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Carbon Emission Analysis and Reporting in Urban Emissions: An Analysis of the Greenhouse Gas Inventories and Climate Action Plans in Sarıçam Municipality

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Abstract: The urban carbon footprint (UCF) is an important tool for assessing an organization's ecological impacts and in guiding sustainability efforts. This calculation is usually measured in tons of carbon dioxide equivalent (CO_2-eq). Calculations provide important data to determine strategies to reduce the carbon footprint and establish sustainability targets. Various standards and protocols guide UCF calculation, and many organizations aim to make these data transparent to their stakeholders and the public. This study aims to calculate the UCF of Sarıçam Municipality (SM) in the Adana Province of Türkiye. This study includes the greenhouse gas emission inventories resulting from all activities of the SM main service building, guest house, construction site service building, Cultural Center service building, and additional service buildings between 1 January 2022 and 31 December 2022. The calculations include generator fuel consumption, electricity consumption, the refrigerant gas leaks and refills resulting from these activities, the fuel consumed in vehicles owned by the company or whose fuel consumption is under company control, emissions originating from personal travel, emissions originating from customers and visitors, emissions originating from business travel, purchases, etc. Emissions from products purchased and emissions from waste transportation are included. The findings show that, in 2022, the total UCF of SM was equal to 10,862.46 tons of CO_2-eq. The Paris Agreement aims to reduce the per capita emissions to approximately two tons of CO_2-eq by 2030. The carbon footprint per employee within the municipality was calculated at 12.43 tons of CO_2-eq, as derived from the analyzed data. The results reveal the importance of implementing sustainable practices and strategies within SM, such as energy efficiency measures, waste reduction, and the adoption of renewable energy sources, to mitigate its carbon footprint. This study plans to provide a basis for SM's reduction efforts by keeping greenhouse gas emissions under control.

Keywords: carbon footprint; carbon accounting; urban sustainability; urban emissions

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1. Introduction

1.1. Background

Filling the atmosphere with greenhouse gases causes heat to be trapped [1]. The Earth can combat these gases through natural processes, such as photosynthesis. However, when the level of these gases exceeds the safe level, more heat is retained, thus, causing climate change [2]. The heating caused by residences, which is caused by electricity consumption in residences, is sourced from natural gas consumption that is produced in industry [3]. In addition, electricity consumption in the industry includes natural

gas consumption in commercial establishments and official institutions [4], electricity consumption in commercial establishments and institutions, and lighting in streets and social areas. Transportation issues and CO_2 emissions resulting from the municipality's activities affect the formation of the carbon footprint [5]. When determining the carbon footprint, the amount of greenhouse gases produced as a measure of the damage caused to the environment by human activities is taken into account [6]. The amount of greenhouse gases is calculated in units of carbon dioxide. The Intergovernmental Panel on Climate Change (IPCC) examines carbon footprint in two different categories: primary, which is expressed as direct carbon footprint, and secondary, which is expressed as indirect carbon footprint. The primary carbon footprint is formed due to energy consumption and transportation activities. Primary carbon footprint is defined as the CO_2 emissions resulting from consumed fossil fuels. Secondary carbon footprint is defined as the CO_2 emissions that occur within the life cycle of all products used, from production to degradation process [7,8].

States that aim to reduce the greenhouse gases that cause climate change can choose to do their part within their means, proceed in the light of joint decisions, or they can ignore this issue entirely [9]. However, every step taken regarding climate change, whether behavior by way of action or behavior by way of omission, entails responsibility toward all humanity and future generations. This is because taking or not taking a step has positive or negative consequences for everyone. Therefore, when considering the effects of climate change, it can be said that this is an important problem that requires extremely important cooperation [10].

1.2. Local Climate Policies

The emergence of a sanctioning power on the effects of climate change—one that combats climate change, as well as encourages cooperation, the determination of responsibilities, the determination of obligations, and what to do in the steps to be taken—should be determined according to certain legal rules. As a result, many issues have arisen for public institutions and organizations, private institutions, and private sectors [11]. The Environmental Law No. 2872, dated 9 August 1983 [12]; the Municipality Law No. 5393, dated 3 July 2005 [13]; and the Metropolitan Municipality Law No. 5216, dated 10 July 2004 [14] are the pieces of legislation that have imposed the most comprehensive duties on local governments. The obligations brought by the European Green Deal (EGD) [15], which aims to become the first climate-neutral continent in 2050, and the Sustainable Development Goals (SDGs) [16], which are addressed under 17 main headings of the United Nations (UN) to ensure the common welfare of humanity in the world by 2030, are for local governments. They help to determine the tasks in the fight against climate change in the international arena.

The source of the problem is the economic system, with all its forms of production and consumption [17]. For this reason, policies to combat climate change are intertwined with many decisions and choices to be made in the field of economy, especially energy. It is known that traditional habits in energy production and consumption cause negative effects on the environment and natural resources on local, regional, and global scales. In this respect, popularizing responsible production and consumption is becoming even more important today [18]. Local governments are often in the best position to identify the gaps in access to affordable energy for vulnerable groups in society. Local governments can contribute to energy efficiency by contributing to reducing public energy expenditures by investing in green buildings and the supply of green energy sources, as well as by adding sustainability-related criteria to procurement practices [19].

In addition to "smart city" applications in cities, local transportation and urban planning policies can also be effective in eliminating energy efficiency and carbon emission problems. Participatory urban planning is more important than ever to reduce carbon emissions in cities. For this reason, as in every state, the responsibilities of municipalities and their practices in reducing the carbon footprint of the Republic of Türkiye should be separately considered and evaluated [20,21]. "SM" in Adana Province can be cited as an example of a local government that is active in climate policies.

The feasibility of a global policy is closely linked to regional, local, and national policy processes. Therefore, climate policies are formed as a result of a multi-layered policy process from the international level to the local level [22]. For this reason, addressing the issue only in a global abstraction may disrupt the applicability of the policies produced.

As municipalities, metropolitan municipalities, and municipal unions, local governments must determine local policies to reduce greenhouse gas emissions, combat the effects of highly effective climate change, and develop low-carbon city policies. In this context, considering models and projections, determining local targets for reducing greenhouse gas emissions comes to the fore. Internationally, it is becoming increasingly important for local governments to take greenhouse gas reduction measures in the fight against climate change, to control greenhouse gas sources from buildings to transportation, and to work on local targets for adaptation. In the coming periods, the action plans created by local governments and the greenhouse gas reduction targets they will set may become more decisive [23].

The Kyoto Protocol until 2020 and the Paris Agreement after 2020 appear as two implementation tools of the United Nations Framework Convention on Climate Change (UNFCCC) [24]. The first mechanism defined in the Paris Agreement [25] is the cooperation approach that allows the combination of emissions trading systems. The second is a new mechanism that will replace the Kyoto Flexibility Mechanisms [26] and "contribute to the reduction of greenhouse gas emissions and support sustainable development". The third is the non-market mechanism, which expects a unified, integrated, and balanced non-market approach. The Republic of Türkiye ratified the UNFCCC in 2004 and the Kyoto Protocol in 2009. According to the provisions of Article 4 and Article 6 of the UNFCCC, "public participation" is one of the most important principles of effective environmental management. The word "public" here refers to stakeholders at the local, national, and international level. According to the UN Rio Declaration on Environment and Development (Rio Declaration) [27], Agenda 21, and the Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters [28], stakeholder participation is a right. The right in question refers to the right to access information, to participate in decision-making mechanisms, and to resort to judicial methods. The Rio Declaration and the Aarhus Convention discuss these three rights in detail. This participation ensures good governance, prevents human rights violations, and guarantees transparency, integrity, and sustainable development.

Public participation assumes an important role in advancing the transformation towards climate neutrality. Strong public and social engagement on climate action should be both encouraged and facilitated through an inclusive and accessible process at all levels, including national, regional, and local government. It must establish relationships with all segments of society to ensure action and empower the public to create a climate-neutral and resilient society against climate change. Establishing the basis of this relationship and determining its standards, rules, and boundaries will depend on the legal process. By establishing a multi-level climate and energy dialogue through national legal regulations, integrated national energy and climate plans will be discussed within the framework of this dialogue [29].

It forms the framework of action plans for local governments that create a city that is resilient to climate change, adaptable, safe, sustainable, affordable, and able to access renewable energy, accelerating the decarbonization of its territories, and allowing the public to access safe, sustainable, and affordable energy. For this reason, it is important to enact legal regulations and implement these regulations in the applicability and functionality of local governments' action plans [30].

1.3. Literature Review

The Mediterranean Basin stands out as one of the world's most vulnerable regions to the impacts of global climate change. A temperature rise of 2 °C in this area is poised to bring about various consequences, including unanticipated weather events, heightened

occurrences of heat waves, a surge in both the frequency and severity of forest fires, prolonged periods of drought leading to biodiversity decline, a drop in tourism earnings, reduced agricultural productivity, and an exacerbation of drought conditions [31–34]. According to the Türkiye's Future Project Final Report carried out by WWF-Türkiye, the main effects of climate change are as follows [35]:

- The temperature rise is expected to be constrained until the conclusion of the 2030s, with a swift escalation anticipated thereafter;
- While variations exist based on seasons and regions, it is projected that the temperature will rise by approximately 4 °C during winter and 6 °C during summer, relative to the period between 1960 and 1990;
- Although winter precipitation is diminishing across Türkiye, there is a notable rise in precipitation expected specifically in the eastern portion of Northern Anatolia.

The 2011 Climate Change National Action Plan projected a 2.5 °C–4 °C increase in Türkiye's annual average temperature in the upcoming years. Specifically, the rise is anticipated to be 4 °C in the Aegean and Eastern Anatolia Regions and 5 °C in the inner regions. This suggests that Türkiye is on course for a climate characterized by higher temperatures, reduced precipitation, and increased uncertainty [36]. The Action Plan warns of significant negative impacts, including diminished water resources, heightened risk of forest fires, prolonged drought, desertification, and associated ecological degradation. Despite Türkiye's industrialization efforts in the 20th century, the country claims no historical responsibility for the surge in greenhouse gases. It pledges to contribute within the framework of the "common but differentiated responsibilities" principle, aligning with each nation's share in greenhouse gas emissions.

The majority of Türkiye's overall ecological impact is attributed to the carbon footprint, accounting for 46%. The most substantial increase in the carbon footprint occurred from 1961 to 2007 [37]. Türkiye experienced a significant surge in greenhouse gas emissions, rising by 115% from 1990 to 2010, reaching a total of 401.9 million tons. This propelled Türkiye to a leading position globally in the rate of increase in greenhouse gas emissions. During the same period, per capita greenhouse gas emissions rose from 3.39 tons to 5.52 tons. In 2010, a substantial 71% of Türkiye's greenhouse gas emissions originated from the energy sector. The country's policies in energy, urbanization, transportation, and industry serve as indicators of its efforts to address global climate change. Despite becoming a party to the United Nations Framework Convention on Climate Change (UNFCCC) in 2004 and signing the Kyoto Protocol in 2009, Türkiye has not established specific reduction targets for greenhouse gas emissions [38]. Furthermore, it did not assume any responsibilities during the Second Obligation Period of Kyoto, which commenced in January 2013. The United Nations Framework Convention on Climate Change encourages member states to reduce greenhouse gas emissions, collaborate on research and technology, and safeguard greenhouse gas sinks such as forests, oceans, and lakes. Despite these international agreements, Türkiye's climate policy has yet to adequately address the pressing urgency of the climate change issue, and effective measures have not been consistently pursued since the 1990s [39].

The Paris Agreement, a pivotal component of the climate change strategy post-2020, was endorsed during the 21st Conference of the Parties to the UNFCCC in Paris in 2015. At COP 21, all countries globally committed, for the first time after 2020, to reducing their greenhouse gas emissions. Effectively taking effect on 4 November 2016, the agreement required ratification by at least 55 parties, representing 55% of global greenhouse gas emissions by 5 October 2016. Remarkably, the Paris Agreement became operational in less than a year after its adoption. The primary objective of the agreement is to limit the long-term increase in global temperatures caused by human-induced greenhouse gas emissions to less than two degrees Celsius compared to the pre-industrialization era. It underscores the significance of striving for a 1.5 °C target. Moreover, the Paris Agreement affirms that countries must contribute to the battle against climate change in line with the principle of "common but differentiated responsibilities and relative capabilities" [40].

The Paris Agreement stands out from the UNFCCC by introducing a system reliant on contributions from all nations. It operates on the premise of distinguishing between developed and developing countries in the climate change battle, emphasizing that every country bears responsibility according to the principle of "common but differentiated responsibilities and relative capabilities". The classification of developed and developing nations lacks specific criteria or differentiation. Within the context of combating climate change, the Agreement establishes a framework to outline procedures for national contributions, covering aspects such as mitigation, adaptation, loss/damage, financing, technology development and transfer, capacity development, transparency, and situation assessment. Its primary focus is on providing financial aid, technology transfer, and capacity building to developing countries, especially the least developed countries and small island states. The goal is to enhance the adaptation and resilience capacities of nations vulnerable to climate change's adverse effects and bolster their capacities to reduce greenhouse gas emissions.

Concerning emission reduction, the Agreement mandates developed nations to uphold absolute emission reduction targets. Simultaneously, it encourages developing nations to incrementally increase their emission reduction goals and adopt new, expanded targets encompassing their entire economies over time, considering diverse national conditions. The practical implementation of these objectives centers on nationally determined contributions (NDCs), representing countries' goals in the fight against climate change. On 20 September 2015, our country announced its "Intended National Contribution" declaration, anticipating a reduction by 2030, deviating from an increase by up to 21%.

On 22 April 2016, Türkiye, alongside representatives from 175 other countries, formally signed the Paris Agreement during a high-level signing ceremony in New York. In our National Declaration, it was underscored that Türkiye endorsed the Agreement as a developing nation. The approval of the Paris Agreement was granted through a Presidential Decree on 7 October 2021, concluding the domestic legal approval process. The documentation for ratification, along with our national declaration, was submitted to the UN Secretariat on 11 October 2021. Additionally, our country has committed to achieving a net-zero emission target by the year 2053.

1.4. Research Aims

Sarıçam is a district of the Adana province of Türkiye. The socio-economic structure of the district is shaped depending on various factors. The population of Sarıçam generally has a young and dynamic structure. The average age and education level of the population are some of the important factors affecting the socio-economic structure of the district. The economy of the district is based on agriculture, industry, trade, and service sectors. Agriculture, especially fruit and vegetable production, can form an important part of the district's economy. In addition, production activities take place in various sectors in industrial zones and organized industrial zones. Employment in Sarıçam is generally provided in agriculture, industry, and service sectors. The agricultural sector is an important source of employment, especially in rural areas. The industrial sector creates employment with the presence of factories and production facilities in the district. Education and health services have an important place in Sarıçam. There are schools and health institutions in the district, and these institutions contribute to the socio-economic situation of the district's people. Transportation is provided by the D400 Highway in the south, the TEM Highway in the north, and the Kozan Connection Road passing through the district center. Transportation is also provided by the railway and Incirlik NATO Base located in the south. Figure 1 shows the localization of the SM building.



Figure 1. Localization of SM building.

Their increasing economic power and the central role they play in climate change have brought cities and city governments to the center of the political struggle in the context of combating climate change and creating low-carbon economies. During the 1990s, first "voluntary local governments" and then, since 2005, the concepts of "strategic urbanism" made world cities, especially in Europe and the USA, and international coalitions of local governments, almost as active players in climate negotiations as governments. It can easily be said that local governments in Türkiye were largely distant from these developments until recently. However, this situation is changing. The main purpose of calculating and reporting greenhouse gas inventories is to pave the way for low-carbon urban development by implementing reduction strategies. The will that emerged on this issue, as emphasized in various sections of the report, has now surpassed national reduction strategies and relatively higher targets have begun to be set.

This study includes the greenhouse gas inventory calculation, which is the first step of the "Climate Change Action Plan" study. The inventory is created based on a reference year (2022), naturally an indispensable element of any mitigation action plan. Sarıçam municipality's Climate Change Action Plan preparation will be the main output of this study. The Climate Change Action Plan first requires determining the institutional emissions of Sarıçam municipality. In this regard, corporate emissions were first documented and determined by international standards, and the carbon footprint inventory was created. This inventory will also provide a useful basis for recording emissions and monitoring reductions against established targets.

For this reason, SM is selected as the pilot institution, and greenhouse gas inventory calculation is carried out in this study. SM plans to create a basis for reduction efforts by keeping greenhouse gas emissions under control with the calculations made within the scope of this study. The main contributions of this paper are presented in the following points:

- By analyzing emissions comprehensively, the study will uncover potential areas for emission reduction, enabling targeted sustainability efforts;
- The study will increase awareness among internal stakeholders about the environmental impact of organizational activities, fostering a culture of sustainability;
- The study will provide clear insight into the organization's resource consumption, emissions, and energy usage, promoting transparency and accountability;
- Findings from the study will lay the groundwork for the development of a structured plan to manage greenhouse gas emissions effectively;
- The study will reinforce SM's commitment to sustainability, aligning actions with its overarching sustainability goals.

2. Materials and Methods

This study includes the inventory of Scope 1, Scope 2, Scope 3, and Scope 4 greenhouse gas emissions resulting from all activities of SM main service building and additional

service buildings between 1 January 2022 and 31 December 2022. The calculations include generator fuel consumption, electricity consumption, refrigerant gas leaks and refills resulting from these activities, fuel consumed in vehicles owned by the company or whose fuel consumption is under company control, emissions originating from personnel travel, emissions originating from customers and visitors, emissions originating from business travel, purchases, etc. Emissions from products purchased and emissions from waste transportation are included. Within the scope of the inventory, emissions were evaluated based on CO_2, CH_4, and N_2O greenhouse gases, and CH_4 and N_2O emissions were presented in CO_2 equivalent units. This report has been prepared in line with the principles set forth by TSE Greenhouse Gases-Part 1: Guidelines and specifications for the calculation and reporting of greenhouse gas emissions and removals at the organization level [41].

2.1. Scope of Emission Sources

The scope approach aims to simplify the calculation and reporting of emissions. In this calculation period and within this report, the organization's Scope 1, Scope 2, Scope 3, and Scope 4 emission sources are calculated. The components of the corporate carbon footprint determined by the Greenhouse Gas (GHG) Protocol scopes are shown in Figure 2.

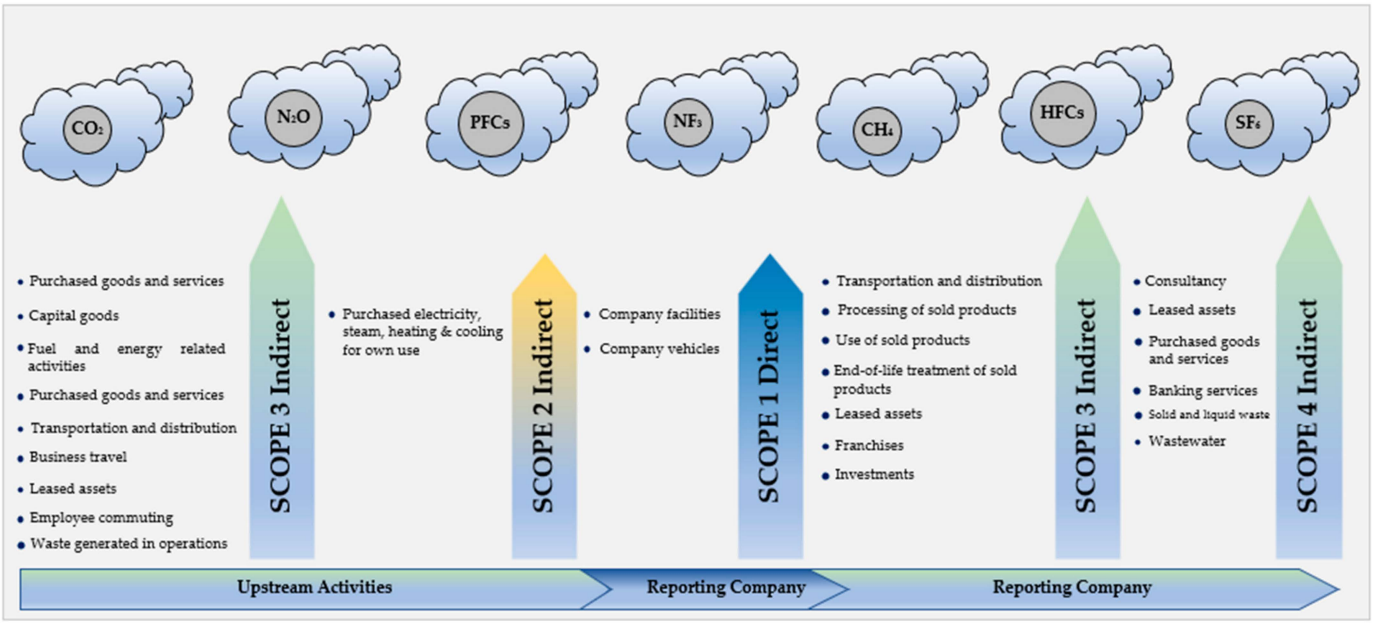


Figure 2. The components of the corporate carbon footprint determined by the GHG Protocol scopes.

2.1.1. Scope 1: Direct Greenhouse Gas Emissions

It covers the amounts of greenhouse gases released directly from greenhouse gas sources owned or controlled by an institution. Activities such as stationary combustion, mobile combustion, process emissions, and fugitive emissions are included in Scope 1. Scope 1 emissions for SM consist of greenhouse gas emissions resulting from fuel consumption of vehicles, emissions from vehicles whose consumption is covered by the company, emissions resulting from fuel consumption of generators used within the scope of office activities and technical activities, and emissions resulting from refrigerant gas leaks/filling.

2.1.2. Scope 2: Indirect Greenhouse Gas Emissions from Imported Energy

It covers greenhouse gas emissions generated during the production of electricity, heat, or steam consumed by an externally supplied organization. All of SM's electricity consumption operations in the locations within the scope of this study are included in the boundaries of the establishment, since they are under the control of the company.

2.1.3. Scope 3: Indirect Greenhouse Gas Emissions from Transportation

These emissions occur from sources outside the boundaries of the organization. These sources are mobile, and emissions mostly occur because of the burning of fuel in transportation equipment. Scope 3 emissions for SM consist of emissions originating from personnel commuting to work, emissions originating from transportation of customers and visitors, and emissions originating from business travel.

2.1.4. Scope 4: Indirect Greenhouse Gas Emissions from Products Used by the Organization

These emissions are greenhouse gas emissions that are associated with the products used by the organization and arise from emission sources outside the boundaries of the organization. These sources can be fixed or mobile and can relate to all types of products purchased by the reporting organization. Scope 4 emissions for SM include the purchased raw materials/finished goods/semi-finished goods, etc., associated with the manufacturing of the product. It consists of emissions from wastewater and solid and liquid waste.

2.2. Calculation Methodology

The basic method used when calculating the greenhouse gas emissions resulting from the activities carried out by SM between 1 January 2022, and 31 December 2022, in the locations evaluated within the scope of this inventory was the multiplication of the defined activity data and the appropriate emission factors. The chosen method was determined by existing activity data and was chosen to minimize the uncertainty of the results and to obtain accurate, consistent, and adaptive results. For this reason, the Tier 1 approach specified in IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories 2006 was applied. Tier 2 approach was applied because the country-specific emission factor (EF) obtained from international sources was used when calculating CO_2 emissions resulting only from electricity consumption.

Emission factors are provided in carbon dioxide equivalent (CO_2-eq) [42]. Emissions of greenhouse gases CO_2, CH_4, and N_2O are calculated separately and converted to CO_2 equivalent. During this cycle, the emission amounts of each greenhouse gas are multiplied by the global warming potential of that gas. Greenhouse gases evaluated within the scope of this inventory and global warming potentials (GWP) used are shown in Table 1. Emission calculation methods of fixed and mobile combustion sources are given in detail in Table S1. In Table S2, emission calculation methods for direct emissions resulting from the leakage of greenhouse gases in anthropogenic systems are given in detail. Table S3 gives the calculation methodology and emission factors for electricity emissions. Table S4 gives the calculation methodology and emission factors for indirect greenhouse gas emissions from transportation.

Table 1. Global warming potentials [43].

Greenhouse Gas	GWP for 100 Years
Carbon dioxide (CO_2)	1
Methane (CH_4)	27.90
Nitrogen oxide (N_2O)	273
R410A	1924
R600A	0.01
R22	1960
R32	771

The list of current greenhouse gas emission sources for the period calculated and reported for 2022 within the scope of this report is given in Table 2.

Table 2. List of greenhouse gas emission sources in 2022.

Emission Source	Scope	Activity
Diesel—generator	1	Electricity generation
Refrigerant gas leaks (air conditioner and refrigerator)	1	Cooling systems—office coolers and refrigerators
Refrigerant gas (air conditioner filling)	1	Cooling systems—office coolers
Diesel—Vehicles	1	Municipal on-road–off-road vehicles' fuel consumption
Gasoline—vehicles	1	Fuel consumption of municipal vehicles
Electric	2	Building operating system—burning for heating, cooling, lighting
Diesel	3	Emissions from combustion for personnel transportation
Transportation and accommodation data	3	Emissions from transportation of customers and visitors
Transportation and accommodation data	3	Emissions from business travel
Purchased products	4	Purchased raw materials/finished goods/semi-finished goods, etc., associated with the manufacturing of the product.
Solid and liquid waste transportation	4	Emissions from the disposal of solid and liquid waste

3. Results

UCF is a process to measure and evaluate the environmental impacts of an organization's activities. This calculation includes the organization's greenhouse gas emissions, energy consumption, waste management, and other environmental factors. The basic steps in this process are scoping, data collection, emission calculation, reporting and monitoring, mitigation, and improvement strategies. Based on the collected data, the amounts of greenhouse gas emissions and other environmental factors are calculated. Carbon emissions are expressed in metric tons. The amount of electricity consumption for 2022 is shown in Table 3. The data collected and provided by the relevant department are taken as MWh and included in the calculations.

Table 3. Electricity consumption amounts in 2022.

Months	Electric Consumption
January	87.88
February	109.39
March	162.79
April	53.72
May	54.12
June	89.81
July	102.00
August	126.96
September	111.89
October	75.53
November	78.99
December	4.43
Total (MWh)	**1057.51**

The diesel and gasoline consumptions used in SM on-road and off-road vehicles and generators are shown in Table 4.

Table 4. Fuel consumption in 2022.

Activity	Fuel Type	Consumption Amount	Consumption Unit
Generator	Diesel	5.12	m^3
Company vehicles on-road	Diesel	112.54	m^3
Company vehicles off-road	Diesel	614.84	m^3
Company vehicles on-road	Gasoline	6.05	m^3
Lawn mowing double-time	Gasoline	9.21	m^3

Total gas capacity is determined according to the types of refrigerant gases used in air conditioners and refrigerators used in the seven main locations where SM operates. The total amount of refrigerant gases used is given by location in Table 5.

Table 5. Illegal refrigerant amounts in 2022.

Refrigerant Gas	Filling Gas Capacity (kg)	Amount of Leak Gas (kg)
Air conditioner gas leak R410A	-	4.30
Refrigerator gas leak R600A	-	0.02
Air conditioner gas leak R22	-	0.01
Air conditioner gas leak R32	-	0.05
Air conditioner gas refill R410A	77	-

Greenhouse gas emissions realized according to the activity headings evaluated within the scope of this inventory are shown in Table 6. Figure 3 shows the percentage distribution of CO_2-eq according to four scopes. A total of 874 employees work in the SM building. It is revealed that the carbon footprint per employee is 12.43 tons of CO_2-eq according to the data obtained from Table 6.

Table 6. Distribution of 2022 emissions by activities and scopes.

Emissions	Total (CO_2-eq)
Scope 1: Direct greenhouse gas emissions and removals	2372.26
Direct emissions from stationary combustion	13.83
Direct emissions from live combustion	2174.79
Direct emissions from leakage of greenhouse gases in anthropogenic systems	183.61
Scope 2: Indirect greenhouse gas emissions from imported energy	495.65
Indirect emissions from imported electricity	495.65
Scope 3: Indirect greenhouse gas emissions from transportation	196.57
Emissions from staff commuting to work	129.67
Emissions from transportation of customers and visitors	26.93
Emissions from business travel	39.97
Scope 4: Indirect greenhouse gas emissions from products used by the organization	7797.98
Emissions from the purchased raw materials/finished goods/semi-finished goods, etc., associated with the manufacturing of the product	7796
Emissions from the disposal of solid and liquid waste	1.98

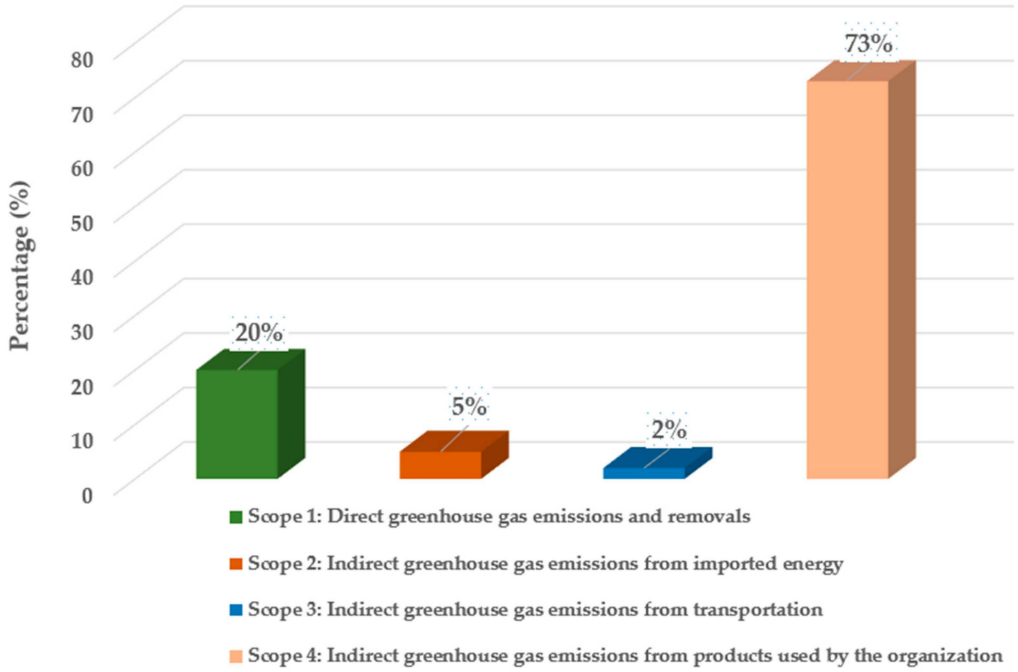


Figure 3. Distribution of CO_2-eq by scopes.

Uncertainty levels for the emission elements in SM's 2022 greenhouse gas emission inventory study have been determined separately for each emission source and emission factor. In the calculations, all data except refrigerant gas leakage amounts were supported by data obtained from existing invoices. Uncertainty activity data percentage (C) was determined as 5% for all Scopes except Scope 3 and 20% for Scope 3. R410A, R600A, R22, and R32 represent refrigerant gases in Table 7. The uncertainties determined within the scope of this study are given in Table 7. Uncertainty emission factor percentage (F) is determined as 10% for all categories except Scope 3 and 20% for Scope 3. The calculated emission uncertainty percentage (I) was determined using Equation (1). The cumulative total uncertainty (u) percentage was calculated using Equation (2).

Table 7. The uncertainty ranking of emissions calculated indirectly.

Source Description	Activity Data	Unit Used to Measure Activity Data	GHG Emission Factor	Uncertainty of Emission Factor
Generator diesel	5.12	m^3	2.51	+/− 5%
Electric	1.12	GW	0.44	+/− 5%
On-road diesel	112.54	m^3	2.69	+/− 5%
Off-road diesel	614.84	m^3	2.69	+/− 5%
On-road gasoline	6.05	m^3	2.31	+/− 5%
Off-road gasoline	9.21	m^3	2.31	+/− 5%
R410A	81.30	kg	1924	+/− 35%
R600A	0.02	kg	0.01	+/− 35%
R22	0.10	kg	1810	+/− 35%
R32	0.05	kg	675	+/− 35%

$$I = \sqrt{(C^2 + F^2)} \quad (1)$$

$$u = \pm \frac{\sqrt{\sum_{i=1}^{n} (tCO_2e_i) \times I_i)^2}}{\sum_{i=1}^{n} (tCO_2e_i)} \quad (2)$$

4. Discussions

According to the results obtained, it is concluded that greenhouse gas emissions from energy use and transportation are quite high compared to other sources. Therefore, the focus is primarily on energy use and transportation-related measures. However, various measures are taken by Sarıçam municipality to reduce greenhouse gas emissions.

The geography of Sarıçam, and its energy consumption habits and textures, are also marked by Türkiye's economic dynamics. It is known that the heating need is largely met by consuming electricity. On the other hand, the high level of emissions resulting from electricity consumption in buildings shows that serious gains can be achieved by applying mitigation techniques for buildings. As it is known, in terms of reducing energy consumption and reducing emissions in this way, the measures that can be applied in buildings are emission reduction measures in the category with the highest economic feasibility and their reduction potential is high. Another striking point of Sarıçam municipality's emission inventory is the emissions resulting from transportation. The high value of this value is a situation specific to our country and increasingly developing countries, and is typical for countries and cities where public transportation is not sufficiently developed. In the city of Adana, to which Sarıçam district municipality is affiliated, transportation problems caused by rapid urbanization, population growth, and migration, similar to the rapidly growing cities of Türkiye, negatively affect the vital functions of the city. Due to the uncontrolled expanding urban area and underdeveloped transportation infrastructures, it is becoming one of the main sources of greenhouse gas emissions. Since they are based on longer-term measures such as reducing emissions from transportation, urban behavior, and infrastructural transformations, they require longer-term political decisions than, for example, reductions that can be made in the built area. Sarıçam municipality's policies and emission reduction potentials in this context are included in the action plan. When evaluated as a renewable energy potential in Sarıçam, solar energy comes to the fore. Sarıçam district has an advantage compared to the Türkiye average in terms of sunshine duration and solar radiation level. Regarding energy, "Developing and diversifying renewable energy sources" is defined under the municipality's strategic goal of "Planning infrastructure works aimed at improving the quality of urban life". It will be ensured that renewable energy sources and technological lighting elements are used in buildings and facilities under the responsibility of Sarıçam municipality. Sarıçam municipality Climate Change Action Plan presents the following actions regarding the transportation sector:

- Encouraging energy-efficient vehicles;
- Development of comparative study on alternative fuels and new technologies;
- Development and improvement of bicycle and pedestrian transportation;
- Reducing automobile use to alleviate traffic congestion in cities;
- Expansion of public transportation.

Sarıçam district has a total activity area of 770 km^2. There is also a landscaping area of 263,790 m^2. There are green areas within our institution's field of activity that can be included in calculations to reduce greenhouse gas emissions. On the way to becoming a green municipality, it is preferred to plant coniferous trees, which absorb most of the dust in the air, and broad-leaved trees, which have a higher CO_2 storage capacity, in areas where vegetation will be planted, to reduce air pollution. Trees planted in 2022 include rubber tree, magnolia tree, jacaranda, dwarf bush, robellini, and goldrider. The regional vegetation has been strengthened in terms of diversity with trees and herbaceous plants. In support of green infrastructure, there is an aim to collect rainwater underground and in the soil.

To meet the Paris Agreement's goal of limiting the global temperature increase to below 1.5 °C by 2050, it is crucial to significantly reduce average per capita emissions. By 2030, the target is to bring per capita emissions down to approximately two tons CO_2-eq per person. This ambitious target requires concerted efforts from nations, industries, and individuals worldwide to transition towards low-carbon economies, adopt renewable energy sources, enhance energy efficiency, and implement sustainable practices across various sectors. Achieving this goal is essential for mitigating the impacts of climate change and safeguarding the planet for future generations. The result of this study is the determination of SM's total urban carbon footprint for the year 2022, which amounts to 10,862.46 tons of CO_2-eq. Additionally, the carbon footprint per employee within the municipality is calculated at 12.43 tons CO_2-eq, derived from the analyzed data. Therefore, SM will take some measures to reduce the amount of greenhouse gas emissions compared to those calculated for 2022. In addition to the projects to be implemented in municipal service units and vehicles, awareness-raising activities will be carried out to increase the knowledge of employees on the subject.

The goals for 2024 include the following:

- Within the scope of renovation projects, the use of luminaires that provide illumination with renewable energy sources and energy-efficient luminaires at suitable points in the parks, thus, ensuring energy savings;
- Developing and implementing projects for the use of renewable energy resources, which is one of the requirements of the age;
- Organizing campaigns to raise public awareness and conducting training activities;
- Preparation of the District-wide Climate Change Action Plan included in the 2022–2023 strategic plan;
- Reducing urban greenhouse gas emissions and increasing public awareness on the subject.

5. Conclusions

In this study, a comprehensive analysis is conducted of the greenhouse gas emissions generated by various activities within the SM building throughout the period from 1 January 2022 and 31 December 2022. The examination involved the participation of 874 employees associated with the SM building. The key finding of this study has quantified the overall urban carbon footprint of SM for the year 2022, reaching a total of 10,862.46-ton CO_2-eq. The carbon footprint per employee within the municipality is calculated to be 12.43-ton CO_2-eq based on the data collected and analyzed. These data serves as a valuable indicator, shedding light on the individual impact of each employee on greenhouse gas emissions within the organizational context. This comprehensive assessment provides a critical baseline for understanding the municipality's environmental impact and lays the groundwork for future initiatives aimed at reducing carbon emissions. The outcomes of this study underscore the importance of implementing sustainable practices and strategies within SM to mitigate its carbon footprint. Initiatives such as energy efficiency measures, waste reduction, and the adoption of renewable energy sources can play a pivotal role in achieving a more environmentally responsible and sustainable operation. The obtained data from the study not only provide a detailed assessment of SM's carbon footprint but also serve as a foundation for future research and action plans aimed at promoting environmental sustainability within the municipality and beyond. In the future study, SM carbon footprint inventory will be created for 2023. The carbon footprint reduction efforts implemented by SM in 2023 will be compared with the 2022 base year. Thus, the impact of the reduction policies implemented for municipalities on the carbon footprint will be investigated. There is also an aim to present per capita carbon footprint calculations on a provincial basis.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16104184/s1. References [44–47] have been included in Supplementary Materials.

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