A BRIEF OVERVIEW TO SOLID WASTE TREATMENT & RECENT PRACTICE OF TURKEY

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Abstract

High rates of energy and goods consumption, combined with increasing population growth and high living standards, lead to the ever-increasing production of solid waste. The amount of solid waste generated today has reached a level that poses serious threats to the environment and the sustainable management of the country's economies. Although action plans are being prepared and implemented by countries, unions and institutions for the environmentally friendly and sustainable management of solid waste, it is seen that the threat still exists for the near future. Within the scope of solid waste, management of household waste is undoubtedly one of the most important issues today. The MSW EU average for 2021 reached 530 million tons. Similarly, a total of 104.8 million tons of waste was generated in Turkey in 2020, 32.3 million tons of which were domestic waste. Although, today, the most common method of solid waste control globally is storage in open or controlled landfills, it is seen that Thermal conversion, MTB or Liquefaction applications, which enable energy production especially within the cyclical economy and production model, are increasingly increasing.
The aim of this compilation study, in which global and country-based statistics are briefly presented, is to raise awareness of the increasing threat.

KATI ATIK ARITIMINA KISA BİR BAKIŞ VE TÜRKİYE'DEKİ GÜNCEL UYGULAMALAR

Anahtar Kelimeler
Katı atık
Sürdürülebilirlik
Atık arıtımı
Evsel katı atık

Öz

Yüksek orandaki enerji ve mal tüketimi, artan nüfus artışı ve yüksek yaşam standartları ile birleşince, katı atık üretiminin sürekli artmasına yol açmaktadır. Günümüzde üretilen katı atık miktarı, çevre ve ülke ekonomilerinin sürdürülebilir yönetimi açısından ciddi tehdit oluşturacak düzeye ulaşmıştır. Katı atıkların çevre dostu ve sürdürülebilir yönetimine yönelik ülkeler, birlikler ve kurumlar tarafından eylem planları hazırlanıp uygulanıyor olsa da yakın gelecek için tehdit hala devam etmektedir. Katı atık kapsamında evsel atıkların yönetimi şüphesiz günümüzün en önemli konularından biridir. 2021 yılı MSW AB ortalaması 530 milyon tona ulaşmıştır. Benzer şekilde Türkiye'de de 2020 yılında 32,3 milyon tonu evsel atık olmak üzere toplam 104,8 milyon ton atık üretilmiştir. Günümüzde katı atık kontrolünün dünya genelinde en yaygın yöntemi açık veya kontrollü depolama alanlarında depolama olmasına rağmen, özellikle döngüsel ekonomi ve üretim modeli kapsamında enerji üretimine olanak sağlayan Termal dönüşüm, MTB veya Sıvılaştırma uygulamalarının giderek arttığı görülmektedir. Küresel ve ülke bazlı istatistiklerin kısaca sunulduğu bu derleme çalışmasının amacı artan tehdit konusunda farkındalık yaratmaktır.

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1. Introduction

Solid waste (SW) generation together with industrial revolutions and increasing urbanization is not a new concept. However, in recent years, the increasing demand due to the increasing global population and high living standards has led to more and more problems regarding the harmful effects of these wastes on the environment and the complexity of their management. Unless it is effectively disposed of or recycled, threats to the environment and economy are increasing. According to statistical evaluations, the world population is estimated to increase to 8 billion in 2025 and 9.3 billion in 2050. The fact that a large part of

this population lives in urban areas gives preliminary information about the future burden of municipal solid waste, MSW (Kaza et al., 2018). Rising energy prices and increasing load on treatment facilities are also the factors to be taken into consideration. Another factor to consider is the increasing use of natural resources. Global resource use has nearly quadrupled in the last 50 years. Considering that natural resources are limited, it requires the use of production methods that will ensure efficient use within the scope of the "green economy" (less air pollution, food security, water scarcity).

In general terms, solid waste can be defined as a non-liquid, insoluble material. However, in this definition a wide range of materials such as domestic, sanitary, commercial, institutional, catering, biomedical and e-waste can be cited. Therefore from past to present, institutions, countries and unions have created and implemented many legislations, regulations, laws and action plans for definition, classification and prevention of the SW. An example of this is the Resource Conservation and Recovery Act (RCRA), passed in the United States in 1976. In this law, "solid waste" is defined as industrial (mining, metallurgy, agriculture, water treatment plants, etc.) or social activities (garbage). Although hazardous wastes are among the materials that meet the definition of solid waste, detailed regulations have been developed to determine which materials will be considered solid, industrial or hazardous waste due to their special emphasis (Criteria for the Definition of Solid Waste and Solid and Hazardous Waste Exclusions, 2023). Later, many classifications of waste were developed depending on their source (domestic/industrial), composition (organic/inorganic) and suitability for recycling or reuse. Broad classification of SW and developments on this subject can be found in above web site. Effective waste management is undoubtedly an important concept in reducing the amount of SW or its impact on the environment. Today, the areas where solid waste management (SWM) is under the most pressure are urban areas where high population density is concentrated and, as a result, garbage generation is observed. Although the role of SWM in achieving sustainable development has been clearly emphasized in many action plans, it continues to dominate as an important social and governance issue. In this context, strategic target models (sustainable development strategy goals, SDG) created by the United Nations (UN) such as access to clean water (SDG6), sustainable and inclusive urbanization (SDG11), control of climate change (SDG13), land protection (SDG15) and sustainable consumption and production (SDG11/SDG12) is important. These models can be given as supporting regulations that promote the reduction of consumption of limited resources and a circular urban economy (Abubakar et al., 2022). Current information on this subject can be found in the 2023 Global Sustainability report published by the UN available at https://sdgs.un.org/goals.

As it mentioned above, with increasing living standards (especially for developed and developing countries), the advancement of technology, combined with consumers' desire to have more personal devices and population growth around the world, not only leads to an increase in waste amount, but also increases the complexity of the collection and pre-classification of waste. This situation requires special attention, precautions and treatment methods for municipal solid waste, MSW (Chen et al., 2020). The increase in the average amount of MSW measured per capita in the EU over just three years (from 2018 to 2021) can be given as one of the indicators showing the importance of this issue. The MSW EU average for 2021 reached 530 million tons. The average amount produced by each of the approximately 448 million people living in the European Union has increased from 477 kg per year in 2015 to 1,180 kg per year in 2021 (Waste Management in the EU: Infographic with Facts and Figure, 2023). This clearly demonstrates the difficulty of MSW control. In the recent article published by Meng et al. 2020, “Compositional Bayesian Regression” analyzes were conducted to predict, past and future waste generation and its impacts on the environment. The authors reported that although the share of waste treated in landfills will decrease from 28% to 18% in 2050 and more recycling, composting and energy recovery attempts will expect to increase, the burdens on environment will keep their importance. It is suggested that current projections will not meet the UN goals for waste reduction. New regulations should be made in this regard. In this context, for the transition from the linear economic model to the circular model and the reuse of waste generated within this scope or the use of secondary metal in production cycles, the evaluation of the latest experiences gained in classification, pre-enrichment and enrichment processes (process development, clean production), including hydrometallurgy, which is generally used for the enrichment of primary ores, for the reuse of solid waste will have positive effects on both reducing the amount of waste, sustainable management of natural resources and less energy use.

1.1. Linear versus Circular Economy model

The linear economy model (Figure 1-a) is a model developed in the 30 years following World War II (Aggeri, 2021). However, during this period, possible limitations in the future projections of rapidly growing economies in accessing raw material resources, increasing raw material prices, increasing production, consumption and the large increases in waste amounts have created high pressure on decision makers, practitioners and the entire public. This situation led to the beginning of research on the development of new economic models since the 1970s. As seen in Figure 1-b,

the circular economy is based on the idea of continuously recycling and reusing raw materials after use, rather than recreating them from limited resources. Compared to linear production/economy, the circular economy model uses a more efficient route and green production rout that allows resources to be created over time in a way that ensures their long-term use.

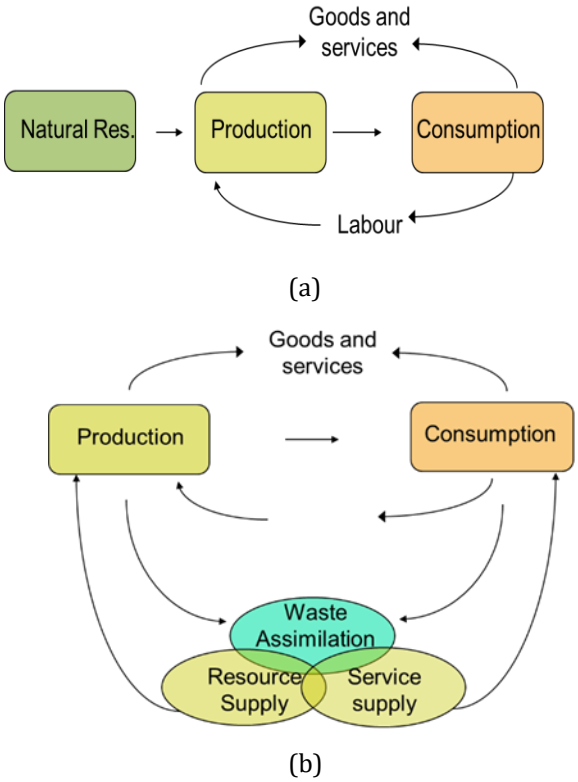


Figure 1. Schematic view of linear (a) and circular economy models (b),

The Strategy for the "Sustainable Use of Natural Resources" can be defined as "developing a framework that allows the sustainable use of input resources in an environmentally friendly manner" while maintaining the 3% economic growth rate targeted in the Lisbon strategy. The concept of 'Sustainability', which we use frequently today, dates back less than 30 years. It was first put forward in 1987 in the famous Brundtland Report (titled 'Our Common Future'), prepared by the UN with the contribution of many countries. In this report, sustainable development is defined as 'meeting the needs of today without compromising the ability of future generations to meet their own needs'.

As can be seen, although production/consumption waste has been on the agenda as a problem for many countries since 1798, it is important to underline the need to manage resources more efficiently for the first time on a global scale (Report of the World Commission on Environment and Development Our Common Future, United Nations, 1987).

When the linear economic model and the circular model are compared in terms of step plan, the linear model is in the form of "Take-make-dispose", while the circular model targets "Reduce-reuse-recycle". Both models can be considered "Eco-efficiency". However, while the linear model includes "short term from purchase to sales", the cyclical model covers the long term consisting of many sub-cycles. The benefits of circular economy can be found at Table1.

Table 1. Benefits of circular economy

Economic and social benefits	**Environmental benefits**
Resource/raw material savings	Reduction of greenhouse gas emissions,
Economic growth	Decrease in global climate temperature
Increase on employment	Ecosystem conservation
Increased consumer awareness	Protection of nature reserves and resources
Sustainable innovations	

In this context, the first EU-SDS was accepted and released by the European Council in 2001. The overall aim of this SDS was defined as supporting and promoting actions that enable the EU to continuously improve both current and existing quality of life. Benefiting from environmental and social advantages as well as the innovation potential of the economy to future generations through the effective management of resources. Later, the EU Directives 2006/12 and revised version of 2008/98 on waste management has generated practical actions on the matter of waste regulations in landfill disposal. This regulation strongly recommends that preventing landfill disposal should be the first priority of waste management. It has also been recommended that promoting reuse and recycling is the best ecological option to improve both the protection of natural resources, human health, the environment and energy recovery. Landfilling not only takes up more and more valuable land space, but also causes the release of carbon dioxide (CO_2) and methane (CH_4) into the atmosphere, the leaching of chemicals and pesticides into the soil, resulting in the contamination of water, soil and groundwater. With this regulation, the main long-term obligations expected from producers regarding waste management are to revise their SWM systems to reduce greenhouse gas (GHG) emissions and increase energy recovery. In this context, developing waste prevention programs through separate collection of bio-waste is another recommended practice.

A report released by European Technology Platform on Sustainable Mineral Resources (ETP SMR), Strategic Research Agenda-March 2009, was also support the above statement and advised that the "Thematic Strategy" on the sustainable use of natural resources should be based on three pillars to manage the implementing of the strategy in securing access to raw

materials (Fourth status report on European technology platforms harvesting the potential, 2009; Being wise with waste – The EU's approach to waste management, 2010). These are;

- Open access to raw materials in world markets,
- Establishing frameworks for sustainable raw material supply within the EU
- Increasing natural resource efficiency and encouraging recycling.

Commission Decision 2011/753/EU and Commission Decision (EU) 2019/1004. The targets have been updated as follows;

- By 2020, increase the use of reusable materials in MSW (such as paper, metal, plastic and glass) in production processes to at least 50% by weight,
- Preparing non-hazardous construction and demolition waste for reuse by 2020, and increasing the usage rate in different sectors to at least 70%,
- Increasing recycling rates for MSW to a minimum of 55%, 60% and 65% by weight by 2025, 2030 and 2035, respectively. (Sustainable Development Guidance on Municipal Waste Data Collection, 2016; Sustainable Development Guidance for the Compilation and Reporting of Data on Municipal Waste According to Commission Implementing Decisions, 2019)

1.2. Present Situation

Today, an estimated 11.2 billion tons of solid waste are collected globally in every year. The increasing volume and complexity of waste, and the relatively low recycling/re-use rates that still continue in developing and underdeveloped countries, which negatively affect ecosystems and human health and pose a serious threat for the future projections (Solid Waste Management, 2023).

The latest statistics data's published by the Organization for Economic Co-operation and Development, OECD for some countries is presented at Fig. 2. When the data's are evaluated, it is seen that countries with high income produce more solid waste (OECD Stats, 2023).

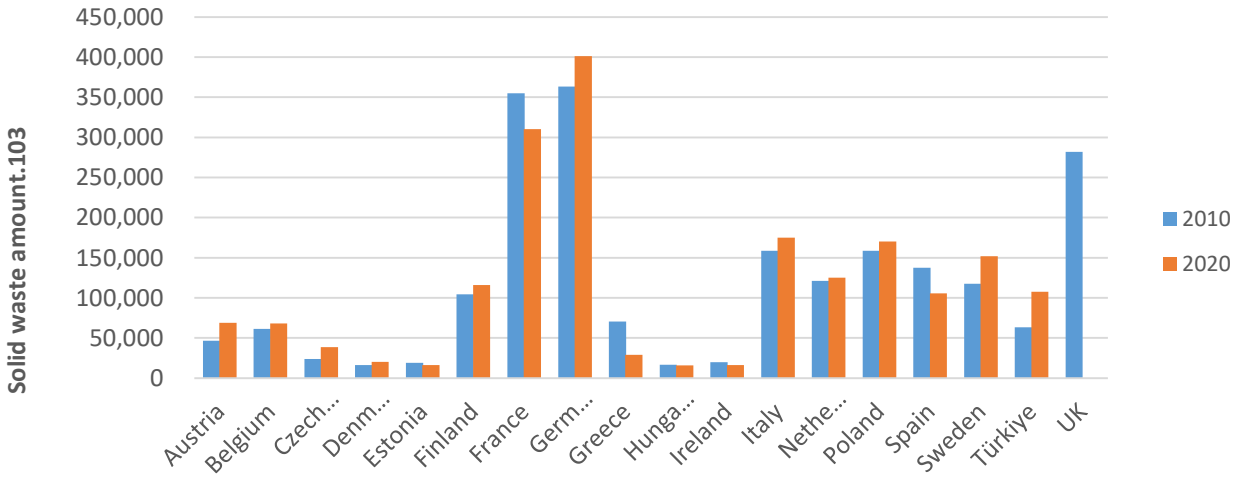
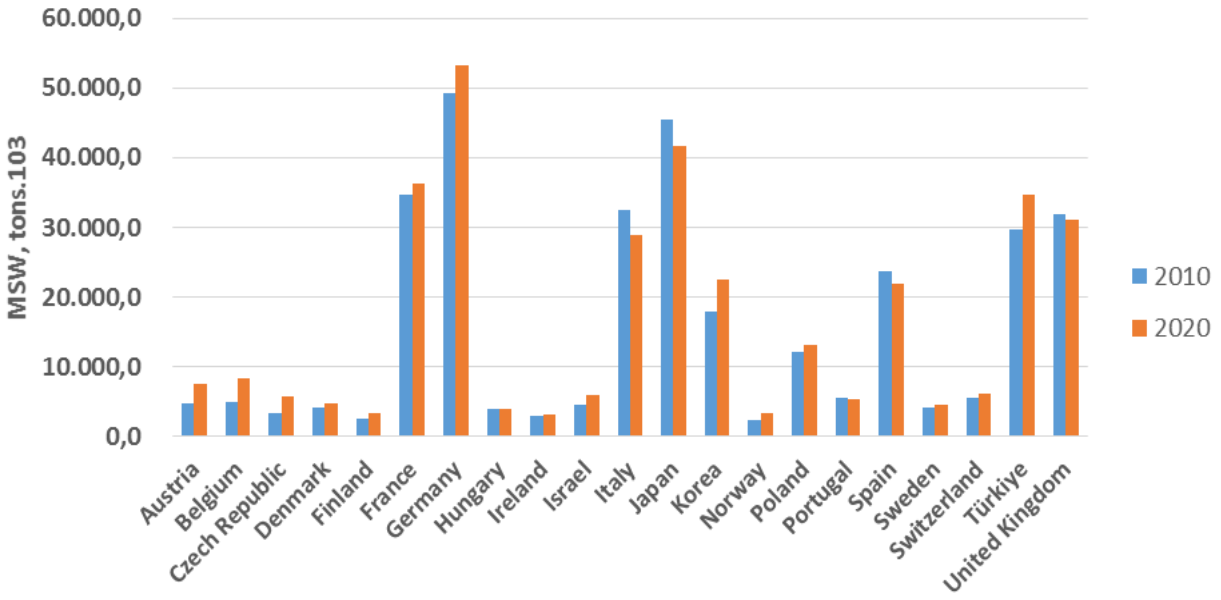
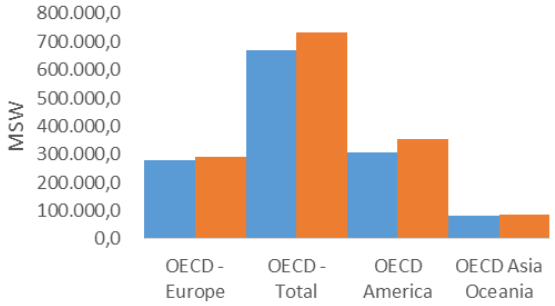


Figure 2. Total amount of SW's generated by selected countries by years 2010 and 2020 (OECD Stats, 2023)

The latest report released by the World Bank for MSW also exhibits similarity with OECD (Figure 3). It was reported that as globally, approximately 2.01 billion tons of MSW is produced annually, and only 67 % of it is managed safely, 33 % still creates environmental problems (kaza et al., 2018)



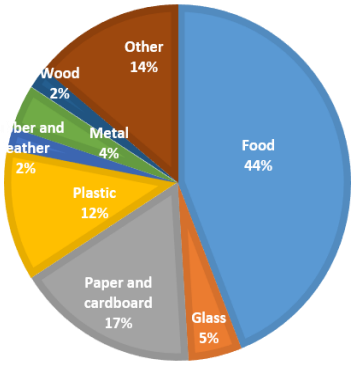
(a)



(b)

Figure 3. Total amount of MSW generated by countries (a) and unions (b) (Kaza et al., 2018).

These countries/unions try to balance this with the developments in the implementation of efficient collection and disposal techniques, however, considering that the problem is global, it necessitates that these countries should increase their responsibilities to include other regions. In this report it was also stated that the amount and the composition of waste varies according to income level and reflects various consumption patterns. Although they make up only 16% of the world's population, high-income countries produce approximately 34% of the world's waste, or 683 million tons. These countries produce relatively less organic waste (32% of total waste) and more dry waste that suitable for recycling, such as plastic, paper, cardboard, metal and glass (51% of total waste), while the wastes generated from middle or low-income countries are completely different, consisting of food (53%) and green waste (57%), respectively. Recyclable materials make up only 20 % of the waste stream (Fig.4-a).



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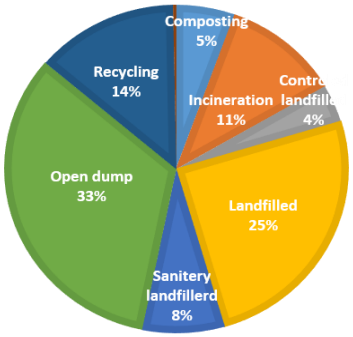


(b)

Figure 4. The shares of MSW contents (a) and the control methods (b) (Kaza et al., 2018).

As can be seen from Figure 4-b, the most preferred method for waste management worldwide is currently dumping or disposal in some form of landfill. Approximately 37% of waste is disposed of in some form of landfill, while 8% of this is stored in regular landfills with gas collection systems. Of the waste stored in open areas (about 31%), 19 % is recovered by recycling and composting, and 11 % is incinerated for final disposal. When these values are examined, the most striking point is that they once again clearly show the impact of income differences on the controlled disposal/stocking of waste. Applications that provide adequate waste disposal or treatment, such as controlled landfills, appear to be concentrated almost exclusively in high- and upper-middle-income countries. Another striking statistic is that 36% of landfill goes to recycling and composting, and 22 % goes to incineration, compared to 39 % for high-income countries. According to the 2021 statistical value, the proportion of MSW recycled or turned into compost in the EU has reached 49.6%. This corresponds to a 3.6 percent increase compared to 2017. Within the same framework, it is aimed to reduce the landfill rate to below 10 percent by 2035 and to increase the reuse/recycling rate to 60% by 2030.

On the other hand, within the scope of waste management, the EU also exports some of the waste collected within its own body. For 2021, EU's waste exports to non-EU countries reached 33 million tons. The majority of these exported waste mainly consists of ferrous and non-ferrous metal scrap as well as paper, plastic, textile and glass wastes. Approximately, 45% of these waste was sent to Turkey (14.7 million tons), followed by India (2.4 million tons), Egypt (1.9 million tons), Switzerland (1.7 million tons) and 1.5 million tons went to England. The share of ferrous metal waste (iron-steel) in total exports was 59% (19.5 million tons). Turkey was the main route in this export with 13.1 million tons (Waste management in the EU: infographic with facts and figures, 2023).

A brief assessment of EU waste management shows that on average a European produces around 5 tons of waste every year. Statistical data show that only 38% of this waste is recycled. As can be seen in Figure 5, composting practices for the recovery of precious metals from waste and energy production have improved greatly. However, material recycling for secondary metal use is still far from targets and below consumption rates.

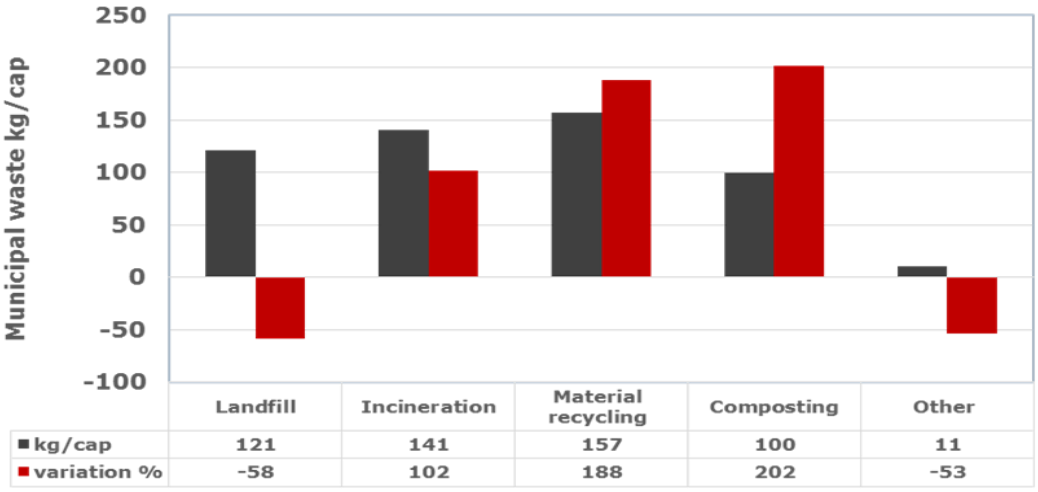


Figure 5. Evaluation practices of collected MSW waste (Waste management in the EU: infographic with facts and figures, 2023)

An overview of MSW waste globally, the importance of stockpiling techniques for controlling these wastes, and further information on landfill classifications can be found in the references that follow (Nanda and Berruti, 2021).

2. Featured applications that serve for effective MSW management / Outstanding practices in service of effective MSW management

An effective waste management system is a prominent issue in the transition to a circular economy, which was developed as an alternative to the linear economic model defined as make-use-dispose. Today, the most common method of solid waste control globally is storage in open or controlled landfills. Although open landfilling is the simplest and least costly method, the use of controlled waste sites, which eliminate undesirable harmful effects on human and environmental health and allow the recovery of reusable/recyclable materials in waste, is increasingly becoming a method adopted by many countries. Classification, shredding and compaction operations are the supporting activities for this type of storage. Some applications are also supported by units that include the collection of leachate and gases. Although these

processes are positive in terms of reuse, what remains after this separation process is of great importance in terms of allowing the generation of electricity and thermoelectric energy from non-fossil sources and the use of thermal energy in an environmentally friendly manner in the residue consisting largely of organic and inert mineral fraction (Panepinto and Zanetti, 2021). Alternative methods, depending on the characteristics of the waste material, are given in the table to achieve a general improvement.

Table 2. Methods used instead of or in combination with controlled storage

Main	Process	Process outcomes
Thermal conversion	• Gasification • Pyrolysis • Combustion	Lower quality SynG High quality SynG , oil Fuel gas Residues
MTB	• Mechanical treatment • Biological conversion Anaerobic digestion	RDF Bio-gas
Liquefaction	Indirect liquefaction Methanation	Oil Bio-alcohol

A Mechanical Biological Treatment (MTB) system is basically a treatment method based on composting or

anaerobic digestion. MTB is the most preferred application type by many countries as it allows the processing of commercial and industrial waste as well as mixed domestic waste (Mechanical Biological Treatment, 2023).

The general application flow chart of this method is given in the Figure 6.

In this applications, "Mechanical treatment" refers to a mechanical sorting step, usually automated, where materials suitable for recycling are separated. Conveyors, industrial magnets, eddy current separators, drums and shredders are the most used devices for this process. In addition, some systems may include enrichment elements that are separated according to material density differences (gravity separation) and physicochemical surface properties differences (flotation). Additionally, MBT systems can alternatively produce waste-derived fuel (RDF), which consists of organic wastes with high calorific value and can be used in many areas from cement kilns to thermal power plants. Additionally, composting, instead of incineration, can be considered an environmentally acceptable way to help sustainably manage large amounts of organic waste by converting it into useful products such as fertilizer or soil conditioner. The basic criteria, applications and kinetics of the composting process can be found in the review article published by Onwosi et al., 2017. In general "Biological Treatment" means one of the following:

• Anaerobic digestion
• Composting
• Bio-drying

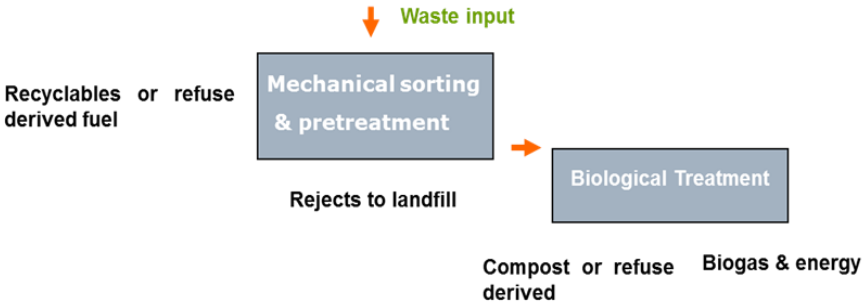


Figure 6. A schematic view of Mechanical biological treatment system

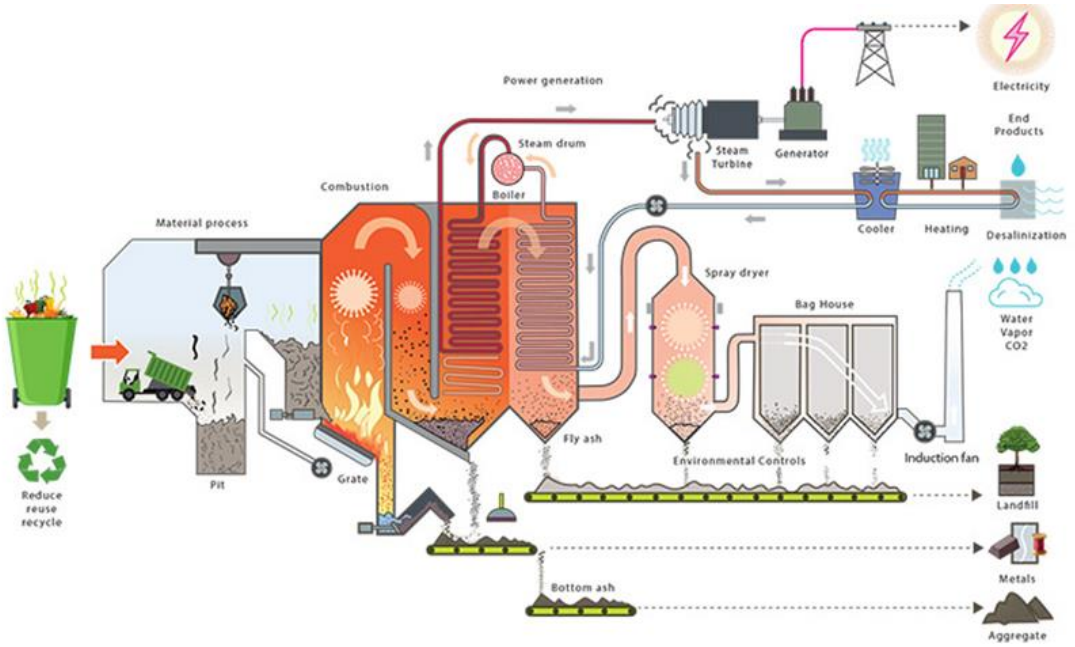


Figure 7. A typical flow-sheet of generating power from waste (waste to energy),

The possible products of this system can be given as follows;

- Biogas that can be use several systems
- Secondary metal, reusable paper, plastic, glass, etc. .
- An organic fertilizer and soil improver
- RDF
- Final safeable residual material

Waste-to-energy (WTE) plants are basically applications in which both domestic and industrial wastes are converted into heat and/or electrical energy. Although the most common application is incineration, pyrolysis and plasma gasification applications for generating electricity from MSW stand out as incineration techniques that have become widespread in recent years. In the incineration process, the main reaction is to burn the product obtained from the waste by contacting it with oxygen. The combustion process can be applied as stoichiometric combustion, excess air combustion and non-stoichiometric combustion.

The process is an exothermic reaction. While the heat generated during the combustion process allows the reaction to proceed, it can also be used to convert water into steam. This drives the turbine and electric generator (Figure 7).

Among thermal conversion processes, pyrolysis is one of the alternative processes that attract attention due to its various advantages such as flexibility in storage, transportation, turbines and different combustion devices. Basically, pyrolysis is similar to combustion, however in this way, decomposition is performed under inert condition in oxygen-deficient environment. The main output of the pyrolysis process is to produce usable high-value energy products instead of non-renewable fossil fuels. Basically, depending on the product properties to be obtained, the pyrolysis process is classified into two types: slow (only heat and biochar) and fast pyrolysis (biochar and bio-oils) (Zaman et al., 2017). However, in recent years, attempts to obtain better quality products by using some catalysts in the conversion process have been continuing with great momentum.

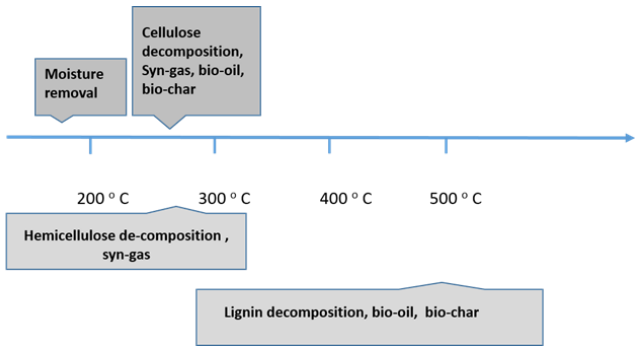


Figure 8. Decomposition reactions at different temperature

The plasma gasification process, in which the waste material is heated at a much higher temperature, differs from other WTE processes with this feature. This temperature is hot enough to break down the waste into its basic components.

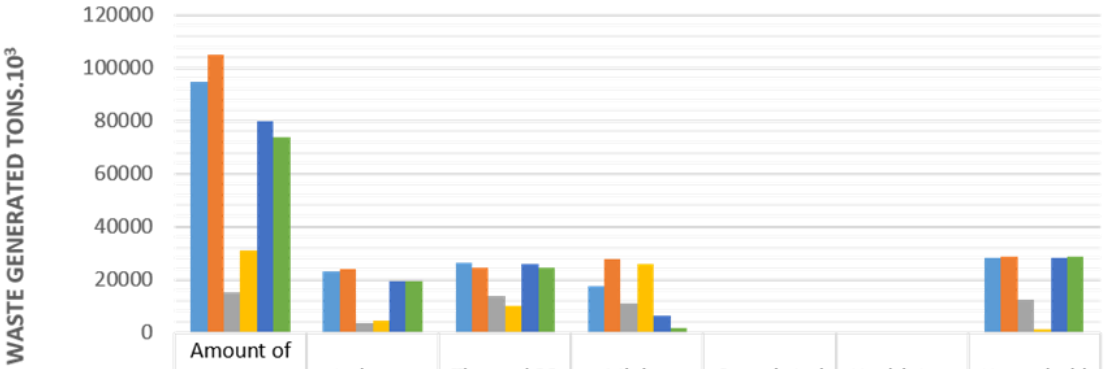
- Fuel gas - producer gas or syngas
- Slag

Plasma gasification applications are still developing as a relatively new technology. Their biggest advantage is ability to produce more kilowatt hours of electricity per ton of MSW fed to the facility than incinerators. (Malinauskaite et al., 2017).

3. Waste Treatment Practice in Turkey

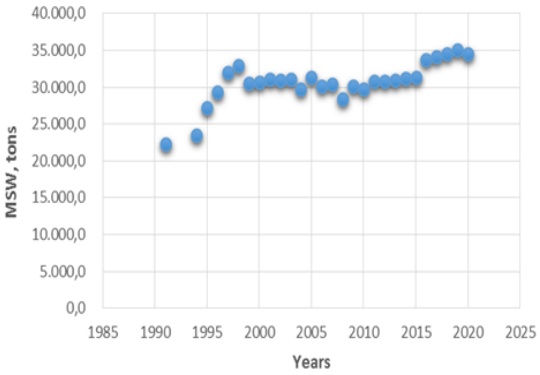
Turkey is one of the countries that has shown rapid economic growth in recent years. The annual GDP growth rate is 5% for 2021. However, this rapid growth also points to environmental challenges, intensive use of natural resources, waste production and an increase in energy demand. This situation clearly shows that in order for Turkey to continue its growth in the long term, it must switch to a cyclical growth model as part of the transition process (Technical Assistance for Assessment of Turkey's Potential on Transition to Circular Economy, 2022).

Environmental protection actions were first addressed in national development programs starting from the 5th Development Plan covering the years 1985-1989. In the 11th Development Plan (2019-2023), it is addressed in a broad framework with additional protocols that make environmental benefits and sustainable environmental management even more important in parallel with increasing economic and social benefits. Nevertheless, as mentioned above, the increasing amount of SW in Turkey along with the increase in the level of production and consumption makes urban areas increasingly dependent on and at the same time suffering from landfills. The current Turkish waste management infrastructure is insufficient to meet the country's needs, which necessitates the development of more efficient waste and resource management. In 2020, 226 million tons (Mt) of MSW was produced in the EU27. In 2020, 76% of municipal waste in the EU27 was recovered through composting/digestion (18%), recycling (31%) and incineration (energy recovery) (27%), while 24% was landfilled (23%). and is recycled through incineration, (Without energy recovery) (1%). Countries such as Germany and Denmark have particularly increased their recycling practices, reaching recovery rates of 99 percent. On the other hand, Turkey sent 87% of the 32 million tons of MSW produced in the same year to landfill. According to Turkish Statistical Institute data TURKSTAT (Waste Statistics 2020). A total of 104.8 million tons of waste was generated in Turkey in 2020, 30.9 million tons of which was hazardous. The distribution and change of the total amount of waste by sectors for 2018 and 2020 is presented at Figure 9. As can be seen, the total amount of waste increased by 10.5% compared to 2018. The high rate of increase in the amount of hazardous waste, reaching approximately 49 % compared to 2018, shows serious threats to human health and environment are not far away if the same trend will continue. The increasing amount of waste observed in the mining sector in the last two years is seen as another source of concern. When compared to other sectors, the mining sector stands out from other sectors and attracts attention with the increase in the total amount of waste by 63 % and approximately 26 M tons of it being included in the hazardous waste class. This situation clearly shows that existing or new techniques within the sustainable production concept for the mining sector should be taken into consideration for both production and reuse, and production plans should be revised.

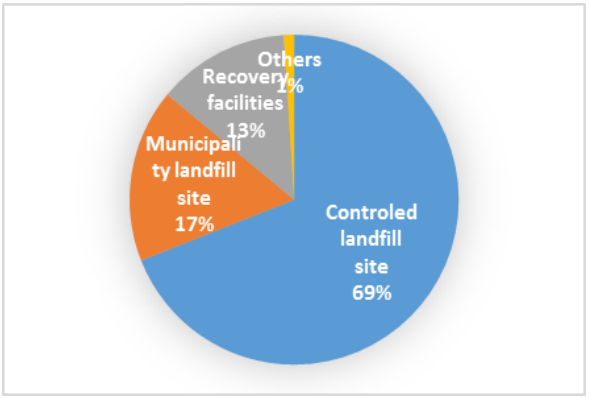


	Amount of waste generated	Industry	Thermal PP	Mining	Organic Ind	Health Inst	House hold
Total 2018	94870	22881	26127	17387	286	89	28099
Total 2020	104848	23867	24375	27581	279	109	28635
Hazardous 2018	15078	3677	13805	11176	111	86	12218
Hazardous 2020	30876	4597	10022	26044	116	106	1352
Non-Hzardous 2018	79792	19203	26113	6210	175	3	28085
Non-Hazardous 2020	73972	19270	24365	1537	152	3	28633

Figure 9. Distribution and change of the total amount of waste by sectors for 2018 and 2020 (Waste Statistics 2020)



(a)



(b)

Figure 10. Change and distribution and of the total amount of waste by sectors for 2018 and 2020 (Waste Statistics 2020)

For house hold wastes, the change is relatively stable (Fig 10-a). In 2020, a total of 32.3 million tons of municipal waste was collected by 1,387 municipalities. Apart from this, approximately 0.4% was disposed of through other methods such as open burning, burial and dumping into rivers/land. The MSW collection area characteristics and recovery shares produced wastes are given in the Figure 9-b.

The waste disposal and recovery facilities and the amounts processed are given in Table 3. When the table is examined, it is seen that although it is positive that the amount of MWS processed has reached 127400 tons in proportion to the increase in the facility, a large part of the collected waste is still stocked in controlled waste areas.

The change in waste amounts according to production sectors for 2018 and 2020, given in Table 4, indicated that larger shares in the distribution consist of basic and fabricated metal products, chemicals, and chemical products, basic pharmaceuticals, rubber and plastic and electronic waste, respectively. It is clear that increasing the precautions to reduce the amount of waste in these sectors in practical applications will make significant contributions to reducing the total amount of industrial waste

Table 3. Waste disposal and recovery facilities in Turkey

	2018	**2020**	**Total amount of waste treated tons**
Waste disposal and recovery facilities	2223	2752	
Controlled landfill site	159	174	77762
Incineration plant	7	10	570
			Total 78333
Waste recovery facilities	2057	2568	
Composting plant	8	9	
Co-incineration plant	40	50	
Other recovery facilities	2009	2509	
			49067

The amounts of manufacturing industry waste by treatment methods, for 2018 and 2020 (tons) is presented at Table 5. Compared to 2018, the amount of waste generated increased by approximately 5% in 2020.

Table 4. Generated waste according the sectors

	2018 tons	**2020 tons**
Manufacturing Indy	22 881 144	23 867 886
Food beverage and tobacco	1 599 234	1 192 000
Textiles	614739	642514
Wood	455474	190157
Pulp and paper	806156	1 112 229
Manufacture of coke and refined petroleum product	49450	51582
Chemicals, chemical products, basic pharmaceutical, rubber and plastic	4 592 012	5 565 587
Non-metallic products	1 317 365	1 205 416
Basic and fabricated metal products	11 689 737	12 075 949
Electronics	1 607 510	1 588 996
Furniture and insulation	149468	243815

Approximately 57% of the waste produced is sent to licensed treatment facilities while 24% of total waste is sent to controlled land sites. When the composition of waste stored in controlled waste sites is examined, it is seen that it reach to 3 474 185 tons, up from 2 436 308 tons stated for 2018. This increase, which corresponds to approximately 42%, is remarkable when compared to the total increase.

3.1. Hazardous Wastes:

There is no doubt that the disposal of hazardous wastes without harming nature and human health is the most fundamental issue of waste management. The Basel Convention on "Control of Transboundary Movements and Disposal of Hazardous Wastes", which was adopted on 22 March 1989 and officially entered into force on 5 May 1992, is undoubtedly an important milestone for the sustainable management of HW's without harming the environment and human health (Basel Convention, 1992). In Turkey, the Basel Convention was accepted in 1989 and came into force in 1992. The main purpose of this contract is; to eliminate the dangers that may arise from the cross-border transportation, disposal and recycling of hazardous and other wastes. The transportation of waste from industrialized countries to developing countries is the most important element that the Convention focuses on (Waste Management in Turkey, 2007). In order to maintain compliance with both the requirements of the Basel Convention and the EU acquis and to establish international standards, important steps have been taken in this regard by publishing/modifying many acquis and implementation plans, with the work carried out with the contributions of relevant organizations. However, the disposal of HW often requires the use of special technologies. The high costs of these technologies, in some cases, this results in being stockpiled in landfills along with other types of waste, despite legal sanctions. Following establishment of legal framework affords for implementation, various plants have been built and introduced to meet the demand for processing capacity.

Currently, there are 5 main HW treatment facility outlets in Turkey for the disposal of both own waste and off-site waste; these:

- İZAYDAŞ
- PETKİM
- TUPRAS
- ERDEMİR
- İSKEN

In these plants, iZAYDAS is the biggest HW disposal plant in Turkey with a capacity of 65,000 tons of controlled landfills and 35,000 tons of incineration. Other plants, such as PETKIM, have a capacity of 7,750 tons/year, TUPRAS (17,500 tons /year respectively. ERDEMIR and ISKEN have land-filling capacity of 6,084 tons/year, and 11,000 tons /year (Akkoyunlu et.al. 2017)

Table 5. Amounts of manufacturing industry waste by treatment methods, 2018, 2020 (tons)

	2018			**2020**		
	Total	**Hazardous**	**Non-Hazardous**	**Total**	**Hazardous**	**Non-Hazardous**
Amount of waste generated	22 881 164	3 667 320	10 203 824	23 867 866	4 597 274	19 270 593
Amount of waste by treatment methods						
Recovery within facility	2 100 077	776	2 099 300	1 677 695	12 324	1 665 371
Solid sent to licensed treatment facility	13 109 284	1 187 410	11 921 873	13 438 779	1 055 755	12 383 025
Used as filling material	93 038	-	93 038	97 53-55	-	97 555
Co-incinerated/ incinerated	465 615	45 010	420 605	400 955	47 481	353 474
Collected by municipality/organized industrial zones	1 023 502	3 613	1 019 888	763 534	1 073	662 481
Sent to controlled land sites	4 794 790	2 436 308	2 358 482	5 776 936	3 474 185	2 302 751
Stored within the establishment	1 257 265	4 202	1 253 063	1 693 288	6 456	1 686 831
Disposed with other methods	37 575	-	37 575	19 124	-	19 124

3.2. Used Batteries and Accumulators:

Although there has been a rapid increase in Turkey in recent years, battery usage per capita in 2018 is below the European average (110 g/year) (Yeşiltepe and Sesen, 2019). Legislation on "Battery Use and Collection" is controlled within the scope of the Regulation on the Control and Control of Waste Batteries (Regulation, 2019). According to 2018 statistical data, battery usage in Turkey is 110 grams/person per year (Eurostat 2018, Directive, 2019). However, it is clear that the consumption rate will increase, especially in recent years, with the increase in the use of other technological equipment, especially in the electric automotive industry, and the contribution of new initiatives initiated to meet the battery demand from domestic sources. This situation indicates the need for a more stringent and effective recycling action plan. Currently, the legislation on battery use and collection is regulated by the Regulation on the Control of Waste Batteries and Accumulators (Regulation, 2019).

On the other hand, the annual amount of accumulators put on the market in Turkey is 74,000 tons. The amount of waste batteries collected is approximately 67% of the batteries put on the market.

3.3 End of Life Tyres (ELT)

One of the sectors that has shown rapid production and consumption growth in recent years is the rubber industry. These materials, whose natural disposal is quite limited due to their structural characteristics after use, are an important environmental problem for both municipalities and governments. Used tires, which are approximately 14,106 tons/year, constitute approximately 2% of the world's total solid waste production. In 2018, 27,269 tons of end-of-life tires were collected in Turkey.

ELT management in Turkey is protected by two main legal regulations. Environmental Law and Regulation on the Control of End-of-Life Tires (RCELT). These arrangements are summarized in Figure 11. In this context, relevant facilities are required to obtain a recycling license in accordance with the provisions of the regulation.

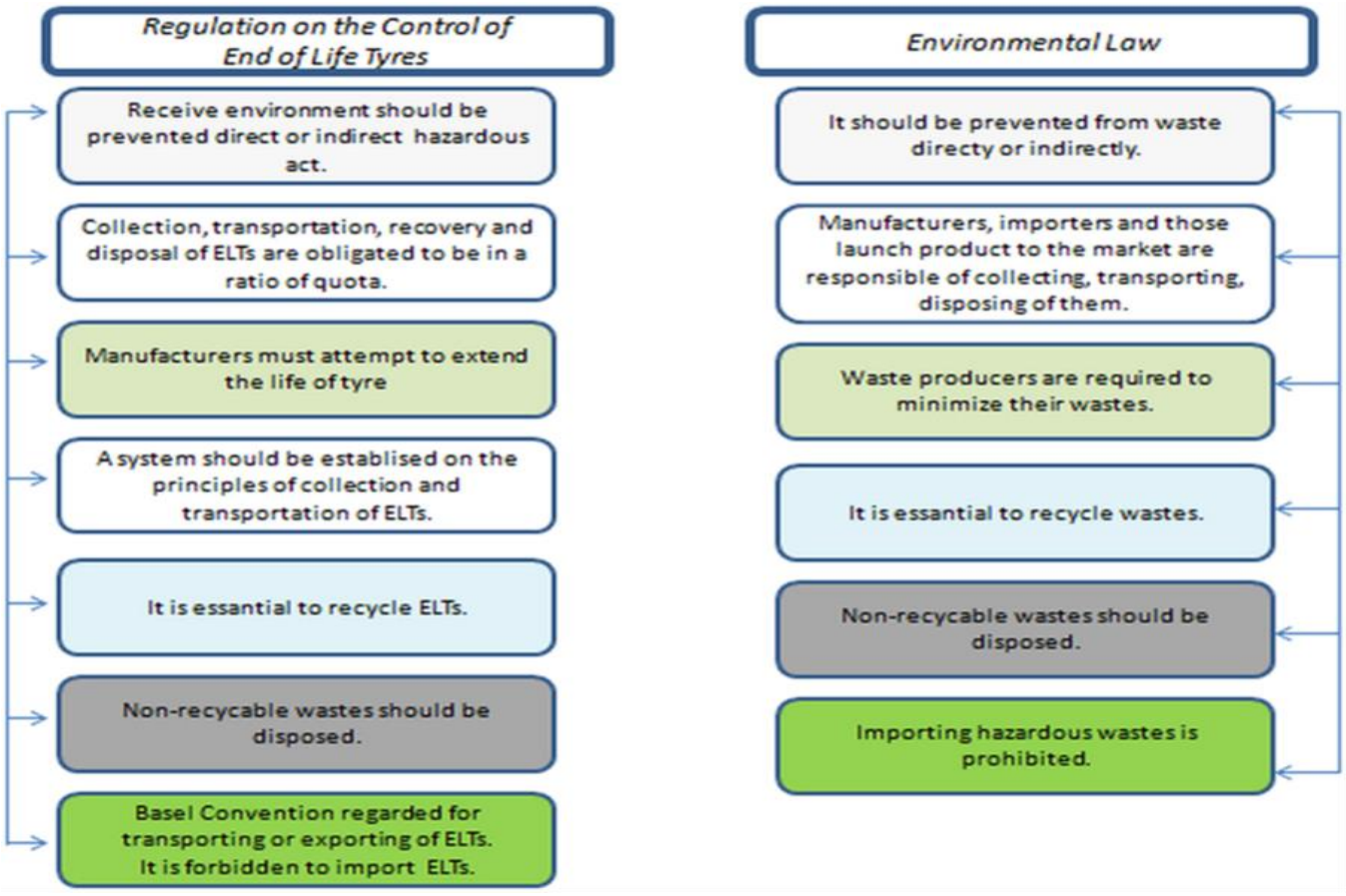


Figure 10. End-of-Life Tires regulations (Karaagac et al., 2017)

3.4. Packaging / Plastic Waste

As discussed before, changing consumption habits, population growth, rising living standards cause changes in packaged product sales and, as a reflection of this, changes in the amount of plastic materials in the solid waste composition. For example, in the last 50 years, the role of plastic in the EU economy has greatly increased. 58 million tons of plastic are produced every year in European countries, and 40% of this consists of packaging. Therefore, under the European Green Deal and the new Circular Economy Action Plan, a new European Plastics Strategy for the revision of Directive 94/62/EC on Packaging and Packaging Waste was launched in 2018 for products used, produced and recycled in the EU. This regulation mainly aims to strengthen the basic requirements for packaging to ensure the reuse and recycling of packaging, the receipt of recycled content and to improve its applicability (…).Similar to EU countries, the solid waste composition has been changing in Turkey in conjunction with the changing consumption patterns. In general, Packaging waste constitutes 30% of the waste by weight and 50% by volume. The principles regarding the collection, transportation, separation and recycling of packaging waste within a specific management system are determined by the "Packaging Waste Control Regulation" prepared by the Ministry of Environment and Urbanization. This Regulation was published in the Official Gazette No. 30283 dated 2017 and entered into force on 1/1/2018.

Material Based Recycling Rate of Turkey was 54 % in 2019. The distribution of this ratio for packaging waste is given in the Table. (6 th. State of Environment Report for Republic of Turkey, 2020, available at https://webdosya.csb.gov.tr/db/ced/icerikler/tc-dr_2020_-ng-l-zce-20210430143751.pdf)

Table 6. Packaging waste recycling rates

Years	Glass %	Plastic %	Metal %	Paper / Cardboard %	Wood %
2018	54	54	54	54	11
2019	54	54	54	54	13

4. Conclusions

In fact, sustainable development is not a new concept and has been discussed since the late nineteenth century. The driving force behind these discussions/regulations is undoubtedly the pressure on managers to manage the increasing solid waste in an environmentally friendly manner due to limited natural resources, increasing production costs with increasing energy costs, and increasing urban population densities. When the approaches adopted in this regard are examined, it is seen that the solutions mainly focus on changes in production processes or new techniques, efficient production using low cost and less raw materials, new material production and recycling. In fact, it is a huge field that brings together the concepts of sustainable development/economy, environmental management, material management, green production, renewable and clean energy technologies, and water and air management under one roof. In this context, it seems inevitable that producers and managers, as well as governments, should increase consumer responsibility through informative publications regarding solid waste management, the amount of which is expected to increase gradually according to future projections.

Implementation efforts continue to increase in Turkey, thanks to the laws, directives and action plans blended with existing EU waste management legislation and the national Zero Waste Program. According to the National Waste Management Action Plan, Turkey aims to store a maximum of 65% of municipal waste and recycle 35%.

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