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Research Article

Calculation of Muğla Sıtkı Koçman University's Carbon Footprint with IPCC Tier 1 Approach and DEFRA Method

Ebruhan HÜNERLİ[1]*, Gülşah KARACA DOLGUN[2], Tolga URAL[2], Hüseyin GÜLLÜCE[3], Durmuş KARABACAK[2]

[1]*Muğla Sıtkı Koçman University, Institute of Science and Technology, Department of Energy Systems Engineering, Muğla, Turkiye*
[2] *Muğla Sıtkı Koçman University, Faculty of Technology, Energy Systems Engineering, Muğla, Turkiye*
[3] *Atatürk University, Vocational School of Technical Sciences, Machinery and Metal Technologies, Erzurum, Turkiye*

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ABSTRACT

Since the Industrial Revolution, the increase and diversification of human needs, particularly the intensified use of fossil fuels to meet energy demands, have significantly contributed to greenhouse gas accumulation, leading to increased environmental pollution and triggering natural disasters. In response to this issue, various international conferences and agreements such as the Kyoto Protocol have been established. Additionally, individual countries have implemented regulations and laws to combat environmental pollution and reduce greenhouse gas emissions. Muğla Sıtkı Koçman University conducted a study to calculate its carbon footprint using the IPCC Tier 1 methodology and DEFRA conversion factors. The findings revealed significant carbon dioxide emissions stemming from the university's fuel and electricity consumption. In 2020, emissions were calculated at 4,759,087.57 kg CO_{2e} using the IPCC Tier 1 approach and 3,419,082.09 kg CO2e using DEFRA factors. These figures increased further in 2021, reaching 8,955,635.86 kg CO_{2e} (IPCC) and 7,511,422.31 kg CO_{2e} (DEFRA), indicating a rising emission trend. The study also highlighted significant differences in the number of trees required to offset the university's carbon footprint between the IPCC and DEFRA methods. For instance, in 2020, while IPCC suggested 211,515 trees were needed, DEFRA recommended 151,959 trees. This disparity persisted notably between the methodologies, emphasizing the importance of standardizing carbon footprint calculations. These findings underscore the necessity for institutions to embrace sustainable practices and reduce their environmental impact. Efforts to decrease carbon emissions and promote sustainability are crucial in combating air pollution and addressing the global climate crisis.

Keywords: Carbon Footprint, Life Cycle Assessment (LCA), DEFRA, IPCC

Muğla Sıtkı Koçman Üniversitesi'nin Karbon Ayak İzinin IPCC Tier 1 Yaklaşımı ve DEFRA Yöntemiyle Hesaplanması

ÖZ

Sanayi Devrimi'nden bu yana insan ihtiyaçlarının artması ve çeşitlenmesi, özellikle fosil yakıtların enerji ihtiyacını karşılamak için kullanımının yoğunlaşmasıyla önemli ölçüde sera gazı birikimine neden oldu. Bu durum, çevre kirliliğinin artmasına ve doğal afetlerin tetiklenmesine önemli ölçüde katkıda bulunmuştur. Bu soruna yanıt olarak, Kyoto Protokolü gibi birçok uluslararası konferans ve anlaşma oluşturulmuştur.

**Corresponding Author: Ebruhan HÜNERLİ*
ebruhanhunerli@posta.mu.edu.tr

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Ayrıca, çevre kirliliği ile mücadele etmek ve sera gazı emisyonlarını azaltmak için bireysel ülkeler düzenlemeler ve yasalar uygulamıştır. Muğla Sıtkı Koçman Üniversitesi, karbon ayak izini IPCC Tier 1 yöntemi ve DEFRA dönüşüm faktörleri kullanarak hesaplamak için bir çalışma yürüttü. Bulgular, üniversitenin yakıt ve elektrik tüketiminden kaynaklanan önemli miktarda karbondioksit emisyonunu ortaya koydu. 2020 yılında, emisyonlar IPCC Tier 1 yaklaşımıyla 4,759,087.57 kg CO_{2e} olarak hesaplandı ve DEFRA faktörleri kullanılarak 3,419,082.09 kg CO_{2e} olarak hesaplandı. Bu rakamlar, 2021 yılında daha da artarak, sırasıyla 8,955,635.86 kg CO_2e (IPCC) ve 7,511,422.31 kg CO_{2e} (DEFRA) seviyelerine ulaştı, artan bir emisyon eğilimini gösterdi. Çalışma ayrıca, IPCC ve DEFRA yöntemleri arasındaki karbon ayak izini dengelemek için gereken ağaç sayısındaki önemli farklılıklara da dikkat çekti. Örneğin, 2020'de, IPCC'ye göre 211,515 ağaç gerekiyorken, DEFRA 151,959 ağaç önerdi. Bu farklılık, metodolojiler arasında belirgin bir şekilde devam etti ve önümüzdeki yıllarda gereken ağaç sayısı büyük ölçüde değişti, bu da karbon ayak izi hesaplarının standartlaştırılmasının önemini vurguladı. Bu bulgular, kurumların sürdürülebilir uygulamaları benimsemesi ve çevresel etkisini azaltması gerekliliğini vurgulamaktadır. Karbon emisyonlarını azaltma ve sürdürülebilirliği teşvik etme çabaları, hava kirliliği ile mücadelede ve küresel iklim krizinin ele alınmasında hayati öneme sahiptir.

Anahtar Kelimeler: Karbon Ayak İzi, Yaşam Döngüsü Analizi (LCA), DEFRA, IPCC

**Corresponding Author: Ebruhan HÜNERLİ*
ebruhanhunerli@posta.mu.edu.tr

1. INTRODUCTION

All living things in the world are in balance with each other and their environment. This state of being in balance is called ecological balance. As a result of human behaviour from the past to the present, the ecological balance is endangered (Ateş, 2021). The deterioration of the ecological balance is caused by the actions of people (Çerçi, 2021). In the past, after the 20th century, as a result of the development of industry, rapid population growth and urbanization, air pollution increased and caused the ecological balance to deteriorate (Ateş, 2021). The 20th century is considered to be the century in which human-induced environmental impacts raised alarms for our world (Rüstemoğlu, 2023). As technology and global perspectives continue to evolve, the rising consumption levels lead to increased production, which, in turn, escalates the demand for raw materials and waste generation (Çerçi, 2021). In the past, fossil fuels have been extensively used in order to meet the energy need with industrialization (Yavuz, 2020). With the use of fossil fuels, events such as the formation of acid rain, high CO_2 emissions, the occurrence of climate change, and the realization of global warming have occurred (Yavuz, 2020). Especially the use of fossil fuels is the leading cause of greenhouse gas emissions (Şanlı, Bayraktar, & İncekara, 2017). Rapid and unplanned urbanization as a result of the development of technology, the diversification and increase of human needs, the industrial revolution, and rapid population growth disrupt the ecological balance by causing air pollution (See Figure 1). As a result of the rapid increase in the amount of greenhouse gases in the atmosphere from the past to the present, the amount of polluting gases in the atmosphere has increased. Air pollution that has occurred since the 20th century causes global warming and climate change in the long term (Birkan, 2022).

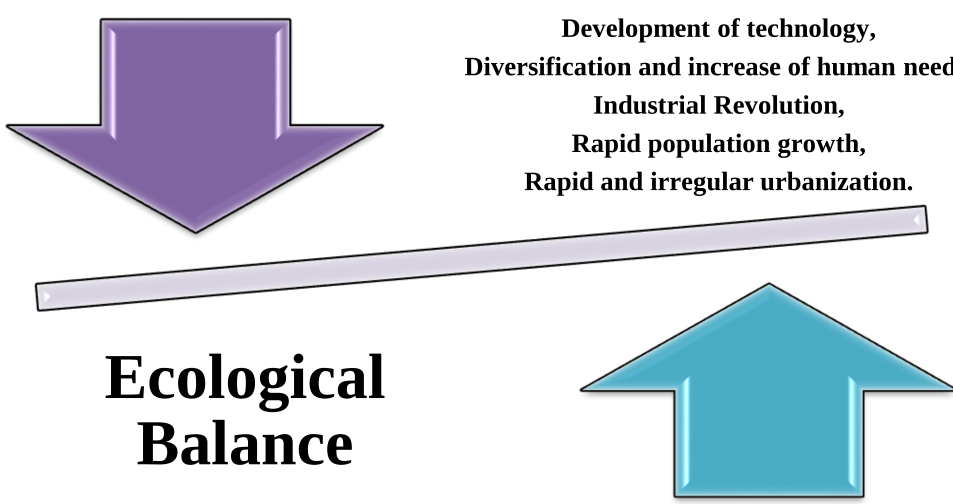

Figure 1: Graphical representation of the elements that disrupt the ecological balance.

Greenhouse gases accumulating in the atmosphere create a greenhouse effect by preventing the sun's reflected rays from being captured and reflected back to space, causing the sun's rays to be trapped in the atmosphere and causing the world to warm up more (Sunturlu, 2017). Overheated air deteriorates the climate and ecological balance of the world (Çerçi, 2021) (Özçelik, 2017). For this reason, it leads to global warming and global climate change in the long term (Çerçi, 2021). Especially after the 19th century, as a result of the industrial revolution and rapid urbanization, there were years when air pollution began to be felt clearly (Beijing, 2006). Thus, after the 1980s, global climate change and CO_2 emissions have become important subjects of research in science (Güller, 2018). If no precautions are taken, it has been observed that these harmful effects will continue to increase and reach more serious dimensions (Özçelik, 2017). Today's ongoing climate change and global temperature increases are becoming the biggest problems of the 21st century and the following years (Rüstemoğlu, 2023). Subsequently, international conferences and meetings were convened to establish protocols and agreements for setting targets and restrictions (Şanlı, Bayraktar, & İncekara, 2017). The "United Nations Environment Program", which first drew international attention to climate change, was carried out in 1975 by American scientists supported by the World Meteorological Organization. These studies concluded that the ozone layer is thinning due to carbon emissions. The First World Climate Conference was held in 1979 and the magnitude of the global warming problem was discussed. The political aspect of climate change was focused on at the meetings held in Villach, Austria, in 1985 and 1987. At the Toronto Conference held in Canada in 1988, some targets and constraints were determined to reduce global carbon emissions by 20% by 2005, and it was proposed to prepare a Framework Convention on Climate Change. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organization and the United Nations Environment Program to provide countries with accurate information about climate change and global warming. The "Second World Climate Conference" was held in 1990 and it was emphasized that the "Framework Convention on Climate Change" should be established in order to quickly prevent the damages of global warming. In 1992, the "Framework Convention on Climate Change" was signed and a restriction was placed on greenhouse gas emissions. For this purpose, at the "United Nations Conference on Environment and Development, it was aimed to limit the accumulation of greenhouse gases in the atmosphere by asking developed countries to reduce their greenhouse gas emissions to 1990 levels by 2000." This agreement, signed by 180 countries, entered into force in 1994. The United Nations Framework Convention on Climate Change is the first precaution against climate change and the first legal step to protect the global climate system. The purpose of this agreement is to limit the amount of greenhouse gases released into the atmosphere from human sources and to ensure the continuation of sustainable development by keeping this value at a level that the ecosystem can tolerate. In this context, countries are required to control and record their greenhouse gas emissions, take some initiatives to reduce climate change, and present these initiatives at the Conference of the Parties. This agreement imposes certain obligations on countries, and these obligations vary depending on the development of the countries. It has been stated that developed countries should implement stricter policies to reduce greenhouse gases. It was emphasized that the Parties should provide financial support to developing countries with the money they collected from developed countries so that they can fulfil their obligations. Thanks to this agreement, it was aimed to reduce the amount of greenhouse gases in 2000 to the levels in 1990. The Kyoto Protocol was prepared in 1997 but came into force in 2005. Countries that signed this protocol committed to reduce their greenhouse gas emissions by 5% between 2008 and 2012. This protocol is an international agreement in which the greenhouse gas emissions of countries into the atmosphere are determined with limit values for the first time. Since the obligations of the Kyoto Protocol will end in 2012, the path to be followed was determined by the "Bali Action Plan" made in 2007 (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2022). At the 15th Conference of the Parties in 2009, the "Copenhagen Consensus" was signed by 140 countries. This agreement is a text that does not require a legal obligation and states that the global temperature increase should be less than 2°C. The Paris Agreement, which will come into force in 2020, was prepared at the 21^{st} Conference of the Parties held in 2015. The Treaty of Paris was signed and entered into force in 2016. The Paris Agreement is the first global agreement to enter into force in less than a year. This agreement is a treaty that states that the global temperature increase should be less than 2°C and even wants to limit it to 1.5°C (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2022). When the global annual average carbon dioxide concentration data is examined in the graph below, it is seen that the carbon dioxide concentration has increased rapidly from 1858 to the present (See Figure 2).

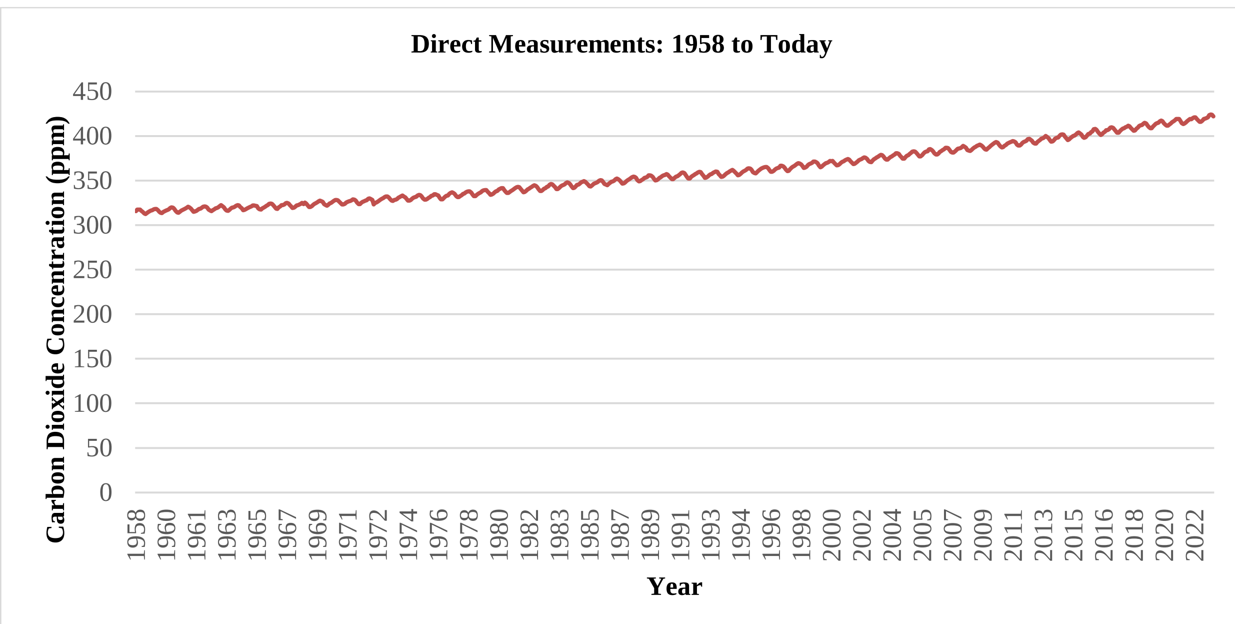

Figure 2: Direct carbon dioxide concentration from 1958 to present (Global Climate Change, 2023)

In Türkiye, air pollution increased its severity after the second half of the 19th century, prompting the introduction of legal regulations (Sümer, 2014). When the per capita amount of carbon dioxide emissions in Türkiye between 1865 and 2022 is examined, it is seen that per capita carbon dioxide emissions have been increasing since 1960 (See Figure 3).

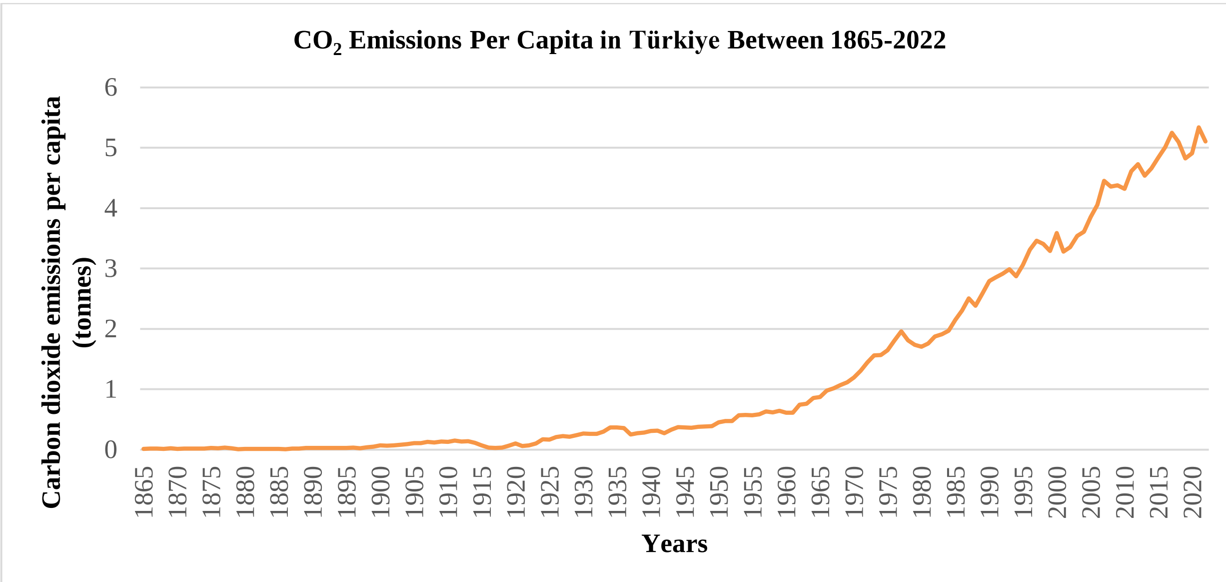

Figure 3: CO_2 emissions per capita in Türkiye between 1865-2022 (Our World in Data, 2024).

With the Kyoto Protocol, an important international agreement, attention was drawn to greenhouse gases and countries were asked to make regulations to reduce carbon emissions (Çelik, 2020). For this purpose, determining the amount of carbon emission has gained importance. Today, we are faced with a climate and biodiversity crisis because the temperature increase is not limited to 1.5°C degrees. The recent occurrence of forced displacements and deaths as a result of extreme weather events, increased food security, difficulties in accessing fresh water, and the occurrence of epidemic diseases of animal origin are due to the deterioration of ecological balance. According to the Living Planet Report (2022) prepared by the World Wide Fund for Nature (WWF), as a result of research conducted worldwide between 1970 and 2018, there is an average decrease of 69% in wildlife vertebrate populations (World Wide Fund for Nature [WWF] Türkiye).

Universities play an important role in the dissemination of sustainable development in society (Figueiro & Raufflet, 2015). Universities serve as a valuable source for creating alternative methods, setting examples for society, guiding it, highlighting important issues, and prompting critical thinking (Valls-Val & Bovea, 2022). Many universities have set an example for other institutions in the society by calculating their own carbon footprint. As can be seen in Table 1 below, some worldwide studies that have calculated the carbon footprint of universities are presented. In some of these studies, the total carbon footprint was determined using various methods or calculated on a per-student basis.

Table 1: Universities that calculate the carbon footprint in the literature scan.

Author	Method	Results	Explanation
Letete et al.	Adapted greenhouse gas protocol	4 tCO_{2e} per student	University of Cape Town Relates to energy consumption of 3.2 t CO_{2e} per student (80%) (Letete, Mungwe, Guma, & Marquard, 2011).
Güereca et al.	Greenhouse Gas Protocol	1.46 tCO_{2e} per person	The carbon footprint of the Engineering Institute of the National Autonomous University of Mexico was calculated (Güereca, Torres, & Noyola, 2013).
Larsen et al.	Greenhouse Gas Protocol / EEIO	4.6 tCO_{2e} per student 16.7 tCO_{2e} per employee	Norwegian University of Science and Technology. Financial criteria focus on Scope-3 (Larsen, Pettersen, Solli, & Hertwich, 2013).
Vásquez et al.	Greenhouse Gas Protocol	3.1 tCO_{2e} per student	The carbon footprint of the University of Madrid (Faculty of Forestry), Mexican Autonomous, Minnesota Mankato State University, Duquesne and Norwegian University of Science and Technology was calculated (Vásquez, Iriarte, Almeida, & Villalobos, 2015).
Li et al.	New survey-based methodology	3.84 tCO_{2e} per capita	Shanghai Tongji University includes a student's personal carbon footprint and GHG emissions from student activities (Li, Tan, & Rackes, 2015).
Almufadi et al.	Greenhouse Gas Protocol	Carbon footprints: Qassim University 4.3 tCO_{2e} per student University of Delaware 7.9 tCO_{2e} per student University of Pennsylvania 13.1 tCO_{2e} per student Yale University 24.6 tCO_{2e} per student Massachusetts Institute of Technology 36.4 tCO_{2e} per student	Qassim University carbon footprint per student was calculated as Scope-1, Scope-2 and Scope-3 (Almufadi & Irfan, 2016).
Görkem Özçelik	DEFRA (2016) conversion factors	Total carbon footprint of the campus: According to Approach-1: 19 709.084 tCO_2/year; 802.7 tCO_{2e}/ha According to Approach-2: 10 122.154 tCO_2/year; 412.3 tCO_{2e}/ha	The carbon footprint of Çanakkale Onsekiz Mart University Terzioğlu Campus is calculated as Scope-1, Scope-2 and Scope-3 (Özçelik, 2017).
Lo-Iacono-Ferreira et al.	ISO 14064	Per student 0.31tCO_{2e} Per employee 2.69 tCO_{2e}	Valencia Polytechnic University covers 3 campuses. The measurement only considers Scope-1 and Scope-2 (Lo-Iacono-Ferreira, Torregrosa-López, & Salvador F. Capuz-Rizo, 2018).

Ali Üreden	IPCC methodology (Tier Method)	Total carbon emissions: 5 633.13 tCO_{2e}/year	The carbon footprint of Çankırı Karatekin University has been calculated (Üreden, 2019).
Kumaş et al.	IPCC methodology (Tier Method)	Total carbon dioxide emissions: 217.503 $kgCO_{2e}$/year	It was calculated using 2017 pollution data consisting of natural gas used for heating purposes, electricity usage, and transportation caused by students and personnel (Kumaş, Akyüz, Zaman, & Güngör, 2019).
Muhammed Çerçi	IPCC methodology (Tier Method) and DEFRA (2016) conversion factors	According to IPCC Tier 1 approach 2019: 2 753.2 tCO_{2e}/year 2020: 2 383.74 tCO_{2e}/year According to DEFRA conversion factors 2019: 2 314.53 tCO_{2e}/year 2020: 1 826.54 tCO_{2e}/year	Erzincan Binali Yıldırım University's carbon footprint in 2019 and 2020 was calculated separately using IPCC Tier 1 and DEFRA conversion factors (Çerçi, 2021).

When reviewing the literature, it becomes it is seen that carbon footprint calculations are made not only for universities, but also in different areas such as hotels, tourism sector, restaurants, road construction, product manufacturing, production facilities, wastewater treatment plants, transportation and green marketing. Kilic et al. (2021), LCA calculation of the disposal of medical wastes by incineration and autoclave method was made using the OpenLCA program (Kuzu, 2021). In a study conducted by Üçtüğ (2017), the LCA calculation and comparison of the electricity production of four countries was made using the OpenLCA program (Üçtüğ, 2017). In a study by Jayamani and Bakri (2021), LCA analysis of flax and glass fiber phenolic composite used in aircraft production was performed using the GaBi program (Jayamani, Jie, & Bakri, 2021). In a study by Zang et al. (2018), sugar and bioethanol production from sugarcane produced using the GaBi program was provided and the calculation of LCA, which is formed by using this bioethanol as fuel in vehicles (Zang, Martins, & DaFonseca-Zang, 2018). In a study by Fındıkçı (2016), LCA calculations of leather industry wastewater were made using the GaBi program with different scenarios (Fındıkçı, 2016). In a study by Hakyemez (2016), the LCA calculation of the solvent recovery unit in a chemical factory was made using the SimaPro program by setting up different scenarios (Hakyemez, 2016). In a study by Hepdurgun (2019), LCA calculations were made of vehicle movements in different scenarios at an intersection where road renewal work was carried out using the GaBi program (Hepdurgun, 2019). In a study by Tükenmez (2019), LCA analysis of 21 different green concretes was performed using the SimaPro program (Tükenmez, 2019). In a study by Gürbüz (2019), LCA analysis of quartz surface production was performed using the GaBi program (Gürbüz, 2019). In a study by Küçükkaraca (2020), the LCA calculation of the wind turbine was made by creating 4 different scenarios (Küçükkaraca, 2020). In the study of Bahadıroğlu (2021), LCA analysis was performed with different scenarios using the data of a cafe in Istanbul using the GaBi program (Bahadıroğlu, 2021). In a study conducted by Ateş (2021), the carbon footprint of Bingöl Wastewater Treatment Plant was calculated within the scope of Scope-1 and Scope-2 according to the Greenhouse Gas Protocol (Ateş, 2021). In the study conducted by Yüksel (2017), primary and secondary carbon footprints were calculated using the DEFRA and Carbon Footprint calculator prepared by the EPA, as a result of the surveys conducted with the hospital personnel (Yüksel, 2017). In Ahmet's (2019) study, the carbon footprint of some livestock enterprises operating in the Bursa region was calculated using Tier-1 and Tier-2 approaches and IPCC methodology (Tier Method) (Ahmet, 2019). In the study of Ünaldı (2016), a survey system was applied to calculate the carbon footprint in green marketing of Çorum province (Ünaldı, 2016). In Özkaynak's (2020) study, the calculation of the carbon footprint with the questionnaire applied to the people residing in the city of Istanbul was made by using the questionnaire and the IPCC methodology (Tier Method) (Özkaynak, 2020). In Demirbaş's (2018) study, the carbon footprint resulting from the activities of the recycling facility was calculated using the IPCC methodology Tier-1 and Tier-2 methods (Demirbaş, 2018). In Altınöz's (2019) study, the carbon footprint of the road pavement layer was calculated using the IPCC methodology (Altınöz, 2019). In Atabey's (2013) study, the carbon footprint of Diyarbakır province was calculated using the IPCC methodology (Atabey, 2013). In the study of Çelik (2020), the calculation of the carbon footprint originating from transportation in the province of Konya in 2019 was calculated with the Tier-2 approach (Çelik, 2020). In the study of Ayan (2019), the calculation of the carbon footprint originating from the fuel consumption in road transportation in Muğla was made using the IPCC methodology (Tier Method), and it was seen that the increase in the amount of migration to Muğla and the increase in the amount of carbon emissions were parallel (Ayan, 2019). In Güller's (2018) study, the carbon footprint of Muğla Domestic Wastewater Treatment Plant was calculated using $CCALC_2$ software, IPCC (2006) and NGA (2014) (Güller, 2018). In the study of Sunturlu (2017), the carbon footprint of the boats working in the tourism sector in Fethiye was calculated using the IPCC methodology Tier-1 method (Sunturlu, 2017). In Yavuz's (2020) study, the carbon footprint of a 5-star hotel in Antalya with a bed capacity of 1907 was calculated using DEFRA (2016) conversion factors from electricity, water, LNG and diesel (Yavuz, 2020). In Pekin's (2006) study, it was observed that there was an increase in carbon footprint when he examined carbon emissions from road, air, rail and sea transportation from 1990 to 2004 using the IPCC methodology (Tier Method).

In this study, the carbon footprint of Muğla Sıtkı Koçman University was calculated with two separate methods: the IPCC Tier 1 method and DEFRA conversion factors. With this study, the carbon footprint of the university was determined for the first time. In this study, the carbon emissions caused by electricity use were also calculated according to national data, and the results obtained with international emission data were compared. With the CO_2 emission results, the amount of CO_2 emissions caused by the university will be calculated and suggestions will be made to set an example for other studies and potential pollution reduction.

2. MATERIAL AND METHOD

The carbon footprint of Muğla Sıtkı Koçman Universty was calculated based on the total electricity consumption of all university units, fuel usage for heating on campus, and the fuel consumed by the university vehicle fleet. The data used in this research are official data obtained from the university. To assess both direct and indirect emissions produced by the university and calculate its carbon footprint, the received data was converted into CO_2 using the conversion factors from the IPCC catalogue. As seen in Table 2, while the emissions from the fuel used by the university for heating and the emissions from the fuel of the vehicles belonging to the university are included in Scope-1, the emissions caused by the electricity consumption of the university are included in Scope-2. Scope-3 was not used in this study. Scope-3 includes emissions produced indirectly and emissions generated by personnel. In this study, the carbon footprint of the university was calculated within the scope of Scope-1 and Scope-2 of the university for the years 2020 and 2021.

Table 2: MSKU emission source.

Source	Scope	Emissions
Fuel consumption from transportation	Scope-1	Emissions consisting of the fuel types used by the university vehicle fleet and the total amount used
Fuel consumption used in heating	Scope-1	Emissions consisting of the types of fuel used by the university and the total amount used as a result of the heating need.
Electricity consumption	Scope-2	Emissions from the amount of electricity consumed by the university as a result of all kinds of activities

All fuel types and amounts used by the university are given in Table 3 below. Using these data, the IPCC Tier 1 method and DEFRA conversion factors and the carbon footprint of the campus were calculated using Excel and the results were tabulated. When the university's annual total fuel consumption data is examined, it is seen that university vehicles mostly use diesel. The total amount of fuel used at the university in 2022 is more than the total amount of fuel used in 2020 and 2021. Natural gas data received from the university is taken in kWh. In the calculations made with the DEFRA method, kWh value was used as the natural gas unit. However, in the calculations made with the IPCC method, the natural gas value was converted to m^3. Due to the completion of the university's natural gas infrastructure system in 2021, the university's natural gas consumption amount in 2021 and 2022 is higher than in 2020. In the calculations, unit conversion was made by taking 1 standard m^3 of natural gas as 10.64 kWh.

Table 3: MSKU 2020, 2021 and 2022 fuel consumption

Fuels	Unit	2020 Fuel Consumption	2021 Fuel Consumption	2022 Fuel Consumption
Gasoline	Litter	49 000	48 000	63 000
Diesel	Litter	2 000	3 000	4 000
LPG	Litter	2 000	2 500	4 000
Natural Gas	(kWh)	8 303 902	26 237 460	24 829 936
Natural Gas	(m^3)	780 442	2 465 927	2 333 641
Compressed Natural Gas (CNG)	(Sm^3)	13 145	10 673	23 165
Fuel Oil	(kg)	26 480	11 580	22 830
Propane	(kg)	15 000	13 720	19 160
Coal	(ton)	-	120	125
Electric	(kWh)	6 160 599	7 570 192	10 192 598

In the university's carbon footprint calculations, the 2006 IPCC Guide was used as a guide and the Tier 1 approach was taken as the calculation methodology. Data and formulas in IPCC calculations; Calculations were made by using the “Monitoring and Reporting Communiqué Sectoral Calculation Examples”, "Monitoring and Reporting Communiqué Monitoring Plan Guide" published by the Ministry of Environment, Urbanization and Climate Change of Türkiye and by taking the emission data in the "Monitoring and Reporting of Greenhouse Gas Emissions" published in the Official Gazette No. 29068 on July 22, 2014 (Türkiye Ministry of Environment, Urbanization and Climate Change, 2015), (Türkiye Ministry of Environment, Urbanization and Climate Change, 2015), (Official Gazette (Issue:29068), 22.07.2014). Emission factors were determined using the data published in the Official Gazette. These are calculation sources created using the emission factors assumed in the 2006 IPCC Guidelines in the data in the Official Gazette. The results obtained by substituting it in Equation 1 enable the calculation of the greenhouse gas emission value.

$$Emission_{greenhouse\ gas,fuel} = Fuel\ Consumption_{fuel} \,.Emission\ Factor_{CO_2,fuel} \tag{1}$$

To calculate CO2 emissions, the amount of fuel consumed, the net calorific value of the fuel and the appropriate emission value, which varies for each fuel, are used.

According to the IPCC method, the following steps are followed to calculate CO2 emissions:

1. The total consumption amount of the fuels used is calculated.
2. Density values of the fuels to be used in the calculations are given in Table 4 (Official Gazette, 2011). Equation 2 is used to perform unit conversion. The density of compressed natural gas (CNG) is calculated based on 15 ℃ and 20 MPa pressure (UNITROVE, 2022). If the fuel used is gas, the volume data of the gas is multiplied by the density in order to convert it to mass (Türkiye Ministry of Environment, Urbanization and Climate Change, 2015). For liquid fuels, unit conversion is done to change from liters to

cubic meters. In the calculations, the density of gasoline was assumed to be 878.65 kg/m^3, the density of diesel was 840.00 kg/m^3, the density of LPG was kg/m^3, the density of natural gas was 0.72 kg/m^3 and the density of CNG was 0.68 kg/m^3 (Official Gazette, 14 Mayıs 2018).

Table 4: Density values of fuels

Fuels	Unit	Density (kg/m^3)
Gasoline	Litter	878.68
Diesel	Litter	480.00
LPG	Litter	495.00
Natural Gas	(m^3)	0.72
Compressed Natural Gas (CNG)	(Sm^3)	0.68
Fuel Oil	(kg)	-
Propane	(kg)	-
Coal	(ton)	-

$$Fuel\ Consumption\ (kg) = Fuel\ Consumption * Density\left({}^{kg}/_{m^3}\right) * Unit\ Conversion \quad (2)$$

Table 5: Net calorific value of fuels (Official Gazette (Issue:29068), 22.07.2014), (IPCC, 2006)

Fuels	Net Calorific Value (TJ/Gg)
Gasoline	44.3
Diesel	43
LPG	47.3
Natural Gas	48
Compressed Natural Gas (CNG)	50
Fuel Oil	40.4
Propane	-
Coal	28.2

$$Energy\ Consumption\ = Fuel\ Consumption * Conversion\ Factor * Net\ Calorific\ Value \quad (3)$$

3. The energy content of the fuel used is calculated. To do this, the fuel amount is multiplied by the net calorific value. Fuel-specific net calorific value (TJ/Gg) conversion factors are given in Table 5, specified in the IPCC 2006 guide and the value included in the communiqué on monitoring and reporting greenhouse gas emissions that came into force by being published in the Official Gazette dated 22.07.2014 and numbered 29068 (Official Gazette (Issue:29068), 22.07.2014). The energy content of the fuel is calculated using Equation 3. For propane, no net calorific value was used in the calculations. In the calculation, "Monitoring and Reporting Communiqué Sectoral Calculation Examples" and "Monitoring and Reporting Communiqué Monitoring Plan Guide" published by the Ministry of Environment, Urbanization and Climate Change were used. According to the guidelines, the calculation was made without using the net calorific value of propane (Türkiye Ministry of Environment, Urbanization and Climate Change, 2015), (Türkiye

Ministry of Environment, Urbanization and Climate Change, 2015). In the calculations, the calorific values were taken as 44.3 TJ/Gg for gasoline, 43 TJ/Gg for diesel, 47.3 TJ/Gg for LPG, 28.2 TJ/Gg for coal, 48 TJ/Gg for natural gas, 40.4 TJ/Gg for fuel oil and 50 TJ/Gg for CNG. The net calorific values given in the IPCC method and the values published in the official gazette in Türkiye are the same. Since the values published by IPCC are suitable for Türkiye, these values were published in the official gazette.

4. The total carbon dioxide content in the fuel is calculated by multiplying the calculated energy consumption value with the carbon emission factor given in Table 6, taken from the values in the communiqué on monitoring and reporting of greenhouse gas emissions, which was specified in the IPCC 2006 guide and published in the Official Gazette dated 22.07.2014 and numbered 29068. Equation 4 is used in this calculation (Official Gazette (Issue:29068), 22.07.2014). The emission factor of the fuels was calculated as 69 300 kg CO_2/TJ for gasoline, 74 100 kg CO_2/TJ for diesel, 63 100 kg CO_2/TJ for LPG, 94 600 kg CO_2/TJ for coal, 56 100 kg CO_2/TJ for natural gas, 77 400 kg CO_2/TJ for fuel oil, 2.99 for propane and 64 200 kg CO_2/TJ for CNG. In the calculations for propane, the emission factor given in the "Monitoring and Reporting Communique Sectoral Calculation Examples" and "Monitoring and Reporting Communiqué Monitoring Plan Guide" published by the Ministry of Environment, Urbanization and Climate Change was used. According to the guidelines, the calculation was made without using the net calorific value of propane (Türkiye Ministry of Environment, Urbanization and Climate Change, 2015), (Türkiye Ministry of Environment, Urbanization and Climate Change, 2015). The emission factors given in the IPCC method are the same as the emission values published in the official gazette in Türkiye. Since the values published by IPCC are suitable for Türkiye, these values were published in the official gazette.

Table 6: Net calorific value of fuels (Official Gazette (Issue:29068), 22.07.2014), (IPCC, 2006)

Fuels	Net Calorific Value (TJ/Gg)
Gasoline	69 300
Diesel	74 100
LPG	63 100
Natural Gas	56 100
Compressed Natural Gas (CNG)	64 200
Fuel Oil	77 400
Propane	2.99
Coal	94 200

$$Emission\ Content\ (kg\ ) = Emission\ Factor\ \left({}^{kg}/_{TJ}\right) * EnergyConsumption\ (TJ) \qquad (4)$$

5. To calculate the carbon value completely involved in combustion, Equation 5 is used to calculate carbon dioxide emissions in kilograms. In order to calculate greenhouse gas emissions, the oxidation and conversion factors were taken as 1.00 and the biomass ratio was taken as 0.00, as stated in the "Monitoring

and Reporting Communiqué Sectoral Calculation Examples" and "Monitoring and Reporting Communiqué Monitoring Plan Guide" published by the Ministry of Environment, Urbanization and Climate Change (Türkiye Ministry of Environment, Urbanization and Climate Change, 2015), (Türkiye Ministry of Environment, Urbanization and Climate Change, 2015), (Official Gazette (Issue:29068), 22.07.2014).

Table 7: Biomass ratio, oxidation factor and conversion factor of fuels (Türkiye Ministry of Environment, Urbanization and Climate Change, 2015), (Official Gazette (Issue:29068), 22.07.2014).

Fuels	Biomass Ratio	Net Calorific Value (TJ/Gg)
Gasoline	0.00	1
Diesel	0.00	1
LPG	0.00	1
Natural Gas	0.00	1
Compressed Natural Gas (CNG)	0.00	1
Fuel Oil	0.00	1
Propane	0.00	1
Coal	0.00	1

$$Carbon\ Emission(kg\ CO_2) = Emission\ Content(kgCO_2) * (1 - Biomass\ Ratio) * Oxidation\ Factor \tag{5}$$

Calculation of the amount of CO_2 emissions for the electrical energy used:

1. The amount of electricity used is calculated in kWh.
2. Electricity emission factors are given in Table 8 below. The value of 0.48 kg/kWh given in the IPCC 2006 guide was used in the calculations. At the same time, calculations were made using the electricity emission factor, which is Türkiye's data. According to the data of the Ministry of Energy and Natural Resources of Türkiye, an average of 0.44 tons/MWh CO_{2e} greenhouse gas emissions are emitted per 1 MWh (unit) of net electricity production throughout Türkiye (Republic of Türkiye Ministry of Energy and Natural Resources, 2023). Using the equations given in Equation 6 and Equation 7, the amount of CO2 emissions is calculated by multiplying the amount of electricity used by the emission factors.

Table 8: Electricity consumption emission factor (IPCC, 2006) (Republic of Türkiye Ministry of Energy and Natural Resources, 2023)

Data Source	Emission Factor (kg/kWh)
IPCC 2006 Guide	0.48
Türkiye Ministry of Energy and Natural Resources	0.44

$$Carbon\ Footprint = Activity\ Data * Emission\ Factor\ Faktörü \tag{6}$$

$$CO_2\ Emission(kgCO_2) = Amount\ of\ Electricity\ Used(kWh) * Emission\ Factor\ \frac{kg\ CO_2}{kWh} \tag{7}$$

To calculate CO2 emissions according to the DEFRA method, the following steps are followed in order:

Equation 8 is used in this calculation.

$$Carbon\ Footprint = Activity\ Data * DEFRA\ Emission\ Factor \tag{8}$$

In the study, DEFRA emission factors will be used to calculate the carbon footprint of Muğla Sıtkı Koçman University. The emission factors used in this article are given in Table 9 (DEFRA, 2022). Since the 2020 emission factor of propane was not given in the catalog published by DEFRA in 2020, the emission value of 2021 and 2022 was used in the calculations.

Table 9: DEFRA conversion factors for 2020, 2021 and 2022 (DEFRA, 2022)

	Fuel Type	Unit	Year	kg CO_{2e}
SCOPE 1	Gasoline	lt	2020	2.17
			2021	2.19
			2022	2.16
	Diesel	lt	2020	2.55
			2021	2.51
			2022	2.56
	LPG (Liquefied Petroleum Gas)	lt	2020	1.56
			2021	1.56
			2022	1.56
	Coal	ton	2020	2 883.26
			2021	2 883.26
			2022	2 883.26
	Natural gas	kWh	2020	0.20
			2021	0.20
			2022	0.20
	Fuel oil	ton	2020	3 229.20
			2021	3 229.20
			2022	3 229.20
	Propane	ton	2020	2 997.55
			2021	2 997.55
			2022	2 997.55
	Compressed natural gas (CNG)	kWh	2020	0.20
			2021	0.20
			2022	0.20
SCOPE 2	Electric	kWh	2020	0.23
			2021	0.21
			2022	0.19

The data obtained as a result of calculating the carbon footprint of MSKU with the IPCC Tier 1 method are given in Tables 10, 11 and 12 below (IPCC, 2006).

Table 10: CO_2 emission calculation for 2021 according to the IPCC Tier 1 approach (IPCC, 2006).

Scope	Fuels	Fuel Consumption	Net Calorific Value (TJ/Gg)	Density (kg/m^3)	Emission Factor (kg CO_2/TJ)	Biomass Ratio	Oxidation Factor / Conversion Factor	CO_2 Emission (kg)
Scope 1	Gasoline (lt)	2 000	44.30	878.65	69 300	0	1	5 394.89
	Diesel (lt)	49 000	43	840.00	74 100	0	1	131 148.11
	LPG (lt)	2 000	47.30	495.00	63 100	0	1	2 954.78
	Coal (kg)	-	28.20	-	94 600	0	1	-
	Natural Gas (m^3)	8 303 902	48	0.72	56 100	0	1	1 506 828.55
	Fuel Oil (kg)	26 480	40.40	-	77 400	0	1	82 801.90
	Propane (kg)	15 000	-	-	2.99	0	1	44 895.00
	CNG (m^3)	13 145	50	0.68	64 200	0	1	28 692.91
					Emission Factor (kg/kWh)			
Scope 2	Electric (kWh)	6 160 599.10	-	-	0.48	-	-	2 957 087.57
TOTAL CO_2 EMISSIONS IN 2020								4 759 803.71

Table 11: CO_2 emission calculation for 2022 according to the IPCC Tier 1 approach (IPCC, 2006).

Scope	Fuels	Fuel Consumption	Net Calorific Value (TJ/Gg)	Density (kg/m^3)	Emission Factor (kg CO_2/TJ)	Biomass Ratio	Oxidation Factor / Conversion Factor	CO_2 Emission (kg)
Scope 1	Gasoline (lt)	3 000	44.30	878.65	69 300	0	1	8 092.34
	Diesel (lt)	48 000	43	840.00	74 100	0	1	128 471.62
	LPG (lt)	2 500	47.30	495.00	63 100	0	1	3 693.48
	Coal (kg)	120	28.20	-	94 600	0	1	320 126.40
	Natural Gas (m^3)	2 465 926.69	48	0.72	56 100	0	1	4 761 057.38
	Fuel Oil (kg)	11 580	40.40	-	77 400	0	1	36 210.20
	Propane (kg)	13 720	-	-	2.99	0	1	41 063.96
	CNG (m^3)	10 673	50	0.68	64 200	0	1	23 228.50
					Emission Factor (kg/kWh)			
Scope 2	Electric (kWh)	7 570 191.62	-	-	0.48	-	-	3 633 691.98
TOTAL CO_2 EMISSIONS IN 2021								8 955 635.86

Table 12: CO_2 emission calculation for 2022 according to the IPCC Tier 1 approach (IPCC, 2006).

Scope	Fuels	Fuel Consumption	Net Calorific Value (TJ/Gg)	Density (kg/m^3)	Emission Factor (kg CO_2/TJ)	Biomass Ratio	Oxidation Factor / Conversion Factor	CO_2 Emission (kg)
Scope 1	Gasoline (lt)	4 000	44.30	878.65	69 300	0	1	10 789.79
	Diesel (lt)	63 000	43	840.00	74 100	0	1	168 619
	LPG (lt)	2 500	47.30	495.00	63 100	0	1	3 693.48
	Coal (kg)	125	28.20	-	94 600	0	1	333 465
	Natural Gas (m^3)	2 333 640.60	48	0.72	56 100	0	1	4 505 647.65
	Fuel Oil (kg)	22 830	40.40	-	77 400	0	1	71 388.50
	Propane (kg)	19 160	-	-	2.99	0	1	57 345.88
	CNG (m^3)	23 165	50	0.68	64 200	0	1	50 564.56
					Emission Factor (kg/kWh)			
Scope 2	Electric (kWh)	10 192 597.97	-	-	0.48	-	-	4 892 447.03
TOTAL CO_2 EMISSIONS IN 2022								10 093 960.88

Fuel consumption amounts for 2020, 2021 and 2022 obtained from the university were used and the total amount of CO_2 emissions produced by the school was calculated with the emission factors published by DEFRA (DEFRA, 2020). The data obtained as a result of calculating MSKU's carbon footprint using the DEFRA method is given in Table 13 below.

In the calculations, the value of 0.48 kg/kWh given in the IPCC 2006 guide was used. The calculation was made using the electricity emission factor of the Ministry of Energy and Natural Resources of Türkiye, which is also Türkiye's data, with an average value of 0.44 tons/MWh CO_{2e} per 1 MWh (unit) of net electricity production. The results obtained with IPCC and Türkiye data were compared (See Table 14) (Republic of Türkiye Ministry of Energy and Natural Resources, 2023). When the emission values obtained by these three methods are compared, it is seen that the result obtained using the IPCC method gives higher results than the result obtained using the DEFRA method and Türkiye data. When calculating carbon dioxide emissions from electricity, energy transmission line losses are not taken into account.

CO2e is a measurement created by the United Nations Intergovernmental Panel on Climate Change (IPCC) to compare the effects of different greenhouse gases. As a result of carbon footprint calculations, carbon dioxide equivalent (CO2e) is obtained. Carbon dioxide (CO2) and carbon dioxide equivalent (CO2e) measure global warming potential, but carbon dioxide equivalent (CO2e) also includes greenhouse gases. It enables the effects of all greenhouse gases to be explained in one unit.

Table 13: 2020, 2021 and 2022 CO_2 emission calculation according to DEFRA approach.

	Scope	Fuels	Fuel Consumption	Conversion Factor (kg CO_2)	CO_2 Emission (kg)
2020	Scope 1	Gasoline (lt)	2 000	2.17	4 336.04
		Diesel (lt)	49 000	2.55	124 755.47
		LPG (lt)	2 000	1.56	3 110.74
		Coal (kg)	-	2 883.26	-
		Natural Gas (m^3)	8 303 902	0.20	1 691 836.99
		Fuel Oil (kg)	26 480	3 221.37	85 301.88
		Propane (kg)	15 000	2 997.55	44 963.25
		CNG (m^3)	13 145	0.20	28 495.65
	Scope 2	Electric (kWh)	6 160 599.10	0.23	1 436 282.07
	TOTAL CO_2 EMISSIONS IN 2020				4 759 803.71
2021	Scope 1	Gasoline (lt)	3 000	2.19	6 580.56
		Diesel (lt)	48 000	2.51	120 591.84
		LPG (lt)	2 500	1.56	3 892.73
		Coal (kg)	120	2 883.26	345 991.20
		Natural Gas (m^3)	26 237 460	0.20	5 325 417.26
		Fuel Oil (kg)	11 580	3 229.20	37 394.14
		Propane (kg)	13 720	2 997.55	41 126.39
		CNG (m^3)	10 673	0.21	23 049.42
	Scope 2	Electric (kWh)	7 570 191.62	0.21	1 607 378.79
	TOTAL CO_2 EMISSIONS IN 2021				7 511 422.31
2022	Scope 1	Gasoline (lt)	4 000	2.16	8 640.00
		Diesel (lt)	63 000	2.56	161 280.00
		LPG (lt)	2 500	1.56	3 900.00
		Coal (kg)	125	2 883.26	360 407.50
		Natural Gas (m^3)	24 829 936	0.20	4 965 987.20
		Fuel Oil (kg)	22 830	3 229.20	73 722.64
		Propane (kg)	19 160	2 997.55	57 433.06
		CNG (m^3)	23 165	0.20	49 854.62
	Scope 2	Electric (kWh)	10 192 597.97	0.19	1 971 044.60
	TOTAL CO_2 EMISSIONS IN 2022				7 652 269.61

Table 14: MSKÜ's CO_2 emission values calculated in 2020, 2021 and 2022 with three different methods.

Year	IPCC Methodology	DEFRA Method	Türkiye Data
2020	2 957 087.57 kg	1 436 282.07 kg	2 710 663.60 kg
2021	3 633 691.98 kg	1 607 378.79 kg	3 330 884.31 kg
2022	4 892 447.03 kg	1 971 077.60 kg	4 484 743.11 kg

3. RESULTS AND DISCUSSION

When the calculation results were examined, it was seen that the emission results of the same fuel type obtained by different methods in the same years gave different results depending on the fuel types. The biggest difference in the calculation results was seen in the carbon dioxide emissions caused by electricity. The following Table 15 was created by dividing the emission production amounts of IPCC and DEFRA methods into Scope-1 and Scope-2. It was observed that the result obtained using the Scope-1 source DEFRA method of the university in 2020, 2021 and 2022 gave higher results than the IPCC. While the difference between the IPCC and DEFRA methods is lower in 2020, the difference is larger in 2021 and 2022. The reason why this difference is low in 2020 is due to less fuel consumption in 2020 compared to other years.

Table 15: MSKU's emission calculation table according to Scope-1 and Scope-2 in 2020, 2021 and 2022.

Year	IPCC Methodology (kg)		DEFRA Method (kg)	
	Scope-1	Scope-2	Scope-1	Scope-2
2020	1 802 716.14	2 957 087.57	1 982 800.02	1 436 282.07
2021	5 321 943.88	3 633 691.98	5 904 043.54	1 607 378.79
2022	5 201 513.86	4 892 447.03	5 681 225.02	1 971 044.60

Total equivalent CO_2 emissions for 2020 were calculated as 4 759 803.71 kg CO_{2e}. The total equivalent CO_2 emission value for 2021 is calculated as 8 955 635.86 kg CO_{2e}. The total equivalent CO_2 emission value for 2022 is calculated as 10 093 960.88 kg CO_{2e}. Calculations made using the IPCC Tier 1 method showed that the activity causing the largest CO_2 emissions in 2020, 2021 and 2022 was caused by the use of natural gas and electricity. And while the highest carbon dioxide production in 2020 was caused by electricity consumption, it was observed that the highest carbon dioxide production in 2021 and 2022 was caused by natural gas (See Figure 4).

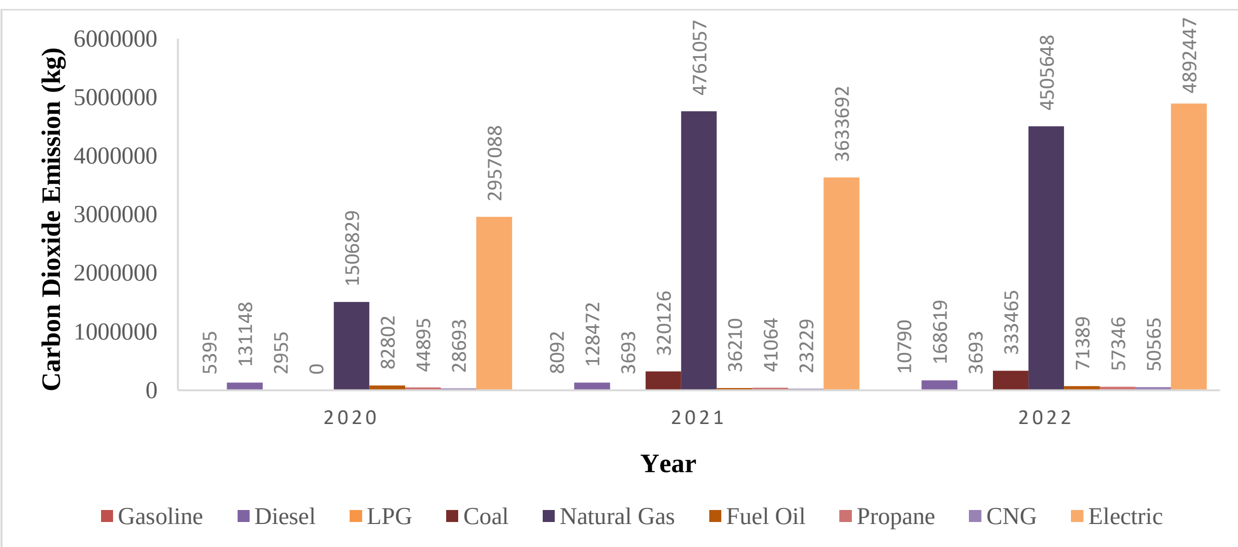

Figure 4: Fuel-based representation of CO_2 emissions at the university in 2020, 2021 and 2022 according to the IPCC Tier 1 approach.

Total equivalent CO_2 emissions in 2020 were calculated as 3 419 082.09 kg CO_2 equivalent. The total equivalent CO_2 emission value for 2021 is calculated as 7 511 422.31 kg CO_2 equivalent. The total equivalent CO_2 emission value for 2022 is calculated as 7 652 269.61 kg CO_2 equivalent. According to the DEFRA approach, when the emission rates of the fuel types that create CO_2 emissions in 2020, 2021 and

2022 are compared, it is seen that the highest CO_2 emissions come from the use of natural gas, followed by electricity (See Figure 5).

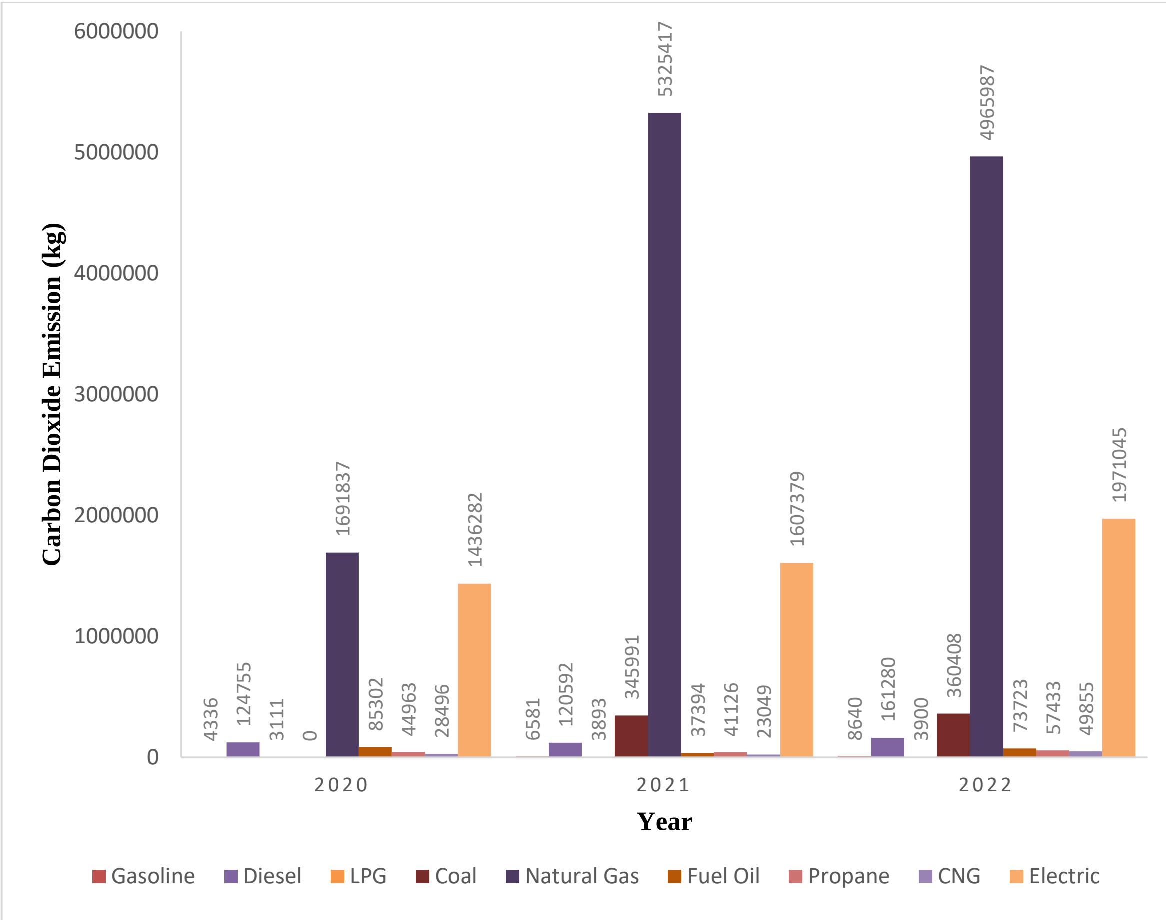

Figure 5: Fuel-based representation of CO_2 emissions at the university in 2020, 2021 and 2022 according to DEFRA conversion factors.

When the annual total fuel consumption data used by the university for heating is examined, it is seen that natural gas is used. The total amount of natural gas used at the university in 2021 is more than the total amount of natural gas used in 2020 and 2022. When the total amount of electricity consumed by the university in 2020, 2021 and 2022 is examined, it is seen that the total electrical energy consumed in 2022 is higher than the total electrical energy consumed in 2021 and 2020.

When the university's emission amounts resulting from Scope-2 in 2020, 2021 and 2022 were compared according to the method used, it was seen that the result calculated with the IPCC method was much higher than the result calculated with the DEFRA method. The difference between the two methods is due to the different emission factors of the IPCC and DEFRA methods. The university's emission value due to electricity consumption between 2020, 2021 and 2022 were compared with the IPCC and DEFRA methods, as well as these results and the results of the use of Türkiye's emission factors due to electricity consumption (See Table 10). When the emission values obtained by these three methods were compared, it was seen that the result obtained using the IPCC method gave the highest value and the result obtained using the DEFRA method gave the lowest value. The reason for this difference is due to the use of renewable energy sources in the electricity production of England, the country that prepared the DEFRA conversion factors (GOV.UK, 2023). Since the electrical energy produced in Türkiye is mostly produced from fossil fuels, its emission factor is higher than DEFRA's emission factor (Republic of Türkiye Ministry of Energy and Natural Resources, 2023). It was observed that the results calculated using Türkiye's data and the IPCC method were similar, but the IPCC method yielded a slightly higher result. The reason for this difference is that the emission value given in the IPCC method is determined as a higher emission value since it is an international value. The reason why Türkiye's data is lower than the value in the IPCC method is that renewable energy is also used in electricity production in Türkiye. In other examined studies, it was observed that the amount of carbon dioxide emissions obtained by the IPCC method gave much higher results than the results obtained using DEFRA conversion factors (Çerçi, 2021).

As a result of all calculations, the amount of Scope-1 emission in 2021 and 2022 is higher than the emission amount of Scope-2. Because the amount of electricity used is low and the amount of fossil fuel used for transportation and heating needs is high. The total amount of emissions in 2020 is lower than the total amount of emissions in 2021 and 2022. Because more fuel was used in 2021 and 2022 than in 2020. When the CO_2 emissions of the university were compared according to Scope-2 in 2020, 2021 and 2022, it was seen that there was a difference between the results obtained using the IPCC Tier 1 approach and the DEFRA method, and this difference was much higher than the difference according to Scope-1. This difference has become more evident, especially in 2021 and 2022. This difference is due to DEFRA conversion factors being lower than the IPCC emission factor. This difference varies in proportion to the carbon emissions created by countries in electricity production. Because the values in DEFRA's catalogue, which is updated every year, are adjusted according to the national data of England, it gave higher values. It has also been seen in other studies that have been examined and previously conducted that the amount of carbon dioxide emissions obtained by the IPCC method gives much higher results than the results obtained using DEFRA conversion factors (Çerçi, 2021). When the university's emission amounts resulting from Scope-2 in 2020, 2021 and 2022 are compared according to the method used, it is seen that the result calculated with the IPCC method is much higher than the result calculated with the DEFRA method. The reason for the big difference in the results is that the emission factor used in the calculation of Scope-2 emissions is different in the IPCC and DEFRA methods. The carbon dioxide emission factor of the UK, which prepares the DEFRA conversion factors, is higher than DEFRA's due to the use of renewable energy sources in electricity production and the high share of fossil fuels in Türkiye's electricity production (Republic of Türkiye

Ministry of Energy and Natural Resources, 2023) (GOV.UK, 2023). As a result of the calculations, it can be seen that the results calculated with Türkiye data and the results obtained with the IPCC method are close to each other. The reason why the value given in the IPCC method is higher than the national data of Türkiye is due to the fact that the emission factor given in the IPCC method was created to calculate carbon dioxide emissions on an international scale and the emission data in Türkiye is a national value. The results were lower than those of the IPCC due to the contribution of renewable energy sources to electricity production in Türkiye. Loss and leakage due to electricity distribution were not taken into account in the calculations.

As a result of all calculations, the carbon emissions at Muğla Sıtkı Koçman University cause the highest emissions in Scope-1 values in 2021 and 2022, except for 2020, and the emission amount in 2022 is higher than the emission amounts in 2021 and 2020. This is mainly due to the fact that the amount of fuel used has increased in 2022.

In cases where it is not possible to reduce or eliminate carbon emissions in a region, afforestation can be carried out in that region to compensate the air pollution caused. According to a study, it was found that a tree photosynthesizes with an average of 22.5 kg of CO_2 annually (Bahçeci, 2013). For this purpose, the number of trees required to zero the CO_2 emission value of Muğla Sıtkı Koçman University is found to be 211,515 and 151,959, respectively, according to IPCC and DEFRA methods for 2020. According to IPCC and DEFRA methods for 2021, it is 398 028 and 333 841 respectively. According to IPCC and DEFRA methods for 2022, it is 448 620 and 340 101 respectively (See Table 16).

Table 16: MSKU's CO_2 emission values calculated in 2020, 2021 and 2022 with three different methods.

Year		IPCC Methodology	DEFRA Method
2020	CO_2 Emission (kg)	4 759 087.57	3 419 082.09
	Number of Required Trees (Grain)	211 515	151 959
2021	CO_2 Emission (kg)	8 955 635.86	7 511 422.31
	Number of Required Trees (Grain)	398 028	333 841
2022	CO_2 Emission (kg)	10 093 960.88	7 652 269.61
	Number of Required Trees (Grain)	448 620	340 101

The university needs to carry out energy saving and energy management studies in order to reduce its carbon footprint. Thermal insulation has been installed on the exteriors of the buildings within the university to prevent heating losses. However, heat losses can be prevented by repairing areas where thermal insulation is not good. Energy saving methods should be investigated to reduce the amount of energy the university needs for heating. For this purpose, the architectural structure of new buildings should be designed to actively use solar energy for both heating and lighting purposes. Project planning should be done during building construction to meet the ventilation and air conditioning needs of buildings. Energy losses resulting from the need for fresh air during the winter months can be minimized by returning fresh air to the building with recovery systems. Heating systems should be replaced with new systems with higher combustion efficiency. Solar chimneys can be used for lighting. The efficiency of heating systems should be checked and if there are leaks, they should be repaired or new efficient systems should be purchased. In order to reduce electricity consumption and emissions, technological devices at the university can be replaced with energy-saving equipment and unnecessary electricity can be avoided. In order to reduce carbon emissions created by the university vehicle fleet, it can be replaced with fuel-saving, energy-efficient and low-fuel-consuming models. By implementing aforementioned measures, the university's carbon dioxide emissions can be reduced. Increasing the use of renewable energy resources on campus and reduction of fossil fuel consumption can be achieved. Thanks to the photovoltaic solar panels located on one facade of the Faculty of Education building located on the central campus of the university, part of the electricity need is met by these panels. Muğla province has high solar radiation due to its location. The Solar Energy Facility at Muğla Sıtkı Koçman University produces an average of 198 000 kWh of electricity annually (Muğla Sıtkı Koçman University , 2024). When the number of photovoltaic panels required for the university to meet all its electricity is calculated as a multiple of the current number of panels, it should be 32 times for 2020, 39 times for 2021 and 52 times for 2022. In order to use this advantage, the number of photovoltaic solar collectors at the university can be increased. Newly constructed buildings at the university can be designed as zero energy. By implementing these measures, the carbon emissions can be significantly reduced.

4. CONCLUSION

In this study, the quantification of Muğla Sıtkı Koçman University's carbon footprint was undertaken via the application of the IPCC Tier 1 methodology and the DEFRA approach. The computations drew upon official datasets provided by the university for determination. In the calculations, the fuel data used by the university in electricity consumption, heating and transportation in 2020, 2021 and 2022 were used. Calculations made using the IPCC methodology showed that carbon dioxide emissions increased by 88% in 2021 compared to 2020 and increased by 13% in 2022 compared to 2021. Calculations made using the DEFRA methodology showed that carbon dioxide emissions increased by 120% in 2021 compared to 2020 and increased by 2% in 2022 compared to 2021. It was observed that carbon dioxide emissions increased with the increase in the amount of natural gas consumed at the university in 2021, and carbon dioxide emissions increased with the increase in compressed natural gas (CNG) consumption in 2022. The increase in emissions during 2021 and 2022 can be attributed to the higher heating demand experienced by the university compared to the preceding year, mainly driven by the prolonged global COVID-19 pandemic, which necessitated the continuation of remote education since March 2020. Therefore, reductions in electricity and fuel consumption resulted in reduced emissions compared to previous years. Furthermore, discrepancies in conversion factors employed in the IPCC and DEFRA methods led to varying outcomes for the university's carbon dioxide emissions in both Scope-1 and Scope-2 categories.

Energy management should be studied at the university in order to reduce the amount of energy the university needs for heating and to save energy. For this purpose, if there is no insulation on the exterior of the buildings, exterior insulation should be provided. If there are leaks in heating systems, they should be checked and old systems should be replaced with new energy-efficient systems. Energy saving methods should be investigated to reduce the amount of energy the university needs for heating. For this purpose, the architectural structure of new buildings should be designed to actively use solar energy for both heating and lighting purposes. Project planning should be done during building construction to meet the ventilation and air conditioning needs of buildings. Fresh air should be returned to the building through recovery systems. In this way, energy loss due to the need for fresh air in winter months is minimized. Heating systems should be replaced with new systems with higher combustion efficiency. Solar chimneys can be used for lighting purposes. Electricity-consuming devices can be replaced with efficient devices. By implementing these measures, emissions can be reduced. By increasing the use of renewable energy sources on campus, the amount of fossil fuel consumed can be reduced by providing the needed energy from clean sources. The university's carbon footprint can be reduced by reducing the energy needs of consumption that will cause carbon emissions by saving energy through measures and suggestions. The biggest change that can reduce the carbon footprint may be the dissemination of efficient technologies by using fuel-saving, energy-efficient systems at universities. In this sense, carbon emissions can be minimized by using renewable energies and choosing energy efficient systems with new systems to be built not only at the university but throughout the country. There are photovoltaic solar panels on the central campus of the university. Since Muğla province has high solar radiation due to its location, an average of 198,000 kWh of electricity is produced annually from these panels (Muğla Sıtkı Koçman University , 2024). The annual electricity amounts needed by the university and the amounts of electrical energy produced from the panels in the university were compared with this study. When the number of photovoltaic panels required to meet all the electricity of the university is calculated as a multiple of the current number of panels, it should be 32 times for 2020, 39 times for 2021 and 52 times for 2022. In order to use this advantage, the number of photovoltaic solar collectors at the university can be increased. The results of this study can be used by the sustainable green campus coordinator to assess our university's place in the emission rankings among other international universities.

Life Cycle Analysis (LCA) has an important place in examining carbon emissions. Life cycle analysis LCA was created according to ISO 14040 and ISO 14044 standards. It is a system that follows and notes all life processes of a product, service or a process, starting from its first acquisition, and includes the calculation of the carbon emissions produced in all steps by noting its final disposal. Since it follows all the steps of a product or service, it is defined by the concept of "cradle to grave" (Ministry of Environment, Urbanization and Climate Change, 2011). According to the results of the report resulting from the life cycle analysis, the step and method that cause the most emissions are determined. Carbon emissions caused by this determined method or step can be reduced. At the same time, the amount of natural resources needed in the same process can be reduced by saving energy and reducing emissions by reusing or recycling by-products and waste materials created while producing the product. It is aimed to eliminate all negativities by popularizing sustainable production. The report resulting from the life cycle analysis reveals the damage caused to the environment at all steps of the product or service, allowing the damage to be seen concretely. By raising awareness of the society that suffers this damage, the climate change and extreme meteorological events we experience today can be prevented. By reducing or eliminating the pollution caused by life cycle analysis, negative effects on the ecological system are prevented and all negativities can be prevented. In this way, by ensuring sustainability, reducing the waste that will occur at every step of production and consumption, using sustainable production, and minimizing the damage to the environment by recycling (recycle-recover-reuse) of the products, this damage is completely eliminated. With the calculations made in this study, the amount of carbon dioxide accumulated in the atmosphere can be estimated and sanctions and regulations can be made to reduce the pollution that will occur. Carbon dioxide emissions can be reduced if universities, one of the leading institutions and organizations in society, draw attention to this field. In this way, it is possible to see the pollution caused by all systems whose life cycle analysis has been performed and to reduce pollution with appropriate interventions.

In this study, two different methods, the IPCC Tier 1 method, and the DEFRA method, were compared. At the same time, it was decided that the use of IPCC Tier 1 was appropriate for Türkiye. It is thought that this study will set an example for other studies to be conducted in the future. Energy consumption and emissions, especially from heating, are high all over the world. Calculating emissions is important for monitoring annual energy consumption and reducing carbon dioxide emissions.

CONFLICT OF INTEREST STATEMENT

There is no conflict of interest among the authors.

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CONTRIBUTIONS OF AUTHORS

E.H. : Conceptualization, methodology, software, validation, formal analysis, investigation, resources, writing—original draft preparation.

G.K.D. : Validation, review and editing.

T.U. : Validation, review and editing.

H.G. : Validation, review and editing.

D. K. : Validation, review and editing.

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