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Research Article

Waste management practices towards low carbon cities

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ABSTRACT

Urbanization has increased rapidly in the world. It uses an intensive resource consumption for urbanization and the expanding economy. The consequences of unconscious consumption of these resources, which constitute the thermodynamic system of cities, are solid wastes, wastewater and air pollution. As a result of improper management of these wastes in cities, it increases the effect of climate change by producing greenhouse gas emissions directly or indirectly. The most innovative approach in controlling these effects is "low-carbon city" studies. Turkey should give priority to low-carbon city applications that comply with the European Green Deal and transition to a green economy. In this context, with this study, applications and solutions were examined together to become a low-carbon city in Turkey. Considering policies and commitments, the roadmap is drawn in this way, the study will be a reference for many cities.

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INTRODUCTION

It has become a living area with intense immigration and a crowded population with the increase in the need for manpower of the industry and the service sector [1]. Cities have the capacity to support their population. When this capacity is exceeded, various problems occur for the city and its inhabitants. The growth of cities is giving way to inefficient layouts that consume large amounts of energy and water, technologies and significant amounts of waste problems [2]. In cities that do not have waste management, many problems arise such as leaving the wastes in various areas with wild storage, decreasing the air quality due to the fossil fuels used in the city, and climate change due to the increase in greenhouse gases [3]. In order to find solutions to these problems, new urban concepts emerged which have been on the agenda in recent years and on which studies have increased [4].

a. Sustainable cities,

b. Ecological cities,

c. Low carbon cities,

d. Livable cities,

e. Smart cities,

f. Digital cities.

Although these terms and their meanings are different, their goals are the same. Each approach aims to find solutions to the city's problems.

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As centers of population, industry, transport and infrastructure, cities are responsible for 70% of global CO_2 emissions. With the gradual acceleration of urbanization and industrialization processes, a series of environmental regulations are needed to reduce greenhouse gas emissions in world cities [5]. The biggest cause of global warming has been identified as the increase in carbon dioxide emissions. This situation has drawn attention to carbon emissions and a low-carbon city strategy has been developed as an effective reduction method [6]. Low carbon city; It is a concept that will reduce the carbon footprint by providing the increasing energy need in cities from renewable energy sources and help increase the quality of life with high efficiency [4]. Low carbon city; it is a concept that focuses on the amount of carbon in order to prevent climate change, reduce greenhouse gas emissions and continue the carbon cycle in the atmosphere. This focal point is included in the solutions of the city's problems, and the contribution of the solutions to the carbon cycle is important. The concept of a low-carbon city differs from other definitions in this respect.

The Latest Status of Waste Management

According to the IPCC 1.5 degree report, they stated that sectors such as energy, transportation, food and waste should switch to low carbon practices in order to take the right steps in the fight against climate change. With the increase in the urban population, the growth in every area causes an increase in the amount of waste produced [7]. Integrated waste management has an important place in the formation of low-carbon cities. This has economic, environmental and social consequences. Inaccuracies and deficiencies in the management of waste negatively affect the environment and constitute 3% of the total greenhouse gas emissions in the atmosphere [8]. Waste management; it is to minimize the effect of the elimination of wastes generated in the system on the environment and economy [9]. The waste management hierarchy has been accepted as in Figure 1 as the opposite of the waste hierarchy that was given and taught before [10]. According to this figure; the importance of waste management hierarchy to prevent waste; by devoting the largest part of the pyramid to waste prevention, it supports savings and emphasizes the minimization of the materials used. In order for this pyramid to function well, first of all, the materials considered as waste should be reduced, and then the benefits that can be obtained from the waste such as reuse, recycling and recovery of the waste ones should be maximized. In the end, it is desired to minimize the amount of waste that will come to the last item by including the disposal item [11]. While in the previous strategy, most of the waste was sent to landfills as disposal, in the new strategy, minimal disposal is accepted in accordance with the zero-waste philosophy.

Turkey now accepts this newly created waste hierarchy and puts the necessary legal regulations into practice. The legislation required for waste management in Turkey is shown in Figure 2.

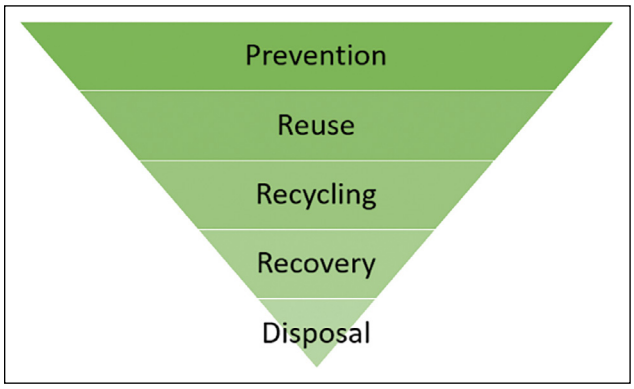

Figure 1. Waste management hierarchy [10].

The Waste Management Regulation published on 02.04.2015 regulates waste management. Among the purposes of this regulation; ensuring the management of wastes from generation to disposal without harming the environment and human health, reducing waste generation, reducing the use of natural resources and ensuring waste management through ways such as reuse, recycling and recovery of wastes [12].

"National Waste Management and Action Plan" was prepared in Turkey in 2015 and this plan, the current state of Turkey's current waste management and the elements that need to be improved and developed by determining the current situation were determined, and investments in waste management and 2023 targets were set [13].

The Zero Waste Regulation, which started to work in our country in 2017, entered into force in 2019. The implementation of the Zero Waste Principle, which includes protecting our resources, preventing waste, reducing the amount of waste, collecting waste separately at the source and recycling waste, is very important in terms of leaving a clean and livable world to future generations [14].

Although the regulations issued for Turkey, which tends to bury more than 65% of its wastes under the ground, show the efficient management of waste, there is a long way to go in waste management practices. Particularly, the problems experienced by municipalities in reaching the households, the increase in street collectors over time and the inefficient development of public awareness on this issue make the management of waste difficult. The Turkish economy, similar to other developing and developed economies, operates on a linear buy-use-dispose resource model that generates significant amounts of waste. It is inevitable that over the years, Turkey's economic and population growth, the increase in resource and energy use, and the waste generation are pending a solution. Turkey is facing the risk of raw material shortages to meet the production and consumption demand, together with the difficulties in waste disposal with increasing urbanization. Similar trends apply on a global scale.

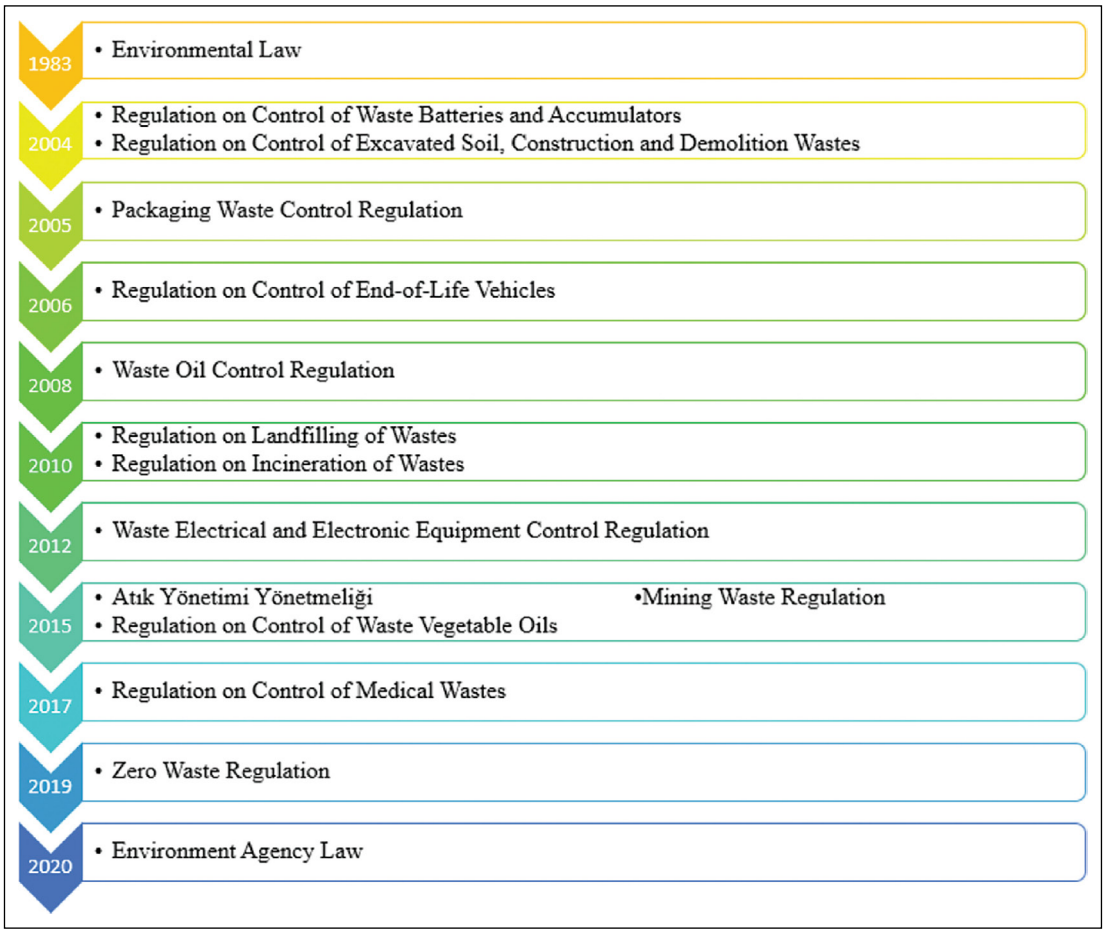

Figure 2. Waste legislation.

Within the scope of the Eleventh Development Plan (2019–2023), waste management under the title of "Livable Cities, Sustainable Environment", provided detailed information. In addition, statements are included "Public awareness will be raised in the recycling of solid wastes. Zero Waste Project practices will be expanded. Technical standards for the recovered secondary product will be developed, incentive and guidance legislation will be improved. A separate collection system of wastes will be expanded." In addition, it was stated in the Eleventh Development Plan that the domestic solid waste recycling and disposal facility projects and the transfer station projects of the local governments with insufficient financial power would be financially supported. In this context, 2023 targets are also included in the plan [15].

Greenhouse gas emissions and climate change are also mentioned in the Eleventh Development Plan. It has been stated that studies will be carried out within the framework of the Intended National Contribution for the emission control of the sectors that cause greenhouse gas emissions. It has been stated that in order to adapt to climate change, regional and city-based needs and solutions will be determined according to these needs, and Climate Change Action Plans will be prepared for this purpose [15].

Inadequate waste management; It supports global warming by producing methane gas, and the leachate flowing from wild storage areas causes pollution of underground and surface waters and endanger human health [16]. Waste production globally has been determined to have increased from 635 million tons in 1965 to 1999 million tons in 2015 and is estimated using modeling techniques to reach 3539 million tons by 2050 [17]. In the studies carried out, 1385 million tons of CO_2 emission value obtained from the solid waste collected in the city in 2018 alone constitutes 3.7% of the global CO_2 emissions of that year [17].

In Turkey, the total greenhouse gas emissions from the waste sector in 2016 are 16.2 million tons of CO_2 equivalent and constitute 3.3% of the total greenhouse gas emissions. There is an increase of 45.9% in greenhouse gas emissions from waste compared to 1990. As seen in Figure 3, the main source of greenhouse gas emissions from the waste sector is solid waste disposal and wastewater discharge and treatment. In 2016, 72.2% of the greenhouse gas emissions from waste were caused by solid waste disposal and 27.7% by wastewater discharge and treatment [18].

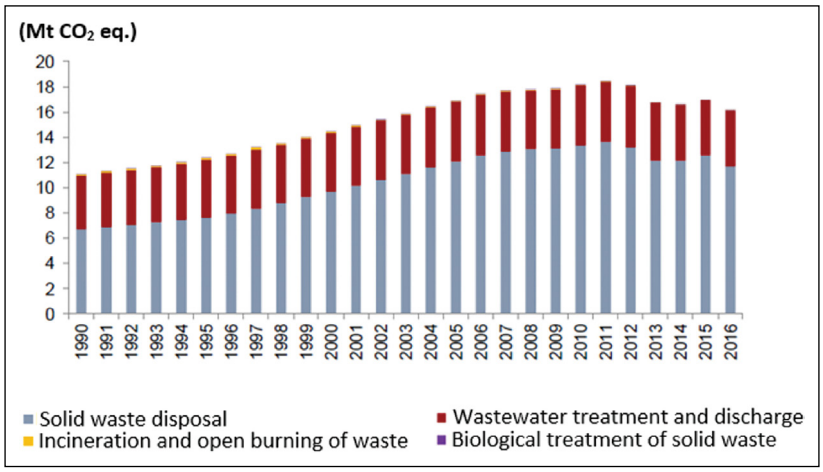

Figure 3. Greenhouse gas emissions from the waste sector, 1990–2016 [18].

Depending on the population growth, waste disposal in regular waste storage and disposal sites is also increasing. As seen in Figure 4, approximately 28.5 million tons of waste was dumped in the landfill in 2015 and 68% of this amount was stored in managed landfills [18].

As the amount of waste sent to the landfills increases, the amount of waste stored in the wild decreases and the greenhouse gas emission rate from the landfills decreases [18]. Solid waste has many negative environmental effects, including increasing greenhouse gas emissions and nitrogen pollution [17]. The rapid increase in the amount of waste and its impact on climate change show that waste management will become more important in the future [19]. Intelligent waste management by efficient application and energy saving; It prevents the formation of gases such as carbon dioxide in the air that can cause air pollution and global warming, making the city and nature more livable and cleaner [4].

Mitigation and Adaptation in Climate Change and Waste Management

In order to contribute to global efforts in the fight against climate change in Turkey, changes and transformations are observed in legal, institutional and policy frameworks. This transformation begins with the establishment of the Climate Change Coordination Board (CCCB) in 2001, with the responsibility of coordinating Turkey's efforts on climate change. In 2013, its name was changed to the Climate Change and Air Management Coordination Board (CCAMCB), and its scope and responsibilities were expanded. The Board is responsible for the coordination of the activities under the United Nations Framework Convention on Climate Change (UNFCCC) and the protocols subject to these agreements and the relevant national policy and legislation [18]. Turkey created the National Climate Change Strategy in 2010 and the National Climate Change Action Plan in 2011. The Regulation on the Monitoring of Greenhouse Gas Emissions was published in the Official Gazette dated 17 May 2014 and numbered 29003 and entered into force. Apart from these, it has been a side too and contributed to international agreements and protocols. The signed or signed agreements/protocols are listed in Table 1 chronologically.

Studies to be carried out to reduce greenhouse gas emissions from waste in Turkey are included in the Intended Nationally Determined Contribution document submitted in 2015 for the Paris Climate Agreement. This document is a document put forward by our becoming a party to the Paris Climate Agreement. In addition, the practices made for the reduction committed by Turkey on behalf of the waste sector are given below. In order for these commitments to be fulfilled and everything not to remain on the writing, it is necessary to carry out various applications. It is clearly seen that Turkey has determined strategies beyond the tasks it has undertaken with it becoming a party to the agreement.

Another important development for Turkey is that it ceased to be a party to the Paris Climate Agreement on 5 October 2021 and was ratified with parliamentary approval, which was signed by many countries in 2015. In this way, while paving the way for green development, the number of tasks to be done has increased while the way for additional budgets has been opened due to the implementation and implementation of many climate-compatible studies. These increases will enable the opening of new business lines.

With the approval of the Paris Climate Agreement, it is important that the public correctly understands this agreement. Therefore, in the fight against climate change, the adaptation of people's lifestyles to the climate comes first. For this, municipalities take the first place in adapting living spaces to climate. Efficient collection and recycling of waste have an important role in reducing a city's

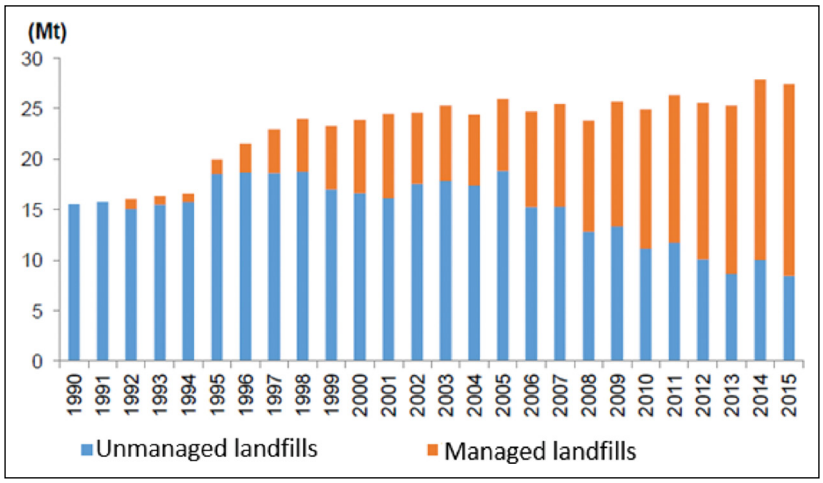

Figure 4. Annual waste disposal at solid waste disposal sites, 1990–2015 [18].

Table 1. Agreements/protocols related to the reduction of greenhouse gas emissions in Turkey [20]

Agreement/Protocol	Acceptance - Effective date	Turkey's Situation
Montreal Protocol on Substances that Deplete the Ozone Layer	Accepted D.: 1987 Effective D.: 1 January 2019	It became a party on 19 December 1991 and accepted all the amendments introduced by the Protocol.
United Nations Framework Convention on Climate Change (UNFCCC)	Accepted D.: 3-14 June 1992 Effective D.: 21 Mart 1994	Joined on 24 May 2004. Turkey is the only country within the scope of Annex-1 that does not have a transition economy and whose "special conditions" were accepted by the resolutions of the Conference of the Parties.
Kyoto Protocol	Accepted D.: 1997 Effective D.: 16 February 2005	It became a party on 26 August 2009. Turkey, which was not a party to the UNFCCC when the Protocol was adopted, was not included in the Annex-B list of the Protocol. Therefore, there is no quantified emission limitation/reduction commitment.
Paris Climate Agreement	Accepted D.: 5 October 2016 Effective D.: 4 November 2016	It was signed on April 22, 2016, but it was not a party. The National Intended Statement of Contribution was submitted on 30 September 2015. According to Turkey's national contribution statement, a reduction of 18% to 21% is foreseen in 2030 compared to the increase in greenhouse gas emissions compared to the reference scenario.
Paris Climate Agreement	Approval D.: 5 October 2021	It was unanimously approved by the parliament. A zero emission target has been set for 2053.

carbon footprint and CO_2 emissions. For this reason, it is necessary for municipalities to carry out many studies and to prepare training programs in order to increase public awareness. It is necessary to carry out intensive practices in order to convey environmental awareness within social activities, to create public service announcements about recycling and to ensure that everything is not at the educational level. Giving priority to encouraging ways in practices has an important place in ensuring public participation.

The items regarding the waste sector of the Intended Nationally Determined Contribution, which Turkey has committed with our becoming a party to the Paris Climate Agreement, are examined in detail below.

- Sending solid wastes to landfills

There were 15 landfills in Turkey until 2003, and there were 89 facilities in 2019. According to the data of the Ministry of Environment and Urbanization for 2019, the ratio of the population served by landfill facilities to the total municipal population is 82%. This situation has been determined by increasing the proportion of the population provided with waste disposal service to 100% by 2023 as a near target, and by spreading the zero-waste management system as a distant target by 2050. In this way, the landfills will be completed gradually, wild landfills will be prevented and projects will be put into effect upon sending less waste [21].

- Reuse, recycling and other processes to obtain secondary raw materials, to be used as an energy source or to be disposed of the waste

The zero-waste management system, which started with the separation of wastes at the source, has made Waste Derived Fuel (WDF) facilities widespread in the waste industry. Waste-derived fuel (WDF) is an alternative solid fuel type that takes the remaining non-recyclable materials as raw materials after the recyclable materials (plastic, glass, metal, etc.) of domestic or industrial solid wastes are separated. End-of-life vehicle tires, wastepaper, waste oils, wood waste, treatment sludge, plastics are WDF raw materials. When WDF and coal are compared, WDF; It is advantageous because it is cleaner, more energy efficient, environmentally friendly and less dusty [22].

- Reducing the amount of biodegradable waste to be stored in 2015 to 75% by weight of the total amount of biodegradable waste produced in 2005, 50% in 2018 and 35% in 2025. Accordingly, the establishment of pre-treatment facilities in order to reduce the amount of biodegradable waste to be stored in 2025 to 35%,

The final product of organic wastes, which is subjected to microbial degradation (decomposition) under aerobic or anaerobic conditions, is called compost [23]. Green garden wastes (leaves, grass, pruning wastes, wood, bark) resulting from the works of the parks, gardens and afforestation units of the municipalities can be converted into compost with the appropriate composting method. Social responsibility projects on compost production have started to become widespread in Turkey [24].

- Ensuring energy recovery from waste by subjecting wastes to processes such as material recovery, bio-drying, biomethanization, compost, advanced thermal processes or incineration,
- Realization of methane recovery from landfill gas originating from regular and irregular landfills,

Methane gases, which cause an increase in greenhouse gas emissions 25 times more than carbon dioxide, are converted into electrical energy by burning after they are collected from the gas collection channels opened in the landfills [25]. Between January and February 2021, 96,358 megawatt-hours of electricity were produced by recovering methane from landfill gas. 52% of this amount was obtained from Odayeri Landfill Gas Power Plant and Seymen Landfill Gas Power Generation Facility [26].

- The industrial symbiosis approach that allows the wastes from industry to be used as alternative raw materials or fuel in another sector, and the waste from one sector to be the raw material of another sector,

Industrial Symbiosis is the union formed by turning the by-product or output of one of the industrial facilities into the raw material of another. Iskenderun Bay (Adana, Mersin, Osmaniye, Iskenderun) Industrial Symbiosis Project; It was carried out by the Technology Development Foundation of Turkey (TTGV) between 2011–2014 [27]. In this project, industrial production on animal feed production from fruit pulp, energy production from agricultural and animal waste, bioremediation product production from cottonseed waste, electricity production from waste oil, granule production from end-of-life tires, lead recovery from scrap batteries and the use of slag from iron and steel production in road construction, symbiosis studies were carried out [28].

- Carrying out appropriate studies for the evaluation of wastes from livestock and poultry farms,

Animal waste is seen as an ideal source for biogas (65% CH4, 35% CO_2) production. The obtained biogas is an important energy input for electricity and heat production. In addition, manure, which is a by-product, is used in agriculture [29]. Establishing facilities such as biogas and biodiesel for the evaluation of animal waste in the world creates a sustainable cycle by preventing the damage of wastes to the environment and human health [30]. In addition, the establishment of meat and bone meal production facilities for the evaluation of animal waste and by-products occurring in slaughterhouses is among the studies evaluated [31].

- Rehabilitation of irregular landfills and ensuring the disposal of wastes in landfills,

Rehabilitation (rehabilitation) by closing the areas where irregular storage is made has been legalized with the "Regulation on Regular Storage of Wastes", which was published in the Official Gazette dated 26.03.2010 and numbered 27533 [32].

In order to fulfill the commitments made regarding the waste sector, the above-mentioned studies are carried out and success is achieved in many areas. It is envisaged that the commitments in all titles will be completed by 2030. In addition to all these studies, strategies are being developed by further studies on waste.

The Paris Climate Agreement, which was signed in 2015 on the mitigation, adaptation and financing of climate change within the scope of the United Nations Framework Convention on Climate Change, entered into force in 2016. Among the countries that did not ratify the agreement, such as Eritrea, Iran, Iraq, Libya, Turkey and Yemen, Turkey was the 191st country to sign the agreement as of 2021. Paris Climate Agreement; It sheds light on what should be done to reduce greenhouse gases that cause global warming and climate change in the world. It aims to limit global warming to 1.5^{o}C. It presents a perspective that aims to reduce greenhouse gas emissions from coal, oil or all other fossil fuels. The living now sees the problem of climate change. For a solution, it is necessary to switch to climate change adaptation policies. The difference of the Paris Climate Agreement from other agreements; The country's need to align its policies, economy and industry with climate change. The Ministry

of Industry and Technology, metropolitan municipalities and local governments will take quick steps, which will ensure that Turkey is less affected by the provisions of the Green Agreement and the Paris Climate Agreement. A resource is created to transfer money from developed countries to poor countries in order to reduce greenhouse gas emissions and adapt to climate change. An annual budget of around 100 billion dollars is envisaged for this resource, which is called the green climate fund.

Waste Management for Low Carbon Cities

Data collection and analysis are a priority for creating low-carbon city strategies [33]. In order to find solutions to the problems, there must be data belonging to the problems. Finding the most appropriate solution over these data is also possible with data analysis. Data analysis is based on organizing the collected data with various methods and eliminating unnecessary, redundant data that will affect the accuracy of the result. When the data analysis is done correctly, it will highlight the appropriate solution [34]. A few of the waste management practices made in Europe in order to achieve the goal of becoming a low-carbon city are listed below.

CO_2 emissions; mostly from the use of fossil fuels or from industrial processes. Renewable energy sources should be used to prevent CO_2 formation. For industrial processes where we cannot prevent CO_2 formation, it is necessary to prevent CO_2 emissions and to ensure CO_2 recovery. Carbon dioxide capture and storage processes are applied to the places where carbon dioxide is produced the most and consist of three stages. These are handling, transport and storage. The process of separating CO_2 from the flue gas formed during the capture phase is carried out. In the transportation phase, there are two options as pipeline or ship transportation. The storage stage is the process of injecting carbon dioxide into an underground rock formation by compressing it. In the storage phase, there are three alternatives: geological storage, oceanic storage and mineral carbonization [35].

One of the most used methods to reduce carbon emissions in the waste sector is biogas plants. Established biogas facilities both meet the city's heat and natural gas needs as a renewable resource and provide fertilizer support to be used in agricultural lands. This method prevents the landfills from exceeding their capacity, thus contributing to the storage of less waste and making fewer landfills and economically contributing to the country [36].

Cities that want to reduce their carbon emissions through waste management focus on new projects by making use of technology. The use of smart waste management systems and the collection of waste with electric vehicles reduce carbon emissions in both the transportation and waste management sectors. Routes created automatically according to the occupancy rate of the waste bins prevent unnecessary vehicle circulation and carbon emissions in the city [11]. The implementations on the so-called Climate Street in Amsterdam demonstrate the contribution of waste management to the low-carbon city. The collection of waste from the city with electrical waste separation vehicles prevents the carbon emissions emitted by the waste vehicles [37]. In addition, another exemplary application seen on the same street is energy-saving waste bins working with solar energy. By compressing the waste with solar energy, it has more waste capacity than a normal waste bin. Thus, the filling time of the waste bins is extended and the working time of the waste vehicles is shortened [38].

In Songdo city of South Korea, the system where waste is sent directly from waste bins to the recycling facility, energy generation or underground waste facility for incineration with pneumatic tube systems is one of the applications where waste management and carbon emissions are minimized. There are no waste and waste vehicles in the city [39].

The Relationship of Waste Management with Carbon Tax

Another method applied to reduce carbon emissions and raise awareness is the carbon tax. It is a consumption tax per ton of coal, per barrel of oil or emissions. Although it is a method that has been applied globally for years, it was first put into effect by Finland in 1990 [40].

According to the Evaluation of Market-Based Emission Reduction Policy Options in Turkey Final Report published by the Ministry of Environment and Urbanization in 2017, priority areas in emission reduction were determined and studies to be carried out on these areas were compiled. It has been stated that the energy, process emissions and transportation sectors will be subject to tax at the first stage, while the agriculture and waste sectors will be exempted from the tax at the first stage. It is stated that it is exempted due to the complexity of emission measurement in the waste and land-use sectors and the need to further develop appropriate methodologies [41].

CONCLUSIONS

The increase in human needs with industrialization in cities has led to population density in cities. The fact that the cities are not ready for such a population leads to the fact that every person living in the city cannot be provided with the same quality of life. Green areas are given up for housing rights and trees are given up for road construction. The lack of adequate infrastructure reveals the most concrete evidence of environmental pollution in rapidly growing cities. Industrialization, which is not controlled against the environment and human health, has ceased to be a problem only for cities.

In recent years, the whole world has started to see how big problems climate change has caused and will cause. It is understood that the absorption of carbon emissions should be provided by human-made solutions. Reducing carbon emissions, which is the starting point of low-carbon cities, can be achieved by reaching all cities. The new regulations that emerged with the Paris Climate Agreement, where the green economy is related to waste management, and these new regulations need to be pointed out in order to reach low-carbon cities.

The legal regulations made by the government in the waste sector in Turkey were examined and the signed/approved agreements/contracts on carbon reduction were listed and it was revealed how much of the commitments were made. It is seen that feasibility studies and legal regulations regarding the reduction of carbon emissions are about to be completed. It is seen that the practices that still need to be done in the waste sector for the reduction at the level committed with the Paris Climate Agreement do not cover 100% of the population in the country. Carbon reduction methods for the waste sector and the work that can be done on behalf of other sectors are explained with examples from abroad. While determining its strategies for the future, Turkey needs to closely follow and realize the changes in the world. This work; forms the basis for many studies on low-carbon cities.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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