. This is not only issue of important elements consumption like steel, aluminum etc. It is also about energy consumption. Because during the production of these products, so much energy is being used, as well as the production waste is generated. Moreover, many manufacturing company leave the flue gases to the air. It pollutes the air and threats the public health and environment. On the other hand, the developed countries survive to minimize the negative impact of waste generation to the world. With slowly increasing awareness of waste danger in the world, almost every country tries to bring some new rules and new approach to waste management. In order to use waste in the most efficient way community waste, recycling, incineration, recovery, reuses, compositing are becoming more and more important in the world. Obviously, landfilling is still one of the most significant and mostly used waste disposal methods. In this work, general problems about waste and its using possibilities in most efficient ways will be presented.

In the first part of the work, waste, waste types and its impact on the whole environment and people's life will be presented. It will be shown why waste management and efficient use is needed. Following that, certain solutions and waste disposal methods will be discussed, along with the results of the techniques used. Finally, global application of waste management in different countries will be displayed, with the recommendations on how different countries can contribute in keeping our environment safe.

2 THE NEED FOR WASTE MANAGEMENT AND THE EFFICIENT USE OF THE COMMUNITY WASTE

Solving environmental problem is a common duty of all people living on the earth, not just those who are experts in this field. Rapidly increasing technology developments influences the total amount of world natural resources negatively. In order to leave a livable world for the future generations and to continue the technological development correctly, it is needed to use the existing natural sources optimal and to provide sustainability. This can also be named as a sustainable development and it aims at ensuring the balance between the todays and future needs development. Environmental pollution can be cause permanent damage to the atmosphere. The greenhouse effect, which has emerged as the most serious ecological problem together with our increasing consumption habits, causes global warming and even slow down the rotation speed of the world. A part of the heat from the sun is absorbed while some of it is reflected. The carbon dioxide layer in the atmosphere create a curtain which resists the heat increase in the atmosphere and it allows the sun rays to get in, but prevents them from coming out like in greenhouses. For example, automobiles are considered as one of the most important elements of environmental pollution due to their carbon monoxide, similar waste gases, and their tires. One hand it is also one reason why the countries want to develop electro mobility and to increase using of electro cars. On the other hand, on the production of the cars many important resources are used like plastics, aluminum etc. In order to minimize the negative impacts of this type of production and consumption on the environment and natural sources consumption, some methods should be applied. In this case, the most important thing is to use raw material efficiently. To make it possible, the material should have a life cycle management instead of having a short life and end. The life cycle of the material should have important management methods like reuse, recovery, recycling, and reproduction. Another important thing is the prevention of unnecessary material and that can support by environmental friendly product design. The packaging plays also vital role on generation of waste and consumption of natural sources. The energy consumption also influences the environment so much and it has to optimize. Recycling is related to the review of used goods, materials, tools and equipment rather than disposal. That is simple but one of the most effective way to combat waste and protect the environment. With these methods, which can be used frequently for solid wastes, the wastes are collected, accumulated, separated according to their type and processed for efficient use and gain back. As an example; the production of an original aluminum drink canister needs 20 times more energy than melting the used aluminum tin cans. Glass can also be recycled many times. Glass bottles, jars are collected at specific local stations and collected in a central collection station for recycling. Since the very high temperatures are used for the production of the glass, the amount of energy consumed is also very high but the amount of heat energy required to melt the collected bottles is very low. That shows also why the waste management is needed. The method used to recycle papers is similar to the process used to make the papers. Instead of wood chips, waste paper is used and pulp is obtained. The use of clean production technology and to have green factory are also big steps in the fight against the waste generation. The principle of this fight is to prevent waste before generation. Nowadays, companies have sensible behavior for the environment. In many industries, the waste which will occur after production already considered in the design phase. However, advanced waste filtering systems are used in the plants to filter sewage slut, waste water, flue gases etc. That is started to support also with zero waste approach. Nowadays, many companies choose their business partner according to their environmental friendly production approach.

With the increase of waste treatment facility number in the world, it is expected to decrease the land pollution. If the waste is managed properly, the dumpsites will decrease. Since the dumpsites on the land are often chosen near rivers or the sea, they may easily contaminate the surface water and the groundwater. Sea has also the marine litter because of dumpsites. This will cause other problems like decrease in local tourism income, increase in polluted beaches, dirty waters, decrease of fisheries sector trade and danger to natural life.

Clean environment is also one of the major issues on public health. That means not-well-managed waste threats public health. Especially electronic wastes are extremely polluting the environment and threat the public health because e-wastes contain more than 1000 substances, most of them are toxic. (Dereli T., Baykasoglu A.,2012) (Yilmaz Aydin C., Evci Kiraz E.D., 2017:47) (UN Environment, 2016)

3 WASTE AND WASTE CATEGORIZATION

By European Union, in the Waste Framework Directive waste is defined as "*any substance or object which the holder discards or intends to or is required to discard*." (European Commission, 2011)

Municipal solid waste (MSW) can be named frequently garbage. MSW can be recycled or composted or can use to produce energy at landfills or at waste-to-energy plants. Any kind of household's garbage can be called as MSW. Paper, plastics, tins and metals, ceramics, glasses, textile wastes etc. can enclosed by municipal solid waste. Generation of MSW volumes is very different country to country. Income levels, socio-cultural models and climate aspects play a vital role in the generation of municipal solid waste. More than half of total waste is created by high-income level countries. MSW generation per capita is in developed countries higher than developing countries and other countries. Municipal solid waste generation is related with the income levels of countries. One hand, as it can find out in the following figure, the countries which have gross national income per capita between about 15000 and 100000 USD are the most municipal waste generators in the world. Moreover, the low gross national income countries influence the world total municipal solid waste generation minimum. On the other hand, since the developed countries have high waste management methods their negative environmental impact to the world is less than lower-middle and upper-middle gross national income developing countries.

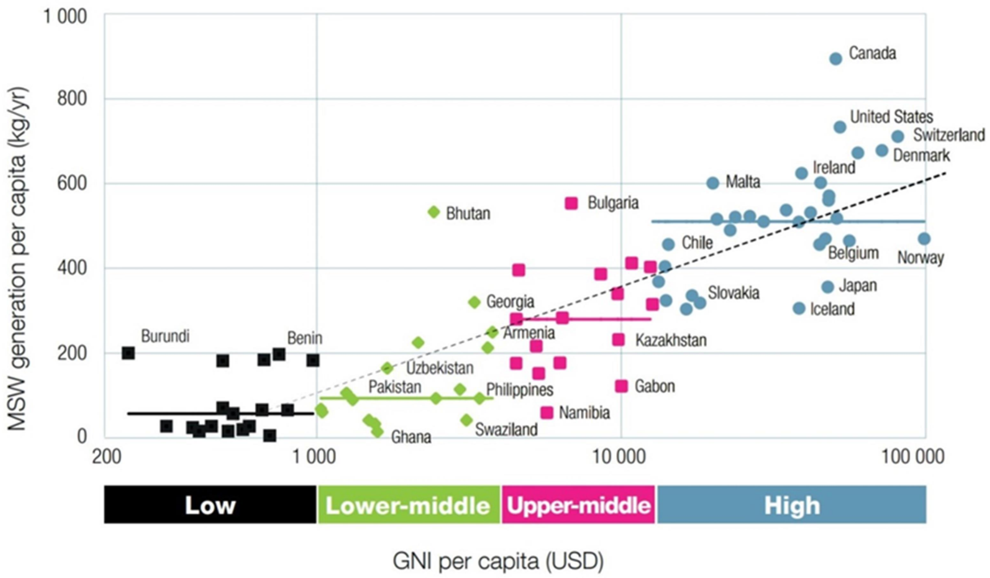

Figure 1 Waste generation versus income level by country

(UN Environment, 2016)

Income level also influence the generated waste type which means people buying habits depend on their income level. When the income level increases, the basic life needs also change. In the following figure this relation is shown. In the low income countries the waste generation of organic materials rate is much higher than high income level countries. Since it is in low income countries around 53 per cent, in high level countries it is around 34 %. This situation shows self on the paper waste generation opposite way. In high income level countries, almost a quarter of total waste generation occurred by paper, but in the low income level countries it is only around 6 %. Paper consumption per capita range is in North America 240 kg, in Europe 140 kg, in Asia 40 kg and in Africa it is only 4 kg. As a result of new life habits and technology development, the total world average paper consumption per capita is decreased by 4 % from 2007 to 2012. The total waste generation of glass, metal and textiles is much more less to compare any other waste generation overall in the world. But to compare this between the high and low income countries is also not different than paper waste. In low income countries the metal, glass and textiles waste generation is around 6 %, it is in low-middle income countries around 9 % and in upper-middle income countries and in high income countries around 12 %.

(UN Environment, 2016)

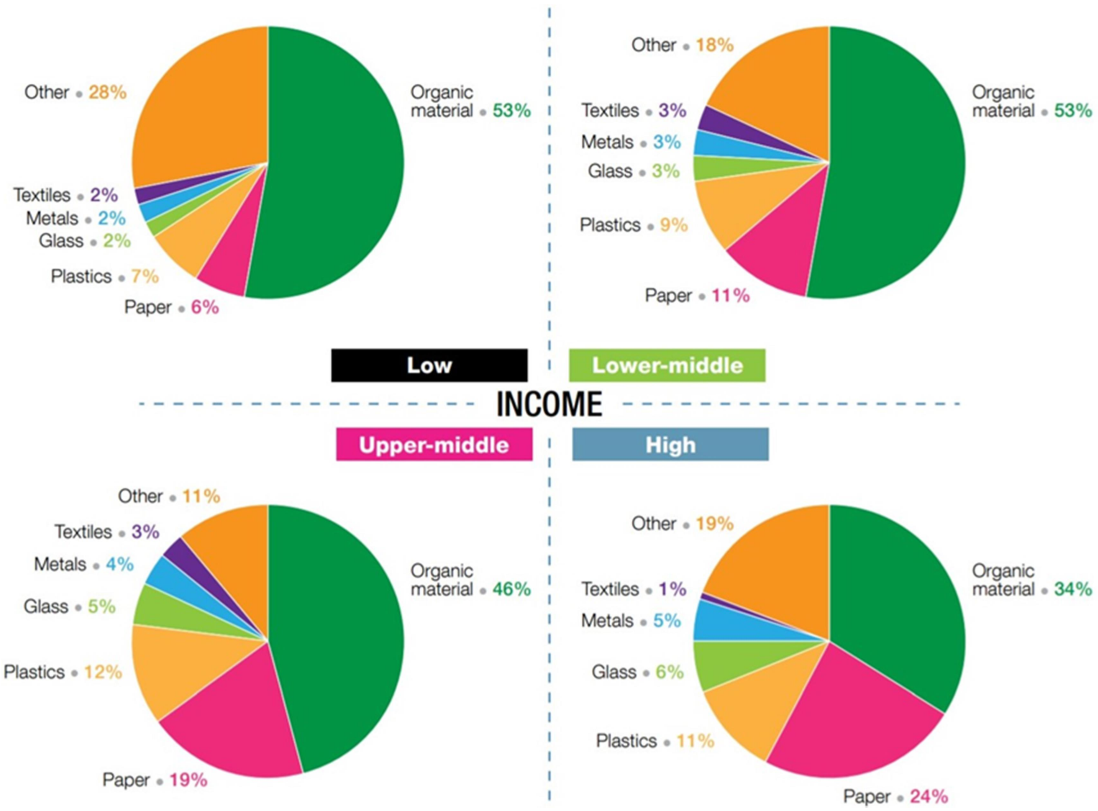

Figure 2 Variation in MSW composition grouped by country income levels

(UN Environment, 2016)

3.1 Plastic Waste

Raw materials of plastic are oil and natural gas. That means to produce plastics, natural sources are needed. For reducing of raw material use Recycling and Reuse of plastic is inevitable. But unfortunately amount of using plastic is increasing day to day. In 2013, that reached up to 299 million tons. To reach to the EU waste management target, European countries export the plastic waste to the Asian countries, especially to the China. (UN Environment, 2016) (Rogoff M.J. 2013:129)

3.2 Paper Waste

The paper, which is a vital source of cellulose fibers, is one of the most generated wastes. It is a recyclable material and its biodegradation period is between 3 and 12 months after it has become waste. Since to production of 1 kg of white paper, too much electricity and water are needed, it is very important to recycle it. By recycling of the paper, 25% of the total needed electricity and %90 of total needed water which is 300l for 1 kg paper production can be saved. The length of the cellulose fiber is decreased in each recycling process. And that causes to reduce mechanical strength and quality of the new paper. That is why each paper can be recycled around 6 - 10 times and low quality produced paper can be used also for other aims in different industries. (Aciu, 2014)

In 2012, approximately 400 million of tons paper and recovered paper are produced all over the world. Almost half of the total paper and paperboard (recovered paper) production was in Asia and 26 % was in Europe. The big amount of the rest production of the paper and paperboard was in Nord America with 21 %.

In the following table, total paper collection and consumption is shown. That includes only the recovered paper and according to this table, each country treated at least 1 million tons of recovered paper each year. (UN Environment, 2016)

Unit: Million tons						
		Collections of recovered paper and board	Consumption of recovered paper	Net flows: positive = imports negative= exports	Regional total net flows	
Region	Country				2012	1997
Nord America	United States	46.3	26.3	-20		
	Canada	4.4	2.6	-1.8		
	Regional subtotal	50.6	29.9	-21.8	-22	-6
Latin America	Brazil	4.5	4.5	0.0		
	Mexico	3.9	4.8	0.8		
	Regional subtotal	12.2	13.1	0.9	1	
Europe	Germany	15.3	16.2	0.9		
	U.K	8.2	3.8	-4.4		
	France	7.3	5.0	-2.3		
	Italy	6.2	4.7	-1.6	-7	-1.6

		Spain	4.6	5.1	0.5		
		Netherlands	2.6	2.1	-0.4		
		Belgium	1.9	1.2	-0.7		
		Poland	1.6	1.3	-0.3		
		Austria	1.5	2.4	1.0		
		Sweden	1.3	1.9	0.6		
		Switzerland	1.2	1.0	-0.2		
		Russia	2.6	2.2	-0.4		
		Regional subtotal	62.0	54.8	-7.2		
	Japan	Japan	21.7	16.8	-4.9	-5	0.05
	PRC	PRC	44.7	75.0	30.3	30	1.6
		Republic of Korea	8.8	9.6	0.8		
		Indonesia	3.6	5.9	2.3		
		India	3.4	5.7	2.3		
		Republic of China	3.1	3.8	0.8		
		Thailand	2.7	3.6	1.0		
		Malaysia	1.2	1.6	0.4	8	2
		Turkey	1.0	1.1	0.1		
Asia	Rest of Asia	Regional subtotal	99.4	130.9	31.5		
		Australia	3.4	2.0	-1.4		
Australia		Regional subtotal	3.5	1.9	-1.6	-1	
		South Africa	1.0	1.0	0.0		
Africa		Regional subtotal	2.8	2.6	0.2	0	
		Named countries	207.7	211.0	3.3		
Totals			230.5	233.2	2.8		

Table 1 Leading countries collecting & consuming recovered paper and regional totals (2012) (UN Environment, 2016) (Magnaghi, 2014)

3.3 Tins and Metals

Using metals is increasing very rapidly everywhere in the world. Technology development is one of the most important reasons of this increase. The materials like iron, steel, aluminum, copper, lead, zinc, nickel are the most important materials as source and they have high value as waste too. That is why their wastes have to manage well and they have to recycle and reuse. Recycle and reuse of those very important materials influence the economy very positive. From 2005 to 2014 Iron and steel production enlarged by 40 % and in 2014 its value is more than 1.67 billion tons. Outside of the EU, between 2010 and 2014, Turkey was the main steel importer with 30%. India with 10 %, the People's Republic of China with 7% and the republic of Korea with 14% are the other important importers. Following figure shows the external trade in the steel scrap. (UN Environment, 2016)

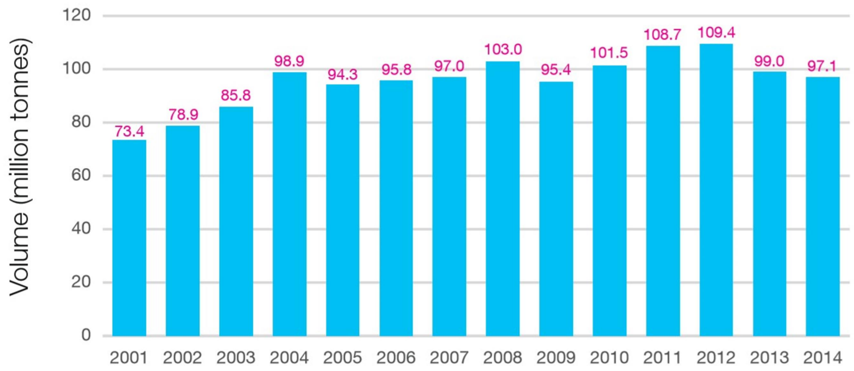

Figure 3 External Global Steel Scrap Trade

(UN Environment, 2016) (Magnaghi, 2014)

In the next table, the non-ferrous metals and global scrap consumption amounts shows. According to this figure, aluminum is the leader of this table. One hand, between 2000 and 2011, total scrap consumption of aluminum is 68 per cent increased. On the other hand, the situation of the global demand for aluminum is also increased rapidly and this rise is around 82 per cent. However, the increase of total demand for metal and scrap consumption is not only seen on the aluminum. Actually, the growth can be appreciated for all below listed materials.

COMMODITY	Global Demand for Metal			Global Scrap Consumption		
	2000 (million tons)	2011 (million tons)	Percentage growth 2000 - 2011	2000 (million tons)	2011 (million tons)	Percentage growth 2000 - 2011
Aluminum	25	45	82 %	11	18	68 %
Copper	15	19	30 %	7.0	10	45 %
Lead	9	12	30 %	3.7	5.8	57 %
Zinc	7	10	40 %	0.8	1.1	34 %
Nickel	1	1.1	10 %	0.6	0.9	42 %
Steel	1444 (number is from 2005)	1607	(40 %)	401	573	43 %

Table 2 non-ferrous metals and global scrap consumption

(UN Environment, 2016) (Magnaghi, 2014)

3.4 Ceramic and Glass

Ceramic and glass can be recycled many time. Therefore, it is better to collect and recycle these materials, after their first use, instead of wasting them.

3.5 Textile

Textile is a need anywhere in the world which means its waste is also generated in every country in the world. And the second-hand textile becomes in an important trade in the world. Between 2001 and 2009, the second-hand textile sector is grown up from 1.26 billion US dollar to 2.5 billion US dollar. This may explain the decrease in total textile waste generation and the increase in textile reuse and recycle. (UN Environment, 2016)

3.6 Organic Waste

Every year, 30% of the total human food is wasted in the world. That affects the environment and resources directly. There are some factors, which causes to food waste. For example, buying habit is one reason. People buy often more than their needs and the food, which bought to purpose of later use, is very often wasted. Another point is that restaurants and other similar enterprises offer standardized portion size. Since everybody does not consume same amount of food, portions should not have standard size. Therefore, so much food is wasted there too. The most important thing to decrease these impacts is the prevention of food waste generation. The next step should be to use the food waste effectively like composting.

3.7 Hazardous Waste

The waste can be called as hazardous waste, when it consists of adequate amount of harmful substances for the human health and the environment. Its waste management has high priority and it has to be done very successfully. In the following figure, the hazardous waste generation in the world is shown. Many developing countries do not manage the hazardous waste well. First of all, the non-hazardous and hazardous waste should be carefully separated. But the developing countries are mixing these wastes. That causes pollution and health problems. (UN Environment, 2016)

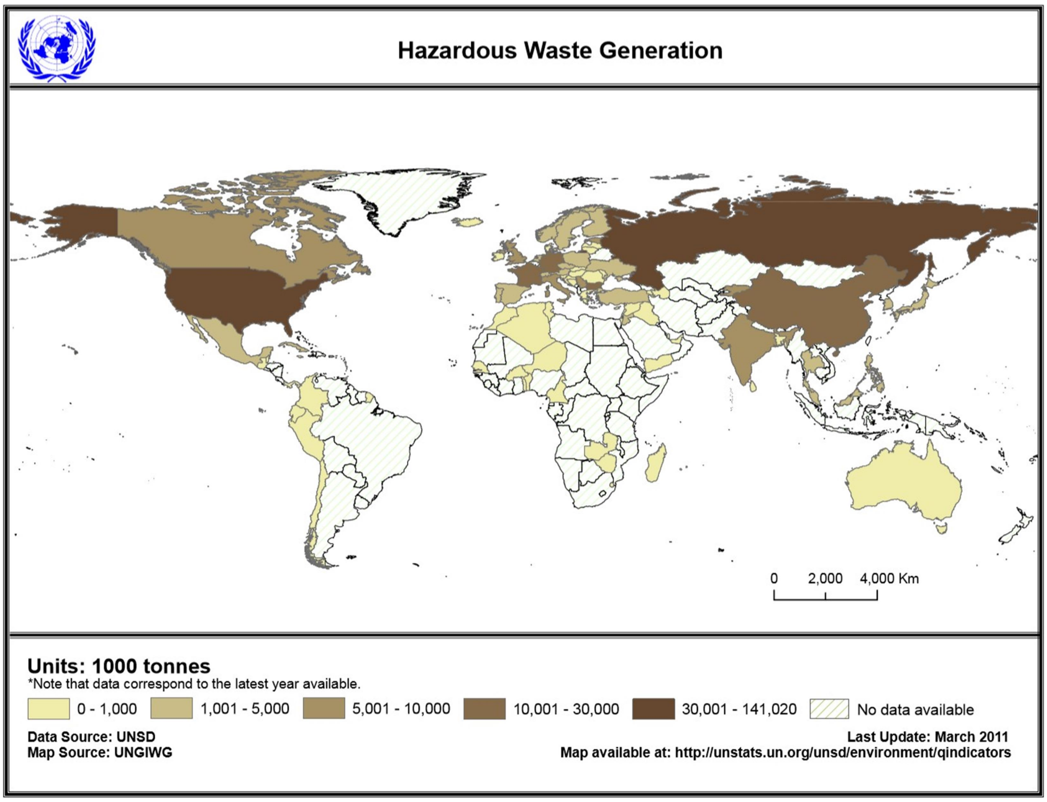

Figure 4 Hazardous Waste Generation

(UN Environment, 2016)

3.8 Construction Waste

As a result of building, road, bridges demolition, construction, renovation etc., construction and demolition waste is generated. In 2012, the generation of the construction and demolition waste was around 821 million tons in EU. That was in Japan 77 million tons and in China 33 million tons. Construction and demolition waste consist of many important materials and also various hazardous materials. These valuable materials can be wood, metal, glass, plastics etc. Since these are very valuable source as economically and also for environment, they should be very well managed. It is important to manage to reuse, recycle the materials and to use the materials efficient. On the other hand, during treatment of construction and demolition waste, hazardous waste occurs and that can bring pollution problems. In 1970s and 1980s, landfilling was the most used treatment method for construction and demolition waste. But nowadays many countries try to recycle this waste to use valuable materials again. That affects also the construction and demolition waste prevention very positive. Unfortunately, in developing countries, the effective waste management methods as recycling and reuse are of construction and demolition waste is still implemented very poor. (UN Environment, 2016)

3.9 E-waste

E-Waste is short form of Electronic waste, which means, is a period products which have turn into undesired, broken, old, not enough capacity for working, or just only because of our pleasure change or do not use them anymore, or they fundamentally achieved the end of their beneficial life. We live in a technology World and the technology is growing, changing, evolving and developing every day. Because of these reasons plenty of electronic products become ‘garbage’, in another name is ‘E-Waste’ just after a few years or few days. Almost every categories of electronic product subscribe to e-waste, for example VCRs switch with DVD players, and DVD players switch with Blu-ray their place in technology world. Actually every product which working with electricity participate e-waste: computers, TVs, monitors, cell phones, VCRs, CD players, fax machines, cameras, printers, electronic toys, fridge, wash machine etc.

Old electronic products are quickly loading the garbage area of the world. Just USA single-handled, over 100 million computers discard and just less than 20% goes to recycle agreeably. Most of discard electronic products implicate harmful materials for example: cadmium, beryllium, lead, mercury. These ingredients may be trace elements, but if supplementary in volume, they become harmful elements for environment. Also throw away destructive elements to the environment; we lose big opportunity of recycling e-waste. Practically every electronic e-waste include many form of recyclable material, such as plastic, glass, aluminum, iron, copper, and some metals even precious material gold. E-waste can be recycled or reused.

Biggest Producers in the World;

In 2018, approximately 50 million tons e-waste is generated. China in the top, with 7.2 million tons per year, the USA is second with 6.3, Japan is third with 2.1, India is fourth with 2.0 and Germany is fifth with 1.9 behind. If we look closely the two biggest populations in the World China and India do not produce as much as e-waste if we compare with e-waste produce of other countries of per capita. In reality, the most e-waste producers in the world are Europe and USA. 9 of top 10 e-waste producers are from Europe. Because of high standards of living and high salary in these countries people can easily upgrade their technology more often than other countries. Astonishingly, Nordic countries are in the top such as, Iceland, Sweden, Norway and Denmark.

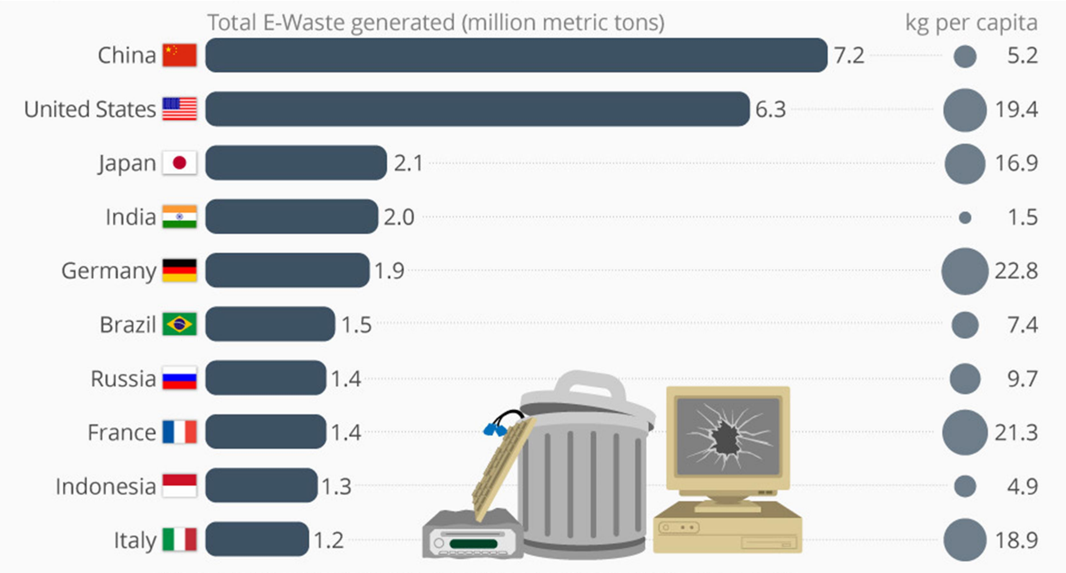

Figure 5 2016, Top 10 countries by the amount of e-waste generation per capita

(Richter F., 2017)

This figure shows, total e-waste generated. China leads this chart, but China is the not 1.place in 'kg per capita' category. China is in the top because of their population and biggest technology producer in the world. In additionally, some countries export their e-waste to the China.

Next figure shows the highest e-waste producer per capita in the world. E-waste generating is in fact directly proportional with income. People they live rich countries can use more technology and they produce more e-waste.

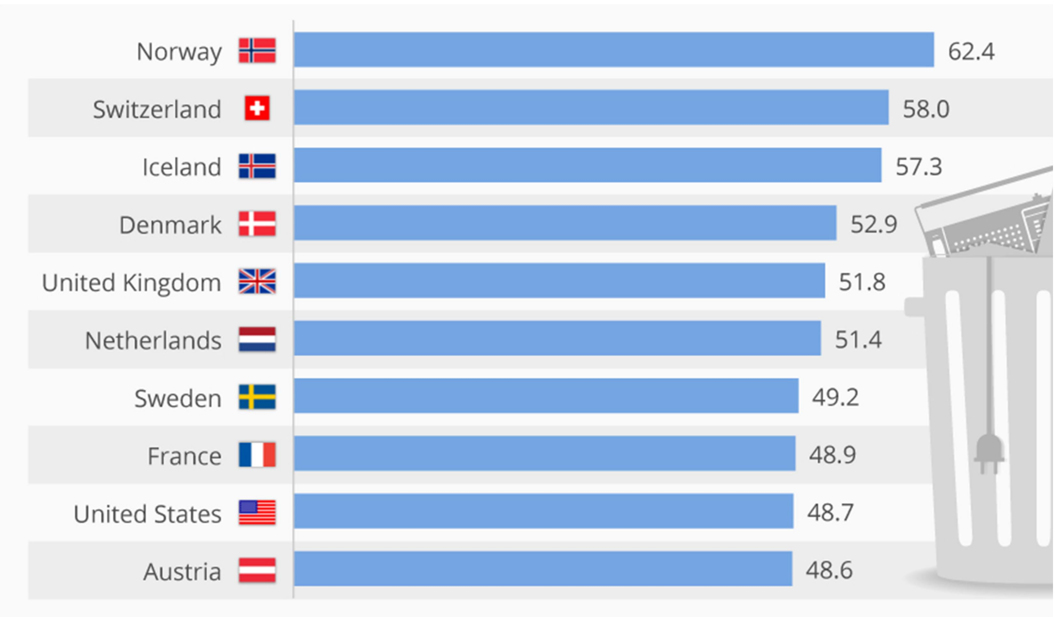

Figure 6 The biggest per-capita e-waste generators in 2014 (lbs per capita)

(Richter F., 2017; Baldé C.P., 2017)

9 of 10 e-waste producer from Europe therewithal Europe is the lead about recycling. Germany is the leader recycling rate. After that, Austria is the second. Third and fourth are South Korea and Wales. These countries recycle almost their municipal waste between 52% and 56%.

E-waste recycling is important because raw materials are very valuable sources. Globally, we can only from e-waste 10-15% gold effectively recover, 90%-85% rest is lost.

Electronic industry is growing very fast. They make too much commercial, they do not upgrade old product and then new apps do not support just few years old products in this manner, they push us buying new product. Our few years old electronic product life became suddenly short. This brings the explosion of rapid acceleration producing e-waste and solid waste.

- Toxic and Harmful Elements

Electronic products have also very harmful, toxic elements. For example, mercury, lead, chromium and cadmium. These materials must not release in to environment. E-waste could also have some heavy metals harmful for earth and flammable chemical.

- World-wide Movement of Dangerous Waste

The explosion of rapid growing of e-waste and unsuccessfully recycle attempts bring health risks for not good trained workers. Because recycling is a long and expensive process and countries trying avoid more money spend.

Acceleration of innovation and rapid growing technology bring along with e-waste problem. Ironically, technology at the same time is answer. We search every solution in technology. We are looking for cure for cancer, answer in technology, we want to travel around the world, answer is technology, we want to discover space, answer is technology, even we want to hang with people who we love and technology is the answer. While technology is finding solution for the human problems, unfortunately it is causing to increasing e-waste volume.

Recycling can be difficult and long chore for consumers sometimes. Therefore people avoid recycling to e-waste. Moreover, some e-waste landfill places want to charge to take the e-waste. This also pushes the people back from e-waste recycling. But if the e-waste can be recycled well, that will influence the economy positive as well. (Baldè C.P., 2017) (Richter F., 2017) (Leblanc R., 2019) (Electronix Rédux Corp, 2011)

4 WASTE MANAGEMENT METHODS

With the global increasing consumption, waste has become a major issue in the world. Therefore, waste has to properly managed and its negative impacts on the world has to decrease. In the following figure, domestic material consumption per capita is shown. Total consumption in European countries increased generally from 2013 to 2017. Nevertheless, it is not same for all European countries. Some countries are stable and some countries consumed less in this period. Especially, in Finland the total material consumption per capita is obviously decreased. Although income level in Finland is very high, the consumption reduced. A logical reason can be efficient use of the waste.

Domestic material consumption per capita										
Tons per capita										
Geo/time	2013		2014		2015		2016		2017	
EU (28 countries)	13,245	(s)	13,39	(s)	13,465	(s)	13,363	(ps)	13,54	(ps)
Belgium	13,573		13,14		12,931		12,474	(s)	13,196	(ps)
Bulgaria	17,075	(s)	18,775	(s)	21,325	(p)	19,38	(ps)	20,793	(ps)
Czechia	14,752		15,238		15,853		15,605		15,185	(ps)
Denmark	21,928		21,929		22,396		22,911	(e)	23,484	(ps)
Germany	16,265		16,824		16,029		15,911	(ep)	15,614	(ps)
Estonia	28,8		28,278		27,483		26,541	(s)	29,425	(ps)
Ireland	21,821		20,792		20,825		22,212		24,308	(ps)
Greece	12,299		12,74		12,017		11,979	(s)	11,993	(ps)
Spain	8,324		8,417		8,754		8,532	(s)	8,746	(ps)
France	11,961		11,762		11,114		10,753	(s)	11,263	(ps)
Croatia	9,951		9,108		9,738		10,127		9,716	(ps)
Italy	8,262		7,811		8,323	(b)	8,377	(s)	8,491	(ps)
Cyprus	13,939		13,992		14,157		16,377	(s)	19,432	(ps)
Latvia	20,778		20,772		21,464		20,153		22,727	(ps)
Lithuania	15,669		14,836		14,973		15,701		16,795	(ps)
Luxembourg	20,804		21,416		23,857		25,801		25,001	(ps)
Hungary	9,992		12,893		12,699		12,517	(ps)	13,413	(ps)
Malta	9,043		12,072		14,046		13,975		13,302	(ps)
Netherlands	10,05	(e)	10,34		11,007	(e)	9,694	(ep)	9,693	(ps)
Austria	20,61		20,594		20,144		20,384	(s)	20,762	(ps)
Poland	17,272	(s)	17,215		16,931		17,696		18,923	(ps)
Portugal	13,952		14,848		15,018		14,806		15,317	(ps)
Romania	22,056	(s)	22,646	(s)	27,202	(s)	26,524	(ps)	25,098	(ps)
Slovenia	12,194		13,089		13,278		12,807		13,537	(ps)
Slovakia	11,368		12,562		12,651		13,34		13,203	(ps)
Finland	37,346	(s)	31,023	(s)	30,528	(s)	31,468	(s)	32,296	(ps)
Sweden	22,622		22,865		22,557		22,663		22,953	(ps)

United Kingdom	8,875		9,124		8,965		8,648	(ps)	8,865	(ps)
Iceland	:		:		:		:		:	
Norway	29,394		28,536		36,556		30,022		:	
Switzerland	12,135		12,126		11,352		11,445		11,085	(p)
Former Yugoslav Republic of Macedonia, the	9,209		9,282		9,291		8,999	(p)	:	
Albania	:	(c)	:	(c)	:	(c)	:		:	
Serbia	15,267		14,474		15,46		16,936		:	
Turkey	11,896		12,068		12,862		:		:	
:=not available	s=Eurostat estimate			p=provisional			e=estimated			
b=break in time series	c=confidential									

Table 3 Domestic material consumption per capita

(European Commission, 2019)

4.1 Landfill of untreated waste

Landfill treatment method is used for the material which cannot be recycled or reused. This is mostly rest of some waste treatment process and stored underground where safe is in the long-term. In many developed countries, it is forbidden to landfill the combustible and organic waste.

4.2 Incineration

In this disposal method, the waste is incinerated. The main aim of this disposal method is to decrease the hazardousness and the volume of the waste. In this way, the damage caused by the waste to the environment will be minimized. On the other hand, that is also supported by advanced filtration systems in the waste incineration plants. That can be categorized to different incineration plants as;

- MSW incineration plant
- Hazardous waste incineration plant
- Sewage sludge incineration plant
- Clinical waste incineration plant
- Animal carcasses incineration plant

Waste incineration plants can be combined with other environmental friendly systems like heat recovery, turbines to use the waste heat as fuel.

4.3 Recycling

Recycling can described as, instead of to landfill or other treatments, a replacement of waste with different treatment to use the material again. It reduces the total resources consumption and its negative impacts on the environment.

The European “Framework Directive on Waste” is the one of the most important legal norm about recycling and re-use. According to this directive, re-use and recycling of the glass, metal, paper and plastic wastes should reach at least 50 per cent and construction and demolition wastes should reach at least 70 per cent until 2020. (Thomé-Kozmiensky K. J., Pelloni L. 2011:94)

In the following figure the municipal waste recycling rates in 32 European countries in 2001 and 2010 is shown. The five best countries on municipal waste recycling are Austria, Germany, Belgium, Netherlands and Switzerland. Bulgaria, Turkey, Romania, Croatia, Lithuania have the lowest municipal waste recycling rates.

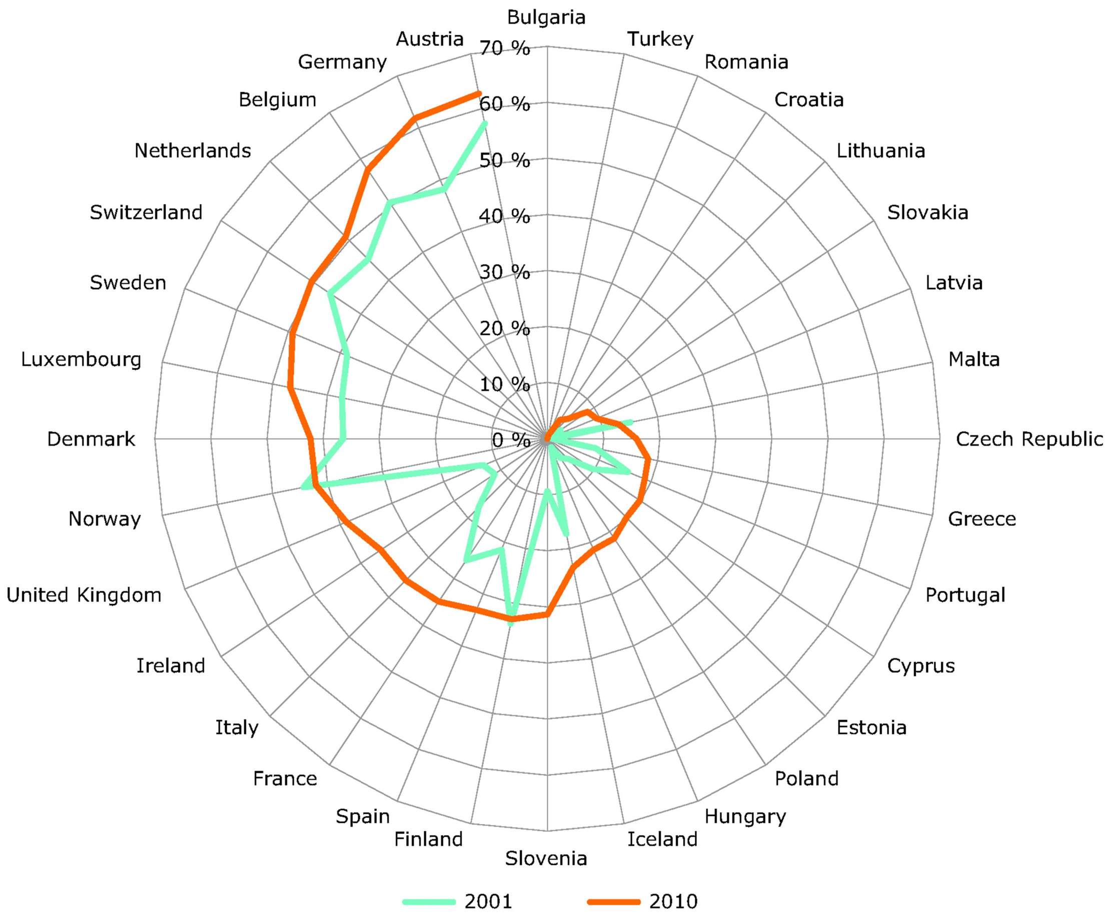

Figure 7 Municipal Waste Recycling rates in 32 European countries, 2001 and 2010

(European Environment Agency, 2013)

4.4 Reuse / Recovery

Recovery is a shared term for recycling, energy recovery and composting.

The discarded material is being used again for the same purpose is reuse.

4.5 Composting and Anaerobic digestion

Composting is a biological aerobic treatment. Composting is considered as recovery. With this was, digestate and biogas are produced and that can be used as vehicle fuel. Compost can be used in gardens, parks and landscaping.

4.6 Energy Recovery

One of the most important processes in waste management is waste to energy concept. During the treatment of waste, heat is occurred and this heat provides city heating or/and electricity. Here waste heat will use as fuel. To burn around three tons of oil or three tons of waste can produce the equivalent amount of energy. Generally, this method is used for the waste which cannot recycle. Use of tires, waste oil or spent solvent in cement kilns and the co-incineration of sewage sludge or refuse-derived fuel from MW in power plant are the mutual cases. (European Commission, 2011)

4.7 Reduction / Prevention of the Waste Generation

According to European Commission and many countries documents, the waste prevention is the most important approach regarding waste management. People have not enough awareness about what they really consume. Moreover, because of this uncontrolled consume habit, waste generation increases. Therefore, the most important approach to waste management has to be waste prevention. Because after the waste is generated, so much energy and effort is needed to dispose or efficient use of this waste.

5 WASTE TO ENERGY

5.1 Waste incineration plants

First, waste is transported by truck to the waste incineration plant. Then it is emptied in the bunker. The waste is thrown over a crane into the garbage Chure where then falls into the combustion chamber. In combustion chamber, it burns between 800 - 1000°C. During combustion, the waste is transported further by rust or by the rotational movement of the different furnaces. Burning arise hot flue gases and ash, slag. The hot flue gases heat the cooling water, which is mounted on the ring pipe around the furnace. The heated cooling water produces steam, which in turn feeds steam turbines. Subsequently, the smoke is removed from the flue gases with an electrostatic precipitator. A washing system filters and cleans the flue gases. The process water for cleaning is transported to wastewater treatment and pressed out as a filter cake. Filter cake is sent to disposal. In the DeNOx system the nitrogen as well as smallest particles are removed in the last step. Ammonia binds such particles. The slag and ash left over after burning are deposited and further processed for road construction.

Figure 8 Thermal waste incineration application in the Spittelau, Wien, Austria

(Wien Energie GmbH, 2018)

5.2 Waste to Energy Methods

Waste to energy becomes popular everywhere in the world. Since it is in developing countries very new subject, it implemented by many developed countries for very long years. First of all, the waste management is a big issue. Because it has impacts on environment, public health and resources.

Secondly, we need energy like electricity, heating, cooling etc. To meet these kind of needs, energy generation is a must. Nevertheless, while to meet human needs, it should not harm the world either and should not cause the other problems. Those energies should generated with environment friendly ways. Therefore, waste to energy concept is a very good opportunity to keep our environment and or resources safe.

- Waste to electricity

Steam produced during combustion is routed via pipelines and heat exchangers in the stream turbine and generate electricity with a generator. This electricity is fed into the power grid.

- Waste heat to district heating

A part of steam is cooled by heat exchangers to a specific temperature and further transported via district heating pumps and via district heating pipeline to the customer.

- Waste heat to district cooling

This system provides to use of existing waste heat during the summer with absorption chillers to district cooling

6 GLOBAL SITUATION OF WASTE MANAGEMENT AND WASTE INTO ENERGY PLANTS

In this part of the thesis, some global waste management and Waste to Energy plants and their technical datas are given. The information is created based on company reports, open data of governments, company web sites, and other statistics etc.

6.1 Vienna

In Vienna, waste heat is used to save primary energy. Every year, with a combination of the thermal waste incineration technology and some other eco-friendly systems in Vienna, about three million tons of CO2 is saved (rescued). Approximately 1200 km of district heating network is fed by Waste to Energy Concept and that is about one third of district heat.

The waste incineration plants of Wien Energie do not only produce environmental friendly energy, they are also a vital part of City Vienna's waste management industry. The household waste has to be thermal treated in Vienna legally. It is not allowed to commonly (simply) landfilled untreated waste in Austria. The Energy is generated from municipal waste, hazardous waste and sewage sludge in the thermal waste incineration plants of Wien Energie. Every year, about 900,000 tons of waste is processed at waste incineration plants in Vienna. In the thermal treatment plants, with maximum degree of efficiency pollutions are destroyed and this reduces the volume to be dumped. The combustion process is monitored and advanced flue-gas cleaning technology prevents any harm from being done to the environment. Thermal waste incineration plants in Vienna are generally 90 percent below the legal thresholds set for waste incineration plants on a yearly average. This is one of the best performances anywhere in the world. In 1960s in Vienna, first Waste to Energy concept was applied for delivering heat to hospitals. In Vienna, as Spittelau, Flötzersteig, Pfaffenau and Simmeringer Haide, four thermal waste incineration plants are in operation.

To keep the environmental impact of incineration process as low as possible, the newest pollution control technology is used and the process is carefully monitored.

After thermal waste treatment, less than one thirds of waste is seemed slag, less than two percent ash and 0.1 percent filter cake as the left over part.

District Heating Supply 2017 in GWh	
Spittelau	504
Flötzersteig	453
Simmeringer Haide	359
Total	1316

Table 4 District heating supply 2017 in GWh

As in the above table, in 2017, 1316 GWh district heating supplied by thermal waste incineration plants in Vienna. It can be commented as this incineration process helped to decrease total oil and gas consumption, which is needed for the heating systems, and supported the carbon emissions in a positive way. For this district heating supply, 841.979 tons of different waste is treated in different plants.

(Wien Energie GmbH, 2018)

Treated Waste 2017 in Tonnen	
Hazardouos waste	85.125
Not Hazardous waste	19.767
Municipal waste	535.713
Sewage sludge	201.374
Total	841.979

Table 5 Treated waste 2017 in tons

(Wien Energie GmbH, 2018)

In Vienna, there are two types of refrigerating machines for district cooling. In the conventional compression chiller, the energy supplier is the electric energy, but the absorption chiller use the thermal energy to run the system. This thermal energy provided by thermal waste incineration plants as waste heat.

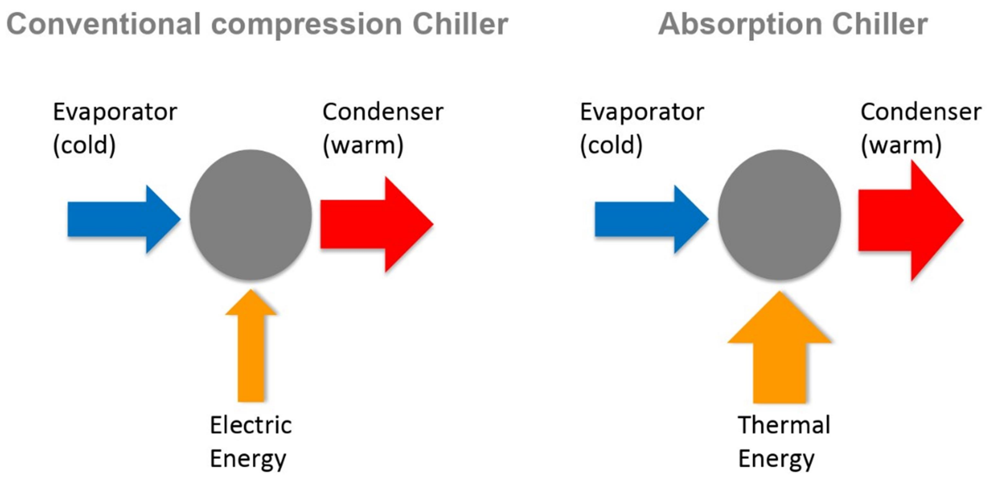

Figure 9 District Cooling, types of refrigerating machines

(Wien Energie GmbH, 2018)

Currently in Vienna, many important places' cooling need is supplied by district cooling system. That includes hospitals, university campuses, main train station, some hotels, shopping malls, company towers etc.

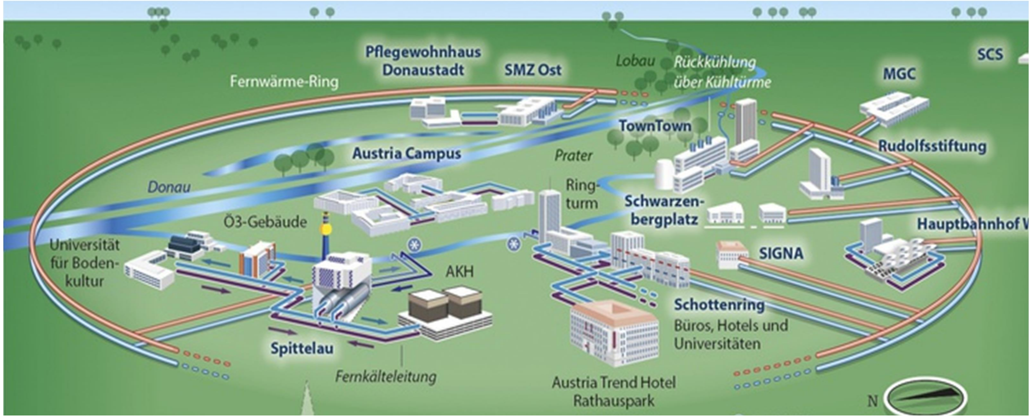

Figure 10 District cooling of Vienna

(Wien Energie GmbH, 2018)

And the cooling can be made by two different principles. One of them is energy supply via District heating and using a chiller. The other principle is directly via district cooling network. Recooling of district cooling made on the Danube Canal.

Cooling plant at the customer side District Cooling

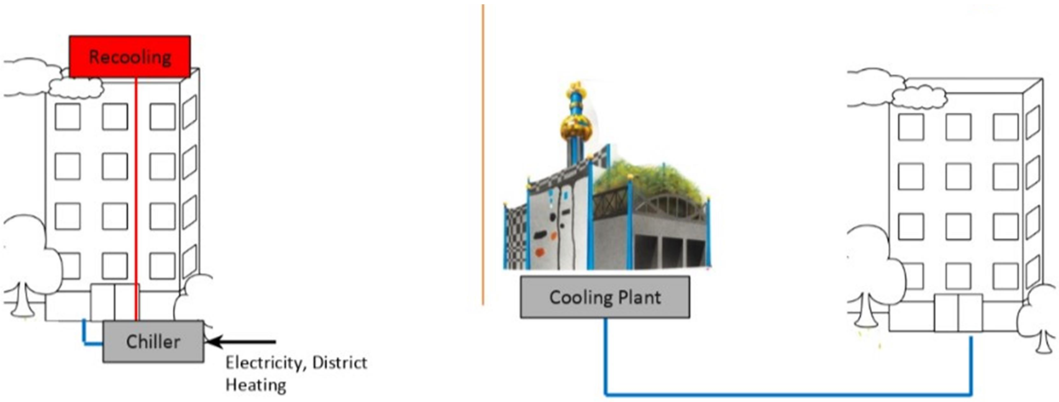

Figure 11 Main principles of cooling

(Wien Energie GmbH, 2018)

6.1.1 Spittelau Incineration Plant

The Spittelau thermal waste incineration plant is the biggest energy supplier between the Viennese thermal waste incineration plants. At this thermal waste incineration plant, the whole district heating technology was offered, that plant is in the city center and the waste is generated where the waste was burned exactly. Spittelau waste incineration plant supplies district heating, district cooling and electricity.

Figure 12 Thermal waste incineration plant Spittelau, Vienna, Austria

(Wien Energie GmbH, 2018)

At the Spittelau waste incineration plant, waste generated to the electricity, heating and cooling.

- Around 250.000 tons of Waste is processed at the plant per year, which can also calculated as 220 trucks of waste delivery from the city.
- Electricity power: 120 GWh
- With electricity supplied households: 50.000
- District heating : 500,000 MWh
- Households supplied by district heating (with heat or hot water): 60.000
- District cooling capacity: 17 MW, which is approximately 115.000 of commercial refrigerators energy need.

- Scrap iron: 6,000 tons.
- Clinker, filter cake and ash 60,000 tons

Energy generation and waste treatment	Unit	2013	2014	2015	2016	2017
Input (Fuel heat capacity)	MWh	218.402	253.579	533.129	734.958	669.492
Output generated electrical energy	MWh	0	2.394	27.883	47.992	50.016
Output generated thermal energy	MWh	131.130	172.234	375.402	507.916	504.319
Input fuels, waste, water						
Natural gas	kNm³	1.547	1.043	1.284	739	994
Waste + other fuels	t	66.391	99.067	189.890	253.417	242.062
Industrial water, drinking water and cooling water	1000 m³	1.214	911	866	633	1.130
Output residues and emissions						
Slag-not dangerous	t	15.568	20.296	39.505	51.903	50.727
Slag-dangerous	t	0	0	0	0	0
Ash-not dangerous	t	0	0	0	0	0
Ash-dangerous	t	1.018	2.314	4.917	6.532	6.054
Filter cakes dangerous	t	105	82	197	279	273
Scrap metal	t	1,76	18	41	-	-
CO2 equivalent	1000t	760	622	150	213	229
NOx	t	6	22	32	46	48
SO2	t	1	1	1	2	1
Dust	t	0	1	1	1	2
Sewage	1000 m³	49	55	84	125	97

Table 6 Energy generation and waste treatment / Input fuels, waste, water / Output residues and emissions

(Umwelterklärung, 2018 Wien Energie GmbH)

As in the table above, total energy generation in Spittelau is rapidly increasing day to day. In 2017, total number of energy-supplied households by waste incineration plant in Spitellau is at least four times more than in 2013. The rest materials like ash and slag are used in the road construction and similar purpose. However, scrap metal cannot burned during this incineration process and they send to recycling.

6.1.2 Flötzersteig Waste Incineration Plant

Flötzersteig plant is the oldest thermal waste incineration plant of Vienna and also of Austria. It is in operation since 1963. With a combination of the Waste Incineration Plants Flötzersteig, Spittelau and Co-Generation Technologies of Wien Energy, the exceptional Vienna district heating network worldwide is made.

At the Flötzersteig thermal waste incineration plant, the district heating system is supplied by waste heat.

- Around 200.000 tons of waste is processed at the plant per year
- Electricity Power: 470 GWh. This is the highest electricity power supplier between the incineration plants in Vienna.
- Households supplied by district heating: 56.000

Energy generation and waste treatment	**Unit**	**2013**	**2014**	**2015**	**2016**	**2017**
Input (Fuel heat capacity)	MWh	603.332	608.355	573.253	579.442	613.965
Output generated thermal energy	MWh	444.083	449.559	421,352	425.789	452.726
Input fuels, waste, water						
Natural gas	kNm³	625	607	578	1.035	746
Waste + other fuels	t	202.058	208.322	194.093	194.807	202.369
Industrial water, drinking water and cooling water	1000 m³	146	135	148	183	166
Output residues and emissions						
Slag-not dangerous	t	45.199	44.814	42.085	40-249	43.367
Ash-dangerous	t	3.615	4.075	3.714	3.754	3.884

Filter cakes dangerous	t	90	99	109	85	95
Scrap metal	t	0	0	0	0	0
CO2 equivalent	1000t	185	196	180	176	190
NOx	t	30	39	41	43	43
SO2	t	3	4	3	3	4
Dust	t	1	1	1	1	1
Sewage	1000 m³	64	67	61	61	69

Table 7 Energy generation and waste treatment / Input fuels, waste, water / Output residues and emissions
(Umwelterklärung, 2018 Wien Energie GmbH)

In this incineration plant, every year almost half million MWh energy generated and that supplies the district heating and the electricity. This total energy generation increases day to day.

6.1.3 Simmeringer Haide Waste Incineration Plant

At the waste incineration plant Simmeringer Haide, household waste, sewage sludge and hazardous waste are burned. Per annual, two million cubic meters of sewage sludge treated at this plant. The difference between this plant and the other waste incineration thermal plant is the burning temperature. Because for burning process of the hazardous waste, higher temperature is needed. Hazardous waste is burned at around 1200 °C and household waste is burned at around 950 °C. There are six furnaces at this plant, two of them are rotary furnace lines for hazardous waste, and four of them are fluidized-bed furnace for household waste. Around 100.000 tons of Household waste, 110.000 tons of commercial waste and 250.000 tons of sewage sludge are processed at the Simmeringer Haide thermal waste incineration plant per year. This waste incineration plant supplies also the district heating and electricity.

- Electricity power 50 GWh
- District heating 450.000 MWh
- 450.000 MWh of district heating and
- 50.000 MWh of electricity

However, as in the next table given, although in this plant hazardous waste is also burned, this plant has still very less emission numbers. That shows also, while the hazardous waste is processed, environment can still kept safe.

Energy generation and waste treatment	Unit	2013	2014	2015	2016	2017
Input (Fuel heat capacity)	MWh	822.911	880.684	880.283	839.979	851.638
Output generated thermal energy	MWh	378.825	385.879	366.584	365.269	359.376
Input fuels, waste, water						
Natural gas	kNm³	0	0	0	0	0
Waste + other fuels	t	371.489	392.742	407.617	395.978	397.548
Industrial water, drinking water and cooling water	1000 m³	1.537	1.571	1.717	1.576	1.438
Output residues and emissions						
Rest material-not dangerous	t	55.997	60.432	55.891	53.872	56.132
Rest material-dangerous	t	5.448	5.157	4.892	3.799	3.649
CO2 equivalent	1000t	326	352	347	327	320
NOx	t	71	67	65	61	61
SO2	t	1	2	3	3	3
Dust	t	0	0	0	0	0
Sewage	1000 m³	208	200	201	238	249

Table 8 Energy generation and waste treatment / Input fuels, waste, water / Output residues and emissions

(Umwelterklärung, 2018 Wien Energie GmbH)

6.1.4 Pfaffenau Thermal Waste Incineration Plant

At this Vienna's youngest thermal waste incineration plant Pfaffenau, household waste is processed. By burning the waste, this plant provides district heating and electricity for households. The wastes are collected from the southeast of the City Vienna. Around 250.000 tons of household waste is treated per year and waste heat is used as a fuel of electricity and heating generation.

- With electricity supplied households: 25.000
- Households supplied by district heating (with heat or hot water): 50.000

(Wien Energie GmbH, 2018)

6.2 Sweden

In Sweden, there are more than 35 waste incineration plants with energy recovery and Sweden stays on the top of waste to energy concept in Europe. (UN Environment, 2016) Waste prevention is the most important waste management method in Sweden.

Hierarchic importance for waste management methods are waste prevention, reuse, recycling and biological treatment, disposal. Swedish Environmental Code defines waste as "*any matter or object that the bearer disposes of, intends to dispose of, or is obligated to dispose of*". (Avfall Sverige, 2018)

Waste treatment facts Sweden in 2017:

- 4.783.000 tons of household waste was processed
- 3.700.000 tons of other waste was processed
- 473 kg of waste were created per person
- 1.617.640 tons of waste was treated for recycling
- 741.280 tons of waste was biological treated
- 50,2 % of household waste were used for energy recovery
- 76.980 tons of hazardous waste was generated by households
- 127.800 tons of e-waste was collected, excluding batteries.
- Per person created around 12.6 kg e-waste
- 2.400,440 tons of household waste processed to energy recovery
- 1.250.000 household heating supplied with energy recovery
- 680.000 households electricity supplied with energy recovery
- Three plants informed that they supplied 74.610 MWh district cooling
- 23.650 tons of household waste was landfilled

• Landfill gas collection in 2017 is around 142 GWh

• For Energy recovery, 102 GWh of total landfill gas collection was used. The Energy which used for heating was 101.6 GWh, and the rest was used for electricity.

Moreover, 1.480.000 tons of waste from other countries processed in Sweden in 2017. In Sweden totally 142.000.000 tons of waste was produced in 2016. (Avfall Sverige, 2018)

6.2.1 Sysav's Waste Incineration Plants

In the Sysav's waste incineration plants, 841.000 tons of waste is treated per annual. In this plant, there are two hot water boiler and two steam boiler, and generate hot water, district heating and district electricity. The objective of the Sysav is to minimize the landfilling and to increase as much as possible the recycling of the material and energy recovery. That render possible to contribute to the circular economy with waste management and also to keep under control the eco-cycle as much as possible. Their eco-cycle concept contains different subjects. Waste management begins with source separation. The separation of waste starts at their home. But then this bulky waste which has still many different material in, arrives to the waste plants and there, the waste is separated into various elements as metal, wood, plastic etc. Around 90 percent of this separated waste is recycled to a material or generated energy and the rest of this separated waste is landfilled. Sysav provides the 60 percent of entire district heating need in Malmö and Burlöv. Another managed waste is garden waste. Every year big amount of park and garden waste arrives to Sysav for composting. Park and garden waste are used as bio-fuel or composted. Composting period takes three years and end of process, composted waste is sold.

Figure 13 Sysav Waste Site

(www.sysav.se, February, 2019)

Figure 14 The eco-cycle approach of Sysav
(www.sysav.se, February, 2019)

As a result of implementation of this eco-cycle approach;

- 841.400 tons of waste is processed in 2017
- 59.900 tons of food waste is arrived in Sysav in 2017. 47.100 tons of that converted into biogas and this is comparable to 3.2 mio. liters of petrol
- 43,4 tons of hazardous waste is treated in Sysav in 2017
- Around 1.477 GWh of district heating provided by Sysav per year
- Around 168 GWh of electricity provided by Sysav per year
- 25.000 tons of bio-fertilizer created by Sysav per year
- Around 10.000 tons of compost is produced per year
- Every year, around 200.000 tons of CO_2 equivalent greenhouse gas emissions is decreased by Sysav

6.3 United Kingdom

United Kingdom wants to reach the EU Landfill Directive. In United Kingdom, many different disposal options are implemented. In the UK, it aimed to have and use more different disposal methods as thermal waste treatment, recycling, composting, anaerobic digestion plants and also methods to generate energy from waste. In 2016;

- Total waste generation is 222.9 million in UK
- 81.1 millions of this all waste were mineral waste
- 58.7 million tons was soils
- 42.7 million tons of commercial and industrial waste
- 136.2 million tons of construction, demolition and excavation waste
- 27.3 million tons of household waste
- 17.7 million tons of other waste are generated in United Kingdom. And comparing to 2014, it is increased 0.3 percent from 222.2 million tons of waste.

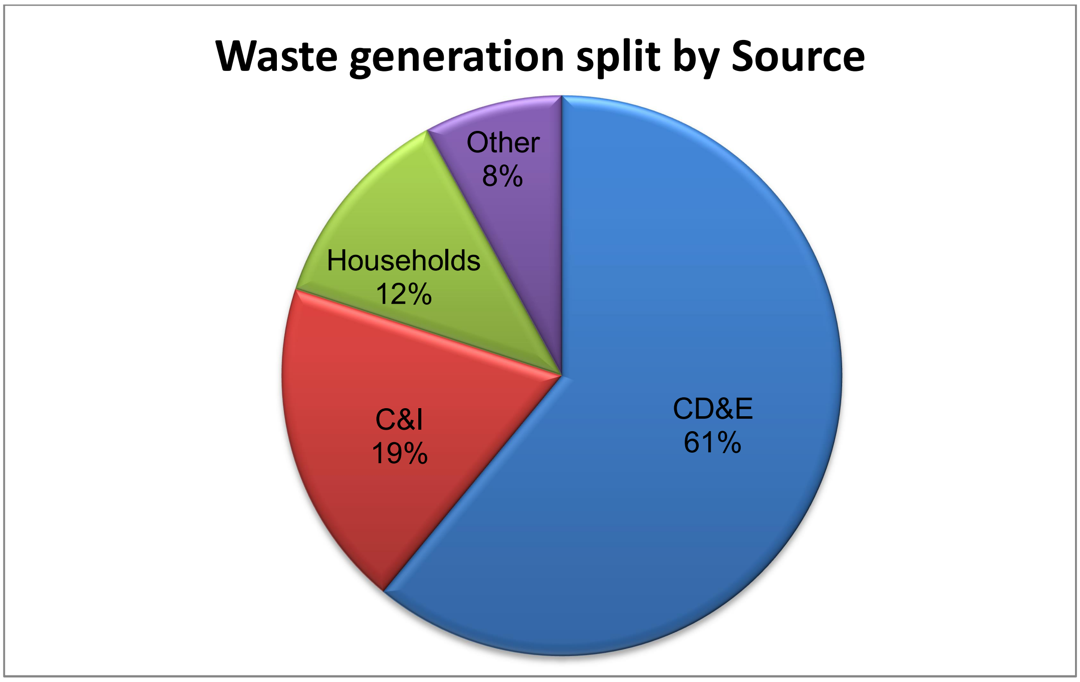

Figure 15 Waste generation split by source, UK, 2016

(Defra Statistics, 2019)

Construction, demolition and excavation waste constitutes 61 percent of total waste generation in United Kingdom in 2016. That followed by Commercial and Industrial Waste with 19 percent. And remain part is generated with 12 percent by households and the 8 percent is other wastes.

In 2017, the recycling rate is increased in all UK countries and the UK recycling rate for waste from households was 45.7 percent and that was 45.2% in 2016. The UK has an objective to recycle to households waste at least 50 % by 2020.

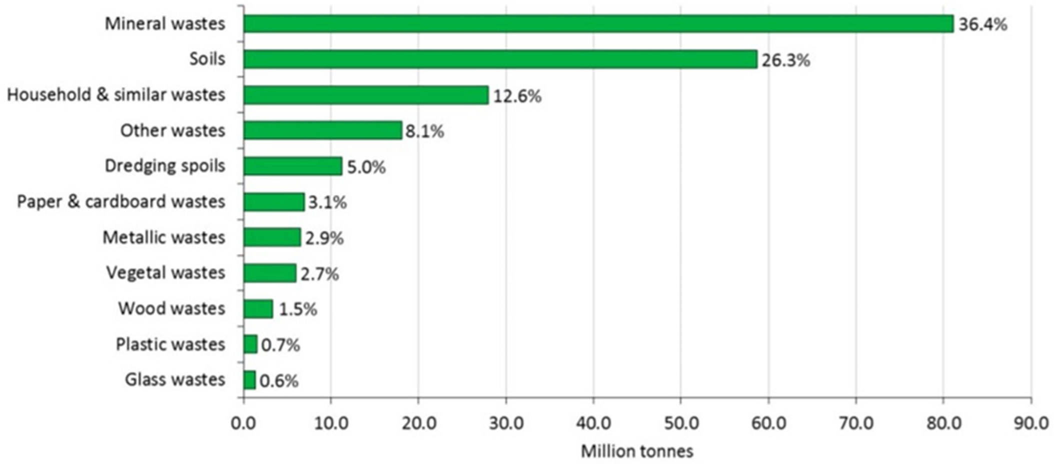

Figure 16 Waste generation by waste material, UK, 2016

(Defra Statistics, 2019)

Mineral waste with 81.1 (36.4%) million tons was the most generated waste on basic material in UK, in 2016 and that followed by soils with 58.7 (26.3%) million tons.

United Kingdom, 214.3 million tons of waste is treated by final treat methods in 2016. By waste treatment, energy recovery, incineration, recycling and other recovery method, backfilling, deposit into or onto land (landfill), land treatment and release into water bodies were used. In 2016;

- The most used final waste treatment method was Recycling and other recovery. That is followed by Landfill
- to energy recovery, 73 million tons of waste is treated which is 278.3 percent increased to compare 2014
- 5.7 million tons of waste incinerated which is 24.8 percent less than 2014
- 104 million tons of waste recycled and it is 8 percent increased to 2014
- 16.8 million tons of waste backfilled which means 22.5 percent less than 2014
- 52.3 million tons of waste is landfilled which means 8.3 Percent more to 2014
- 28.2 million tons of waste is land treated and released into water bodies which is 5.4 percent less than 2014

• totally, 214 million of waste is treated and it is increased from 205.4 million tons as 4.3 percent to compare 2014

% waste material, by treatment type						
Waste material	Energy Recovery	Incineration	Recycling and other recovery	Backfilling	Deposit onto or land (landfill)	Land treatment and release into water
Metallic wastes	0%	0%	14%	0%	0%	0%
Glass wastes	0%	0%	2%	0%	0%	0%
Paper and cardboard wastes	0%	0%	4%	0%	0%	0%
Wood wastes	8%	13%	2%	1%	0%	0%
Vegetal wastes	0%	1%	4%	0%	0%	0%
Household and similar wastes	76%	38%	1%	0%	11%	0%
Mineral wastes	0%	0%	55%	5%	6%	60%
Solis	0%	0%	12%	89%	55%	0%
Dredging spoils	0%	0%	0%	1%	0%	40%
Other wastes	16%	48%	6%	4%	27%	0%
All wastes	100%	100%	100%	100%	100%	100%

Table 9 Final treatment methods for waste, split by material, UK, 2016 – proportion of tonnages (Defra Statistics, 2019)

“Household & similar wastes” was the most common treated waste at the energy recovery and it consisted the 38 percent of total incinerated waste, but the largest amount (48%) of incineration system is provided by other wastes. With 55 percent soils were the most important waste material for recycling and other recovery methods in UK. Backfilling is also supplied by soils with 89 percent. On deposit onto or into land, soils has seen as a majority with 55 percent and the majority (60 %) of waste at land treatment and release into water bodies was mineral wastes.

In UK, between 2014 and 2016, number of energy recovery plants is increased from 29 to 37. With that increased number of facility, the capacity is doubled and it reached from 4.9 million tons to 9.8 million tons per annual that means automatically landfill is decreased as aimed. But in interesting way, total numbers of incineration facilities are decreased in UK and in England. For non-reused or / and non-recycled waste, the energy from waste is the generally the best waste management option and at the same time it is one of the most environmental friendly disposal methods. In the following figure, number and capacity of permitted final treatment facilities in UK and England, 2014 and 2016 is shown.

Facility type	Measure	UK 2014	UK 2016	England 2014	England 2016
Energy recovery	Numberof facilities	29	37	13	23
	Capacity (thousand tons/year)	4862	9808	2803	7202
Incineration	Numberof facilities	83	78	60	57
	Capacity (thousand tons/year)	9859	8474	9040	8193
Recovery other than energy recovery (includes backfilling)	Numberof facilities	2660	3506	1669	1944
	Capacity (thousand tons/year)	-	-	-	-
Deposit onto or into land (landfill)	Numberof facilities(incl. Closed facilities)	596	604	493	510
	Rest (remaining) capacity (thousand m³)	592637	554751	484370	464891

Table 10 Number and capacity of permitted final treatment in UK and England, 2014 and 2016

(Defra Statistics, 2019)

According to Resource and Waste Strategy document, which is published in December 2018, England's strategic indicators are as given in the table below;

Maximise value of resource use, and minimise adverse environmental impacts
1) Raw material consumption
2) Carbon footprint of resource use
3) Carbon footprint of a basket of consumer goods
Miniminse waste and impacts on the environment
1) Waste generation
2) Recycling
3) Landfilling
4) Illegal waste sites
5) Fly-tipping
6) Litter

Table 11 Strategic Indicators

(HM Government 2018; Defra Statistics www.defra.gov.uk February 2019; www.government.uk, February 2019; European Commission, 2011)

6.3.1 Runcorn Energy Recovery Facility

Runcorn energy recovery facility is the one of the biggest energy recovery plant in Europe. There the fuel is created from non-recyclable waste and used for generation of heat and electricity. In this plant, household waste and commercial waste is treated. Before the treatment, the recyclable materials have been removed. Each year, this plant

- treats between 850.000 and 890.000 tons of refuse derived fuel
- generates around 70 MW electricity and this supplies around 90.000 households
- generates 51 MW heating

6.4 Norway

Since 1995 Waste volumes in Norway have increased by 60 per cent. In 2016, 11.4 million tons of waste is generated in Norway. The majority is created by construction waste and that followed by households waste. In the following figures waste accounts for Norway are given. The source of origin, material type and the treatment are the three different characteristics of waste streams quantify. (Statistics Norway, 2019)

Waste account for Norway, amounts of waste by source of origin			
	2016		Per cent change
	1000 tons	Share	2015 - 2016
Source of origin, total	11390	100	3
Manufacturing industries	1499	13	5
Construction	2840	25	10
Service industries	2270	20	-2
Households	2444	21	-1
Other or unspecified	2338	21	3

Table 12 Waste account for Norway, amounts of waste by source of origin

(Statistics Norway, 2019)

Norway is very successful in waste management. The waste can processed in composting, biogas production, incineration, material recovery, land filling etc. Very big amount of paper and cardboard waste is sent to material recovery. Incineration is the most preferred treatment method for wood waste in Norway as well as for mixed waste. However, park and gardening wastes are generally composted. In addition, the hazardous waste in Norway is partly incinerated, partly sent to material recovery or landfilled and treated by other disposal methods.

Waste in Norway by treatment and material. 1 000 tons.							
	2016 In total, except slightly polluted soil	Wetorga-nic waste	Park- and gardening waste	Wood waste	Sludge	Paper and cardboard	Other
Treatment, total	11390	410	183	792	229	750	1487
Sent to material recovery	3963	46	13	64	23	583	1182
Biogas production	226	197	0	1	16	0	2
Composting	360	93	149	5	109	0	1
Filling compound and cover material	321	0	0	0	1	0	6
Incineration	3815	49	19	708	22	14	11
Landfill	1910	1	0	5	49	0	205
Other disposal	723	24	2	8	8	152	14
Unknown	72	0	0	0	0	1	66
	Rubber	Textiles	Discarded vehicles	Radio-active waste	Hazardous waste	Mixed waste	Slightly polluted soil
Treatment, total	58	3	216	0	1482	2958	2262
Sent to material recovery	31	3	184	0	254	231	0
Biogas production	0	0	0	0	0	10	0

Composting	0	0	0	0	0	3	0
Filling compound and cover material	0	0	0	0	0	70	21
Incineration	6	0	25	0	353	2419	0
Landfill	0	0	7	0	518	212	2241
Other disposal	21	0	0	0	358	12	0
Unknown	1	0	0	0	0	2	0

Table 13 Waste in Norway by treatment and material 1000 tons

(Statistics Norway, 2019)

The concrete and bricks, metal waste, wood waste and paper and cardboard waste are the most generated waste types in Norway. Total waste generation is affected mostly by manufacturing industries, construction industries, households and service industries.

Waste in Norway by source and material. 1 000 tons.							
	2016 In total, except slightly polluted soil	Wet organic waste	Park- and gardening waste	Wood waste	Sludge	Paper and card-board	Glass
Source of origin, total	11390	410	183	792	229	750	124
Agriculture, forestry and fishing	135	43	8	1	0	5	0
Mining and quarrying	407	3	0	2	0	1	0
Manufacturing industries	1499	49	0	92	75	94	16
Electricity, gas, steam and air conditioning supply	157	0	0	0	0	0	0

Water supply, sewerage, waste management and remediation activities	614	0	0	1	115	0	0
Construction	2840	0	0	262	0	23	13
Service industries	2270	123	21	150	14	367	33
Other or unspecified	1025	1	0	0	25	0	0
Households	2444	189	153	284	0	260	63
	Metals	E-waste	Concrete and bricks	Cinders dust bottom ash and fly ash	Plastics	Rubber	Textiles
Source of origin, total	804	147	989	513	244	58	3
Agriculture, forestry and fishing	2	3	0	0	23	0	2
Mining and quarrying	10	1	0	0	1	0	0
Manufacturing industries	142	4	38	71	39	2	0
Electricity, gas, steam and air conditioning supply	9	1	0	102	0	0	0
Water supply, sewerage, waste management and remediation activities	16	0	0	171	2	0	0
Construction	100	9	838	0	9	0	0
Service industries	177	34	12	1	30	57	0

Other or unspecified	259	45	100	168	100	0	0
Households	90	50	0	0	40	0	0

Table 14 Waste in Norway by source and material. 1 000 tons

(Statistics Norway, 2019)

In Norway, up to twenty years ago, landfill was the most common waste treatment method, but day to day it has rapidly decreased. Nowadays, the most common treatment methods in Norway are material recovery and incineration with energy recovery. Instead of the landfilling the waste, using as source helped to reduce greenhouse gas emissions. In the next figure below, the treatment methods are shown.

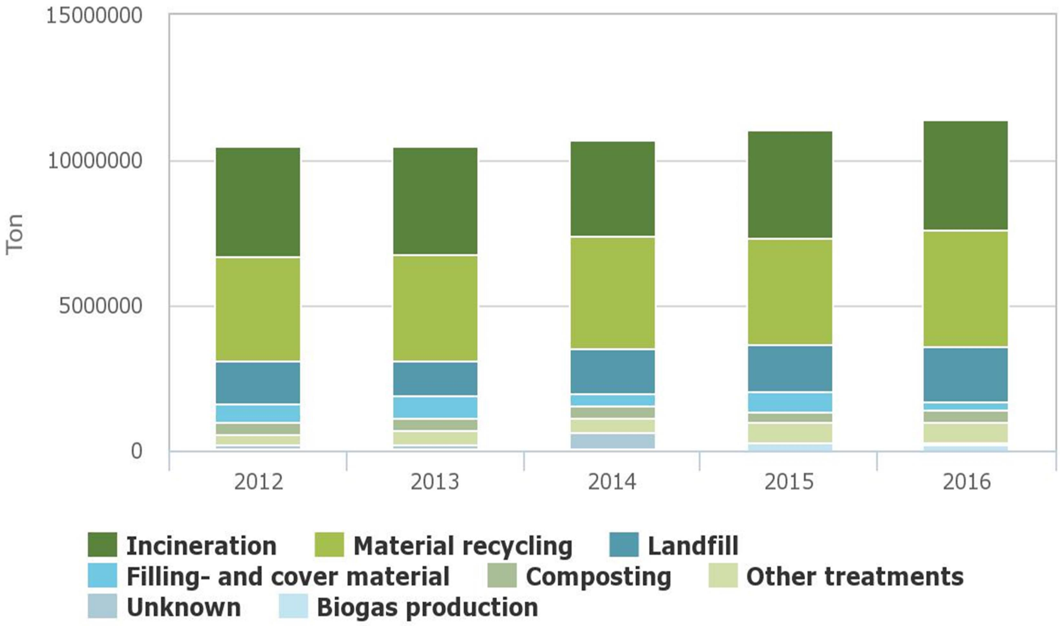

Figure 17 Non-hazardous waste in Norway, by method of treatment

(Statistics Norway, 2019)

As in the table below, the energy recovery method was the most implemented method in 2017 and that followed by waste incineration. The Combustion is very poor in front of the energy recovery and waste incineration methods.

Waste incineration 1000 tons	
	2017
Waste incinerated in total	1683
Energy recovery	1317
Waste incineration	366
Combustion waste	279

Combustion waste for recycling	268
Combustion waste landfilled	12

Table 15 Waste incineration 1000 tons

(Statistics Norway, 2019)

In Norway, recycling method is implemented very well. At the beginning of the 90's, the recycling rate was already around 64 per cent and that is actually already good range to compare with many countries. Nevertheless, Norway recycling rate is reached to higher number. In 2011, recycling waste was around 88 per cent.

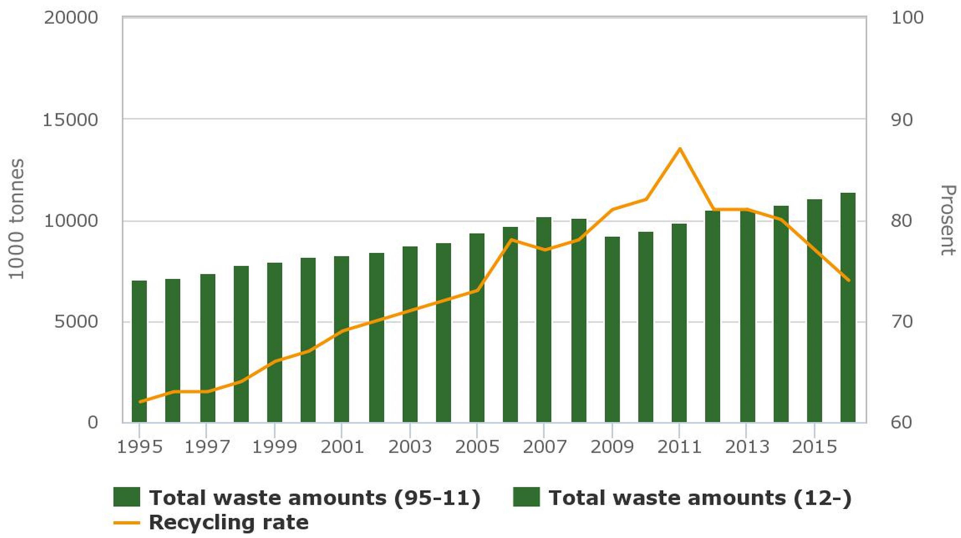

Figure 18 Total waste amounts and recycling rate

(Norway Statistics, Norwegian Environment Agency)

6.4.1 Klemetsrud, Oslo Waste to Energy Plant

Klemetsrud is the biggest energy plant in Norway. The recycling capacity of the plant is around 330.000 tons. Total estimated annually generation is around 187 GWh and total capacity is 114 MW.

- Electricity production: 175 GWh/year
- Heat production: 750 GWh/year

Figure 19 Klemetsrud, Oslo Waste to Energy Plant

(http://www.trackmyelectricity.com/plants/klemetsrud-chp/, February, 2019)

Before the waste sent to incinerate, a successful waste analysis, filter is supposed. On the band the green bags which contains food waste and blue waste which contains plastics are sorted from the residual waste by using camera technology. This is a optical sorting system to sort the garbage. Because the green bags are not good for bio gas plants and the blue bags are carried to Germany for material recovery. Plastic and food waste sorting capacity to process 50.000 tons of waste annually which is equivalent to approximately 120.000 households. The rest of the waste is incinerated and feed into the district heating for around 84.000 households and the electricity to supply the schools electricity in Oslo. Incinerator works around 850 °C and the incinerator surrounded by water and the water heated up by this incineration process. Incineration process continuous 24 hours all year long. Around 50 per cent of the district heating is supplied by waste incineration. By 2020, it is supposed to stop using the fossil fuel completely from the Oslo. Waste incineration produces greenhouse gases and the emissions have to be reduced as well. Smoke of the incineration process goes through to advanced purification process and then the smoke comes out from the chimney consist of more than 99 per cent pure water steam. (Carbon negative waste-to-energy in Oslo, Johnny Stuen, Waste to Energy Agency Oslo, http://www.trackmyelectricity.com, February 2019)

6.5 United States

As a very large waste producer, U.S. is very sensible about waste management. Recycle, Reuse and Recovery are vital issues in U.S. like EU as well. United States Environment Protection Agency (EPA) shows in their websites the ways from how to prevent to produce waste up to all possible waste management methods and it can be said EPA website is a very good prepared guide regarding to waste management.

In 2015, about 262.5 million tons of MSW is generated in US. In the next figure, total MWS generation and the waste generation based on per capita are shown. As the US is developed country, of course it is one of the most responsible countries in the world for the municipal waste generation. As it can seen in the figure, total waste generation between 1960 and 2015 increased more than three times. While it was around 88.1 million tons in 1960, it reached up to 262.4 million tons in 2015. That means logically, the total daily waste generation per capita increased too.

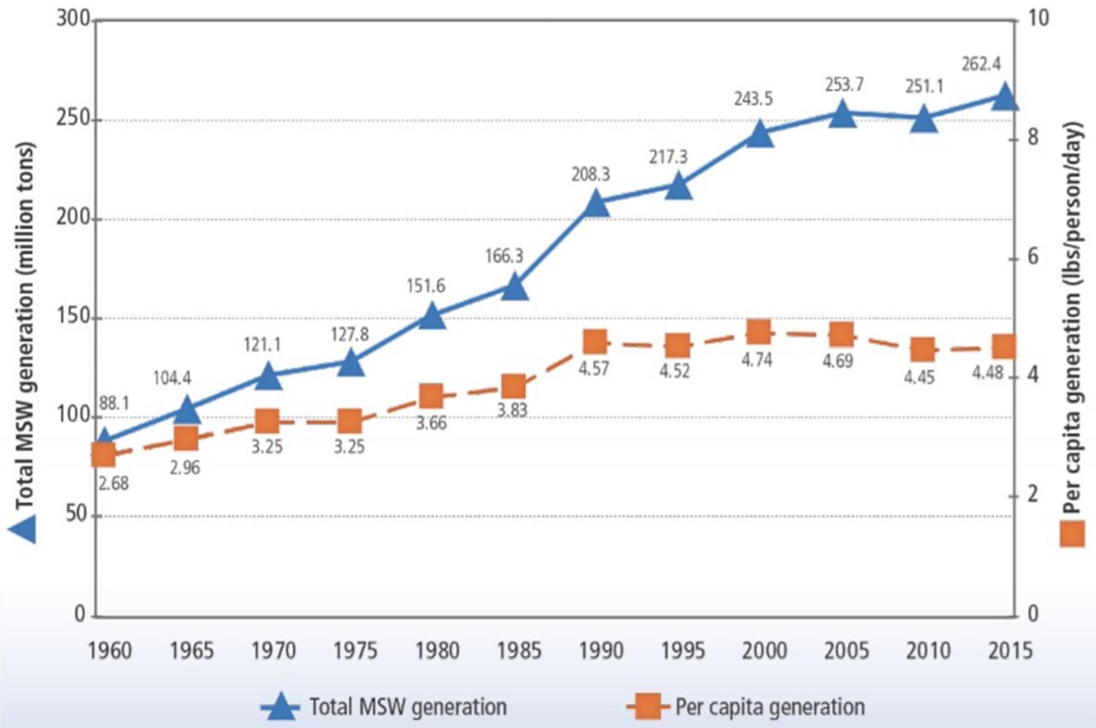

Figure 20 MSW Generation Rates, 1960 to 2015

(U.S. EPA OLEM, 2018)

In 2015, more than half of MSW is landfilled and, around quarter of MSW is recycled. For the rest of generated MSW is only composted and partly composted with energy recovery. Following figure shows the management methods in U.S., in 2015.

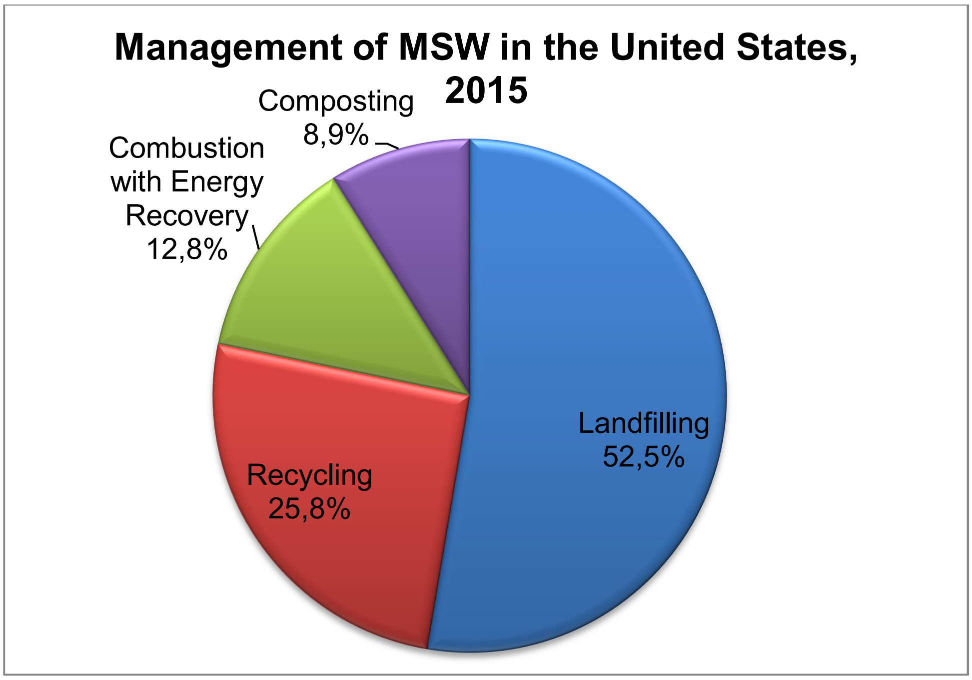

Figure 21 Management of MSW in the United States, 2015

(U.S. EPA OLEM, 2018)

The most generated municipal solid waste was paper waste in 2015 and that followed by food waste, plastics and yard trimmings waste.

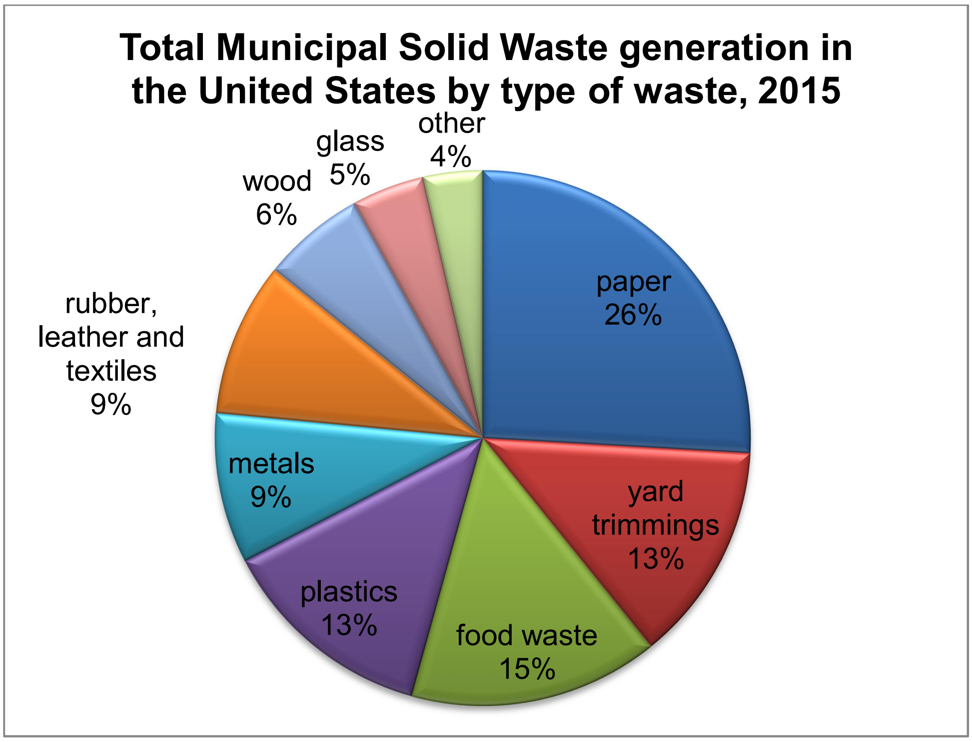

Figure 22 Total Municipal Solid Waste generation in the United States by type of waste, 2015

(U.S. EPA OLEM, 2018)

In last half century, waste management methods are rapidly developed in U.S. In the following figure, the waste management methods are shown. In the table given numbers;

- Composting; *"does not include backyard composting"* (U.S. EPA OLEM, 2018)
- Composting with energy recovery; *"includes combustion of municipal solid waste in mass burn or refuse-derived fuel from, and combustion with energy recovery of source separated materials in MSW (e.g., wood pallets, tire-dried fuel)."* (U.S. EPA OLEM, 2018)
- *"Landfilling after recycling, composting and combustion with energy recovery. Includes combustion without energy recovery."* (U.S. EPA OLEM, 2018)

Activity	1955	1970	1980	1990	2000	2005	2010	2014	2015
Generation	88.1	121.1	151.6	208.3	243.5	253.7	251.1	259.0	262.4
Recycling	5.6	8.0	14.5	29.0	53.0	59.2	65.3	66.6	67.8
Composting	Neg.	Neg.	Neg.	4.2	16.5	20.6	20.2	23.0	23.4
Combustion with energy recovery	0.0	0.5	2.8	29.8	33.7	31.7	29.3	33.2	33.5
Landfilling and other disposal	82.5	112.6	134.3	145.3	140.3	142.2	136.3	136.2	137.7

Table 16 Generation, Recycling, Composting, Combustion with Energy Recovery and Landfilling of Municipal Solid Waste, 1960 to 2015 (in millions of tons)

(U.S. EPA OLEM, 2018)

In 2015, around 4 million tons of MSW combusted with energy recovery and the important player of this recovery was food waste and that was almost a quarter of all combusted materials. The next important elements for combustion with energy recovery were plastics and rubber, leather and textiles wastes. Following figure shows the combusted MSW with energy recovery in 2015 based on material classification.

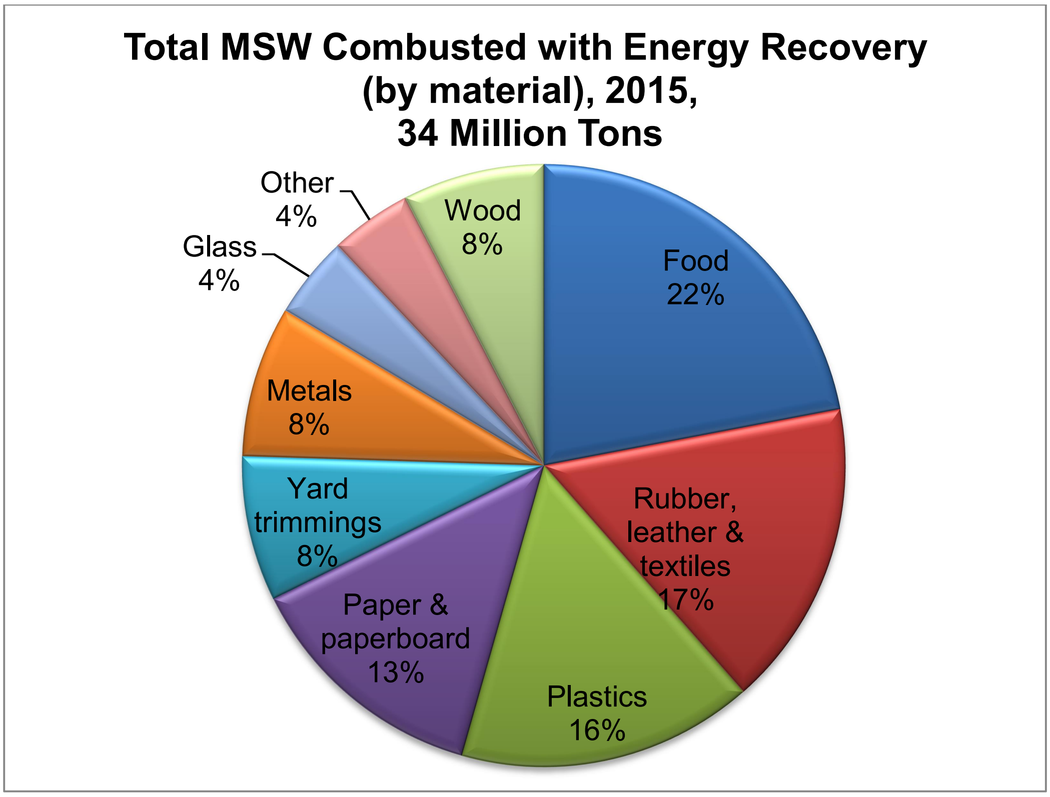

Figure 23 Total MSW Combusted with Energy Recovery (by Material), 2015, 34 Million Tons (U.S. EPA OLEM, 2018)

68 Million tons of MSW is recycled in 2015. The most recycled material was the paper and paperboard. Less part of recycled materials consisted by metals, glass, plastics, wood, rubber, leather and textiles. In the following figure, total MSW recycling amount in 2015 is shown based on materials.

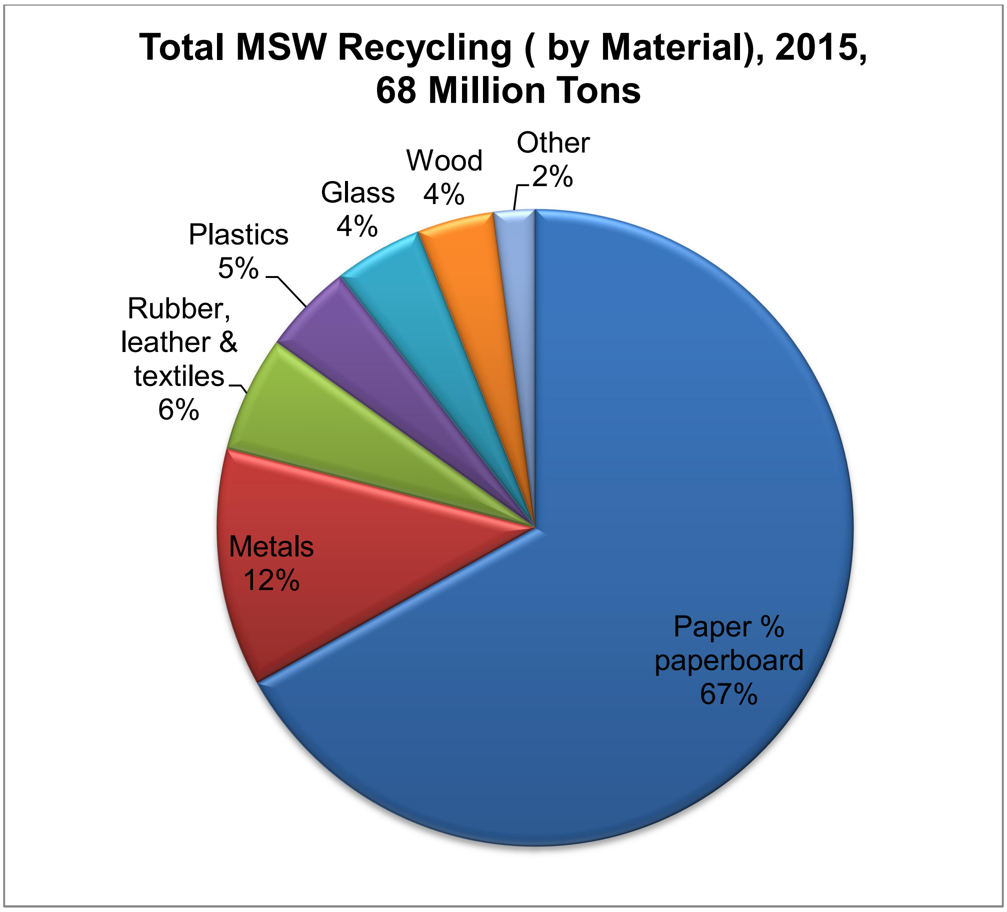

Figure 24 Total MSW Recycling (by Material), 2015, 68 Million Tons

(U.S. EPA OLEM, 2018)

Construction and Demolition waste is also another important waste type in U.S which has to manage. Because of U.S. population, not only MSW generation is too much, also the construction and demolition waste generation is pretty much. 548 million tons of construction and demolition waste is generated in 2015. Construction and Demolition waste includes steel, drywall and plaster, concrete, asphalt etc. They are mostly created during building construction, renovation and demolition. The largest part of construction and demolition comes from concrete. In the following figure, construction and demolition waste generation in 2015 is categorized and shown.

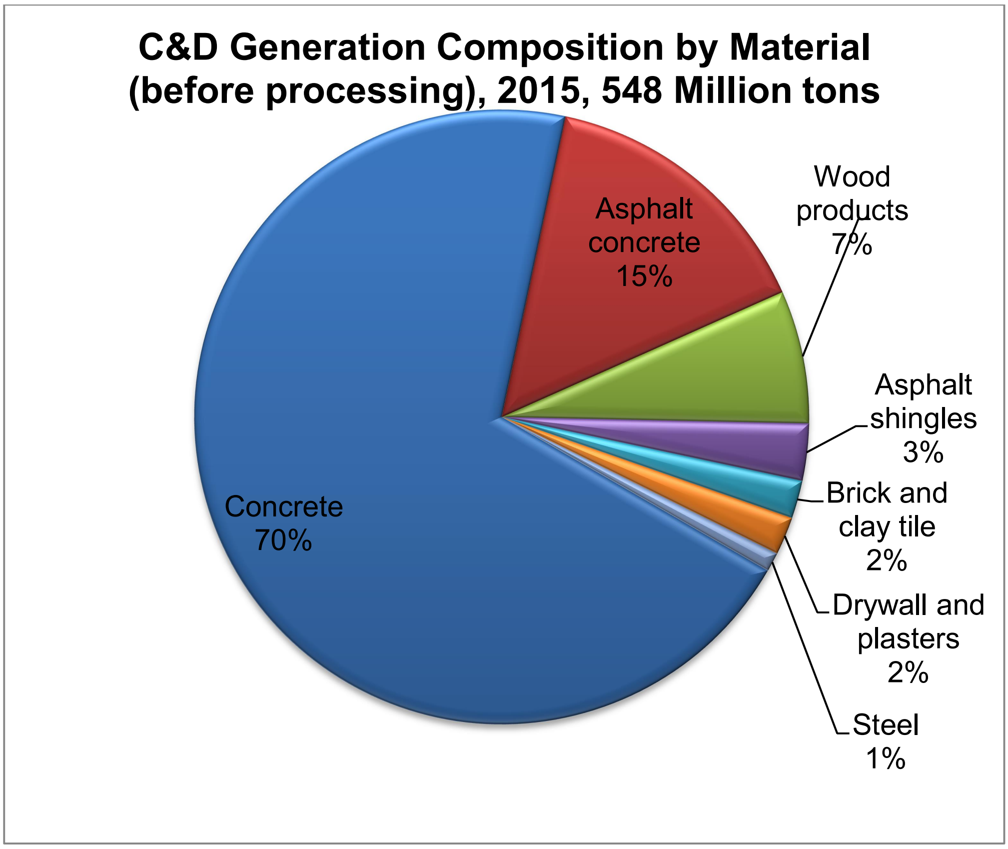

Figure 25 C&D Generation Composition by Material (before processing), 2015, 548 Million tons (U.S. EPA OLEM, 2018)

In US there are many Waste-to-Energy facilities. The majority is with 11 facilities in Florida, and that is followed by New York with 10 facilities. In the following table, the number of the WtE facilities in the U.S. leading states is represented.

	Number of facilities
Florida	11
New York	10
Minnesota	8
Pennsylvania	7
Massachusetts	6
Connecticut	5
New Jersey	5
Virgina	4

Table 17 Leading U.S. states based on number of waste to energy plants 2018 (www.statista.com, February 2019 Michaels T., Krishnan K. (2018))

Total capacity of U.S waste to energy facilities are;

- 75 waste to energy facilities are in operation
- In 21 States there are Waste to Energy plant
- Municipal solid waste treatment capacity is 94,243 tons in a day
- 29,276,060 tons of MSW is generated in 2017
- 13,876,446 MWh electric is generated in 2017
- Electric capacity generated by WtE plant is 2,534 MW

Florida has the highest waste-to-Energy plant capacity based on the electricity generation. In Florida;

- There are 11 Waste-to-Energy plants
- Municipal solid waste treatment capacity is 20.114 tons in a day
- Electric capacity generated by WtE plant is 560 MW
- 21 per cent of total municipal solid waste is treated by waste to energy plants
- 27 per cent of total municipal solid waste is recycled or composted
- 51 per cent of total municipal solid waste is landfilled

The next highest capacity of waste to energy plants is in New York based on the electricity generation. In New York;

- There are 10 waste-to-Energy plants
- Municipal solid waste treatment capacity is 11,131 tons in a day
- Electricity capacity, generated by WtE plants is 285.1 MW
- 21 per cent of total municipal solid waste is treated by waste to energy plants
- 20 per cent of total municipal solid waste is recycled or composted
- 59 per cent of total municipal solid waste is landfilled

The third largest waste to energy capacity is in Pennsylvania based on the electricity generation. There;

- There are 6 waste-to-Energy plants
- Municipal solid waste treatment capacity is 9,560 tons in a day
- Electricity capacity, generated by WtE plants is 267,9 MW
- 22 per cent of total municipal solid waste is treated by waste to energy plants
- 36 per cent of total municipal solid waste is recycled or composted
- 42 per cent of total municipal solid waste is landfilled

(Michaels & Krishnan, 2018)

6.6 South Korea / Seoul

Waste management is an important subject in South Korea and its improvement has seen especially positive since 1990's because the national policy on the solid waste management is developed and accepted in 1990's. According to this new policy approach, waste decrease at source and waste usage are focused points. While the landfilling rapidly decreases in the South Korea, the environmental friendly waste treatment methods increase.

Figure 26 Waste Management Hierarchy, Seoul

(Seoul Urban Solutions Agency, www.susa.or.kr , 03, 2019)

As in the below figure, Landfilling started to decrease rapidly after 1991. One hand, that decreasing amount replaced itself with waste incineration and recycling methods. On the other hand, total waste generation is decreased and that already proves the Seoul waste management hierarchy.

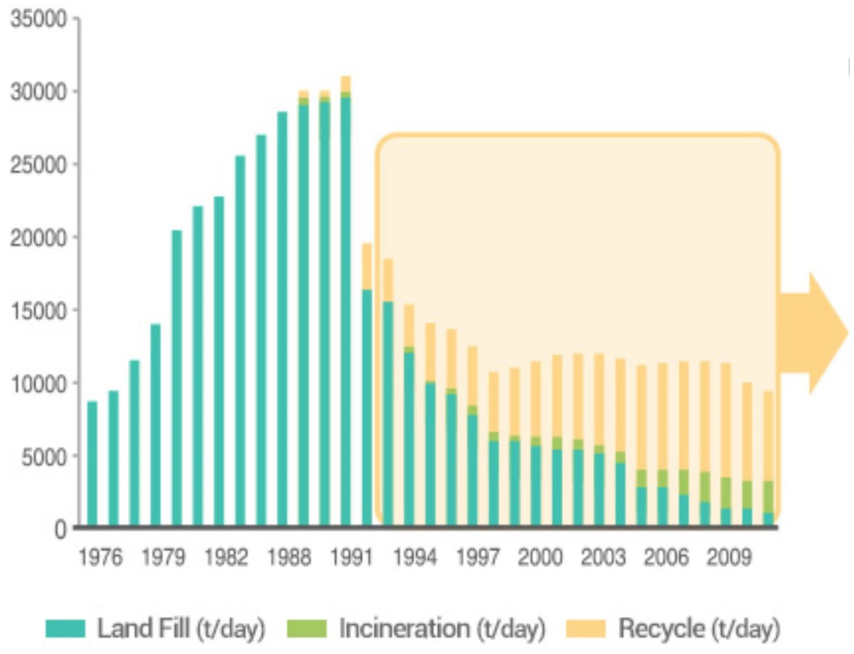

Figure 27 Waste treatment amount based on treatment methods in ton/day
(Seoul Urban Solutions Agency, www.susa.or.kr , 03, 2019)

As in the below figure, comparison between 1993 and 2011, the recycling treatment method is preferred more than other waste treatment methods. Total recycling amount, which is around 18% in 1993, reached up to 65% in 2011.

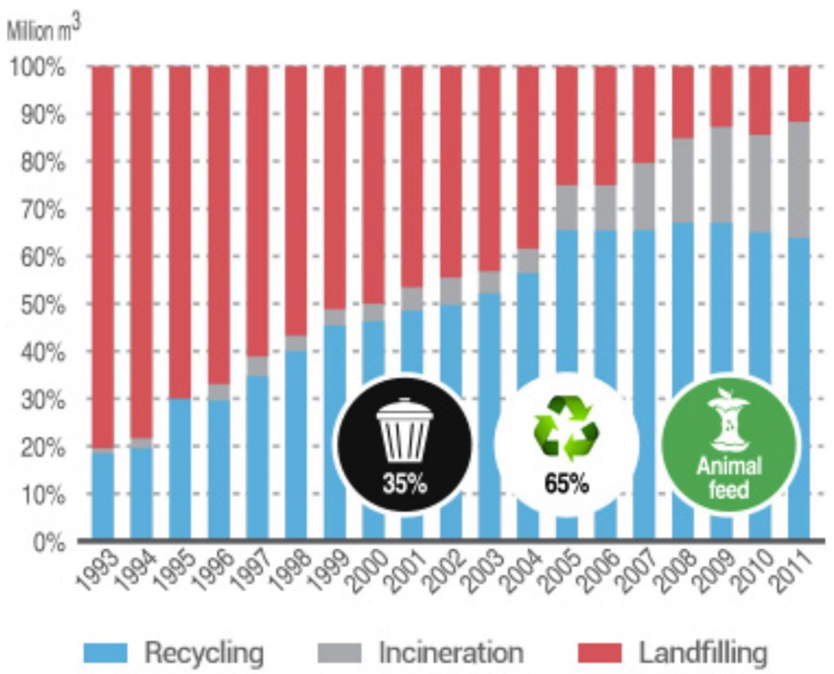

Figure 28 Waste treatment rate on treatment methods
(Seoul Urban Solutions Agency, www.susa.or.kr , 03, 2019)

The waste is categorized as household waste, organic food waste, sludge and construction waste. The waste generally processed by incineration, recycling, drying. The waste treatment generates electricity, construction block, animal feed, some energy blocks and construction materials. In the following figure that is shown.

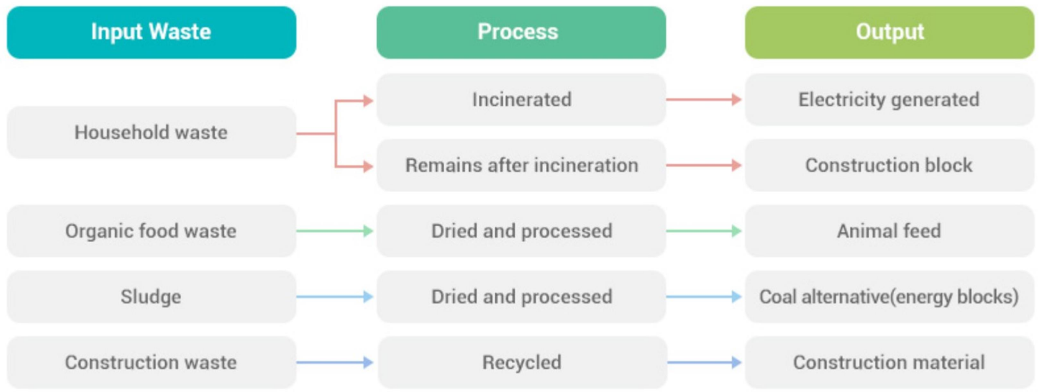

Figure 29 Waste as resource

(Seoul Urban Solutions Agency, www.susa.or.kr , 03, 2019)

Category	Yangcheon Facility	Nowon Facility	Gangnam Faciliy	Mapo Facility
Capacity	400 Tons/Day (2 Units)	800 Tons/Day (2 Units)	900 Tons/Day (3 Units)	750 Tons/Day (3 Units)
Construction Period	1992.12~1996.2	1992.12~1997.1	1994.12~2001.12	2001.12~2005.5
Area	14.627 m²	46.307 m²	68.813 m²	58.435 m²
Construction Cost	32.1 Billion KRW	74.3 Billion KRW	115.5 Billion KRW	171.2 Billion KRW
Incinerator	Stoker Type	Stoker Type	Stoker Type	Stoker Type and Rotary Kiln
Air Purification Facility	Wash Tower Semi Dry Reactor Bag Filter	Electric Precipitator Wet Wash Tower Bag Filter	Wash Tower Semi Dry Reactor Bag Filter	Semi Dry Reactor Bag Filter SCR Catalyst

	SCR Catalyst Tower	SCR Catalyst Tower	SCR Catalyst Tower	Tower Police Filter

Table 18 Construction of Incineration Facilities in Seoul

(Lee & Hur, 2017)

Via waste incineration generated waste heat supplies the district heating in Seoul. Total number of district heating supplied household is around 514.000 and that provided by four waste incineration plants in Seoul, South Korea.

In the following table, incineration plants district heating amount is shown.

Category	Yangcheon Waste Incineration Plant	Nowon Waste Incineration Plant	Gangnam Wate Incineration Plant	Mapo Waste Incineration Plant
Size of District Heating Facility	140.000 households	128.000 households	176.000 households	70.000 households
Energy Recovered from Incineration Plant	Heat and Electricity	Heat	Heat	Heat and Electricity
Energy Source of District Heating in 2012	Heat from Incineration: 15.7 % Heat from Energy Generation: 51.0 % Produced Heat: 33.3 %	Heat from Incineration: 23.2 % Heat from Energy Generation: 37.8 % Produced Heat: 39.0%	Heat from Incineration: 27.0 % Heat from Energy Generation: 12.7 % Produced Heat: 60.3%	Heat from Incineration: 56.8 % Heat from Energy Generation: 33.8 % Produced Heat: 9.4 %

Table 19 Incineration Facilities and District Heating Plants Cooperation Status

(Lee & Hur, 2017)

The incineration plants in Seoul have very complex gas purification systems and according to gas emissions report in 2012, these four waste incineration plants emissions numbers are less than half of the as standard given values.

In the following table the gas emissions values are shown.

Category	Emission Standard	Yangcheon Waste Incineration Plant	Nowon Waste Incineration Plant	Gangnam Waste Incineration Plant	Mapo Waste Incineration Plant
Dusty (mg/Sm³)	20	2.07	1.74	1.14	0.88
Sulfur Oxides (ppm)	30	0.43	0.14	0.29	0.34
Nitrogen Oxide (ppm)	70	23.00	23.78	12. 39	16.67
Carbon Monoxide (ppm)	50	10.30	7.16	10.55	1.07
Hydrogen Chloride (ppm)	20	2.26	0.48	2.73	1.15
Dioxin (ng/Nm³)	0.1	0.000 ~ 0.009	0.000 ~ 0.003	0.000 ~ 0.002	0.000 ~ 0.000

Table 20 Gas Emission Report of Incineration Plants in Seoul, 2012
(Lee & Hur, 2017)

According to statistics, the landfilling was around 61.9% of total amount in 1997, but with successful waste incineration plants, it decreased up to 7.8 % in 2012. In 2012, total waste incineration is 771.110 tons and landfill is 262.435 tons.

Category	1997	2003	2006	2010	2012
Incineration Plant	Yangcheon Plant Nowon Plant	Yangcheon Plant Nowon Plant Gangnam Plant	Yangcheon Plant Nowon Plant Gangnam Plant Mapo Plant	Yangcheon Plant Nowon Plant Gangnam Plant Mapo Plant	Yangcheon Plant Nowon Plant Gangnam Plant Mapo Plant
Total Incineration	187.096 tons	162.795 tons	320.562 tons	740.287 tons	771.110 tons
Total Landfill	2.730.200 tons	1.866.096 tons	1.033.738 tons	527.790 tons	262.435 tons
Total Treatment: Incineration + Landfill	2.917.296 tons	2.028.891 tons	1.352.300 tons	1.268.077 tons	1.033.545 tons

Table 21 Landfill and Incineration Waste Treatment in Seoul

(Lee & Hur, 2017)

7 SUMMARY AND OUTLOOK

Waste is one of the major global issues in the world, while it presents threat to the environment and public health. Waste management is an essential utility service in the world. For a sustainable society and economy it is vital to ensure proper waste management along with healthy water, shelter food, energy transport and communication. Although the awareness of the issue is important among the political and public spectrum, the significance given to the waste management is relatively lower than all the other utility services. Not having a waste management system can result in having bad economic impact overall, and also be very costly for the community. Moreover, not paying enough attention to this issue can lead to air pollution, health problems, resource depletion, and economic difficulties are encountered.

A good waste management goes far beyond just solving environmental problems such as air pollution, public health etc. It opens also new doors to use of the waste as energy source. The first approach to minimizing the negative impacts of waste must be prevention of waste generation. Waste generation is influenced mostly by developed countries.

In this paper, we will see the relation between income level of the countries and their waste generation. The income level of the countries affect their buying and consumption habits which can also described as their waste generation. But it is also shown that while the developed countries generate too much waste, they are also managing the waste very well. Moreover, they do not use only some disposal methods like landfilling, composting, but they often convert the waste to create the energy. Therefore, it can be accepted that the negative impact on the environment and world resources by developed countries is less than developing countries and less developed countries.

The most used waste management methods in the developed countries are recycling, composting and incineration. That shows, in those countries the waste is actually no more only waste, it is more like a new energy source. Many materials can be recycled many times which reduces the raw material consumption. The composting provides to use the food waste in a good way and it is environment friendly waste management method. Incineration plays also very important role in waste management. First, it reduces the landfilling, and therefore, helps keeping the ground clean and safe.

Another very important issue is to use the waste as source. At the beginning, waste incineration may sound also not environmental friendly. Because the people can think, during the incineration, flue gases occur which is left into the air at the end of the process and it pollutes the air. But of course, the countries do not want to bring other problems while they solve waste problems. That is why many countries have their own regulations about waste incineration plants. For the European Countries that is described very detailed by European Commission. Although the European Countries can succeed to stay under the emission values of incineration plants which are given by European Commission, many of them try to keep their thermal waste incineration plant commission values much lower than asked. Many countries combine their thermal waste incineration systems with other technical systems in order to use waste as source. Because waste is often incinerate between 750° C and 1400 °C and also during the incineration process, waste heat is occurred. It is wise to use waste heat as fuel in our world where our natural energy resources are quickly consuming. Waste incineration plants are often connected with generators, district heating systems or district cooling systems. There the waste heat can be used in the steam turbine and generator. And it generates the electricity which can provide to supply electricity of households.

Another efficient using methods of the waste heat is to supply the district heating. The waste heat can cooled by heat exchangers and transports its heat to the district heating. That provides the using of heat in the households for heating in winter and as hot water all year long. With that method, total use of natural gas and electricity consumption is reduced. Moreover, during the summer time, when the household heating is not needed, the waste generation is not different than in winter. Therefore, the waste heat occurs also in summer time. Here by, another technique is implemented by many countries to use this waste heat efficient in summer time too. This waste heat is used with absorption chiller to produce cooling and that supplies the district cooling during summer time. Since many air condition gases are still not environment friendly, using a waste heat in summer for cooling is an environmental friendly solution. And that helps also again total consumption of natural resources. In the developing countries and in the other countries the situation is different from developed countries. According to many statistics which transferred also into this paper, in the developing and less developed countries waste to energy concept is very rarely implemented. In those countries, most preferred waste management method is landfilling. Therefore, it is not mistaken to say that developing countries and less developed countries are still far from efficient use of community waste. Moreover, the situation in the less developed countries is pretty poor. In these countries, the unmanaged waste threats public health and is in a major environmental problem. In the developing countries, the awareness of waste management and using the waste efficient is rapidly increasing. Although, their most used waste management method still landfilling, they try to increase the material recycling. Furthermore, many developing countries started to open thermal waste incineration plants. Thus, in those countries, the landfilling started to reduce and some of them started to generate electricity from this incineration process.

In order to deal with these problems we need to raise the awaraness of the importance of waste management in the developing countries, both as the effects of not implementing it. Since the developed countries already have good knowledge about this very important topic for us, they should find a way to influence the others. We are not alone on this planet and therefore, we should always bare in mind consequences that our current actions will live to the generations to come.

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LIST OF ABBREVIATIONS

BIR	Bureau of International Recycling
CD	Compact Disc
C&D	Construction and Demolition
CD&E	Construction, demolition and excavation
C&I	Commercial and Industrial
CO2	Carbon dioxide
Defra	The Department for Environment, Food and Rural Affairs
DVD	Digital versatile disc
EPA	Environment Protection Agency
ERC	Energy Recovery Council
E-Waste	Electronic waste
EU	European Union
GWh	Gigawatt hour
HM	Her Majesty's
Kg	Kilogram
km	Kilometer
KRW	South Korean won
L	Liter
mio.	million
MSW	Municipal solid waste
MWh	Megawatt hour
MW	Megawatt
PRC	Peoples Republic of China
t	Ton
TV	Television
UK	United Kingdom
UNU	United Nations University
USD	United States Dollar
U.S.	United States
U.S. EPA OLEM	United States Environment Protection Agency Office of Land and Emergency Management
USA	United States of America
UN	United Nations
VCR	Videocassette recorder

WtE	Waste-to-Energy

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