Original Paper

The carbon footprint of a university campus.

Case study of Yildiz Technical University, Davutpaşa Campus, Turkey.

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Abstract. *In this study, the carbon footprint of Yildiz Technical University (YTU), Davutpaşa Campus was calculated to draw attention to the sustainable use of resources, what needs to be done against global climate*

change, and to reveal the responsibilities of universities in this regard and the importance of their contributions. This study was carried out to emphasize the need for higher education institutions to lead in reducing the carbon footprint in every living area in our country. IPCC and DEFRA methods were used to calculate the carbon footprint. The emission values obtained for 2019 and 2020 were 15244.4 and 7213.3 t of CO_2, respectively. The largest component of emissions is electricity consumption, followed by transportation. The obtained values are similar to the results of the studies conducted on other university campuses. The reason for the low emission value in 2020 is the application of the online education system due to the pandemic. The precautions to be taken to reduce the carbon footprint are stated and suggestions are made. YTU, which has already adopted a new environmental policy, is rapidly advancing towards becoming a sustainable campus. In line with the sustainable campus vision, the carbon footprint is expected to decrease significantly.

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1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) defines the term climate change as "change in climatic conditions occurred by long-term changes in climate characteristics" (Eggleston et al., 2006). On the other hand, the United Nations Framework Convention on Climate Change (UNFCCC) attributed climate change directly or indirectly to human activities (UN, 1992). Both definitions of climate change are based on direct or indirect human impact.

Depending on the population growth in the world, anthropogenic greenhouse gas emissions show a rapid increase. Atmospheric concentrations of carbon dioxide, methane, and nitrogen oxides have reached their highest levels in recent years. Greenhouse gases have been accepted as one of the main causes of climate change and global warming since the middle of the 20th century. Anthropogenic greenhouse gas emissions (carbon dioxide, methane, and nitrogen oxides) have been increasing since the beginning of industrialization. Carbon exists as carbon dioxide in the atmosphere (2 %), biomass in terrestrial plants and soils (5 %), fossil fuels in various geological reservoirs (8 %), and as a combination of ions in the ocean (85 %) (McKinley, 2009). The greenhouse gases emitted to the atmosphere as a result of human activities include carbon dioxide (54.7 %),

methane (30 %), other gases (9.8 %), nitrous oxide (4.9 %), and fluorinated gases (0.6 %) (IPCC, 2007).

Cumulative anthropogenic CO_2 emissions between 1750 and 2011 were measured as 2040 Gt CO_2 on average; about 40 % of this remained in the atmosphere, and the rest was stored in the land and oceans. The 30 % absorbed by the oceans causes ocean acidification. More than half of the total anthropogenic CO_2 emissions between 1750 and 2011 occurred in the last 40 y (Pachauri et al., 2014). Total greenhouse gas emissions increased more rapidly from 1970 to 2010, with the greatest increase occurring between 2000 and 2010 despite the measures taken regarding climate change. About 78 % of the increase in total greenhouse gas emissions from 1970 to 2010 comes from fossil fuel use and industrial processes. Similar values were observed between 2000-2010. Globally, economic and population growth are the most important reasons for the increase in CO_2 emissions due to fossil fuel use. Although the population growth between 2000 and 2010 is not different from the last three periods of 10 y, very significant growth was observed in the economy (Pachauri et al., 2014).

As stated in the 4th assessment report of the IPCC, the increase in CO_2 concentrations can be explained by direct and indirect human activities such as fossil fuel use, transportation, heating and cooling activities, manufacturing, and other industrial activities. Carbon dioxide emissions are the largest contributor to climate change (IPCC, 2007) and carbon dioxide emissions can be estimated by the carbon footprint concept. Carbon footprint states to the greenhouse gas emissions released into the atmosphere during the production of the energy needed for each product we purchase or each activity we perform (Bonamente et al., 2015). Since each activity has a different carbon footprint, it is necessary to calculate different factors by carrying out studies on an individual or company basis (Widmann & Minx, 2008). Various methods and standards have been developed in the international arena for carbon footprint calculation. In addition to the methods published by the IPCC, the GHG Protocol, ISO 14064, and PAS 2050 come first among the standards that deal with the 6 main greenhouse gases (CO_2, CH_4, N_2O, PFCs, HFCs, SF6) in the Kyoto Protocol (Güllü, 2011). First, an analysis of the current situation is required to set targets for reducing the carbon footprint. The carbon footprint, which is an indicator that emerges in greenhouse gas accounting (Wiedmann et al., 2010), emerges as a measure that includes direct and indirect greenhouse gas emissions (WRI/WBCSD, 2004).

Turkey became a party to the UNFCCC in 2004 and the Kyoto Protocol in 2009. As an Annex-1 country of the Convention, Turkey is obliged to prepare the greenhouse gas emissions and sinks that cannot be controlled with the Montreal

Protocol with the IPCC methodology and send the national greenhouse gas emission inventory to the UNFCCC Secretariat. By becoming a party to the UNFCCC and the Kyoto Protocol, Turkey has demonstrated its desire to struggle with climate change, and the greenhouse gas emission inventory is the cornerstone of the fight against climate change. Achieving success in this struggle is only possible with the contribution of all segments of society. Universities, private sector organizations, public institutions, non-governmental organizations, and, of course, citizens, who are the biggest stakeholders of society, should act with high awareness and responsibility for sustainability. Universities are institutions that have pioneered society by producing scientific solutions to social problems. In this struggle, it is the responsibility of universities to investigate the causes of global warming, to put forward strategies to reduce the components that cause global warming and to improve them qualitatively, and to determine the measures to be taken. Considering all these issues, universities should first calculate their carbon footprint and implement them by taking the necessary precautions. YTU is one of the largest universities in Turkey with more than 25,000 students and more than 3,000 academic and administrative staff and the Davutpaşa Campus is the central campus of the university. Although reducing greenhouse gas emissions is of great importance on this campus, where human activities are intense, Turkey's leading universities must do this work in terms of awareness. The aim of this study was not only to determine the carbon footprint of YTU Davutpaşa Campus considering the emissions caused by various activities such as fuel use, electricity consumption, vehicle emissions, water consumption and waste amount, but also to create awareness in all segments of the society, primarily universities in Turkey and to be a driving force. Although there are many studies on the determination of the contribution of the carbon footprint to global warming by revealing the universities in the world, the number of studies on this subject in Turkey is limited. The fact that Yıldız Technical University is located in Istanbul, the largest city in Turkey, makes a difference in terms of the size of the components of this footprint. At the same time, these studies are both more difficult and more important in big cities. This study will make a significant contribution to the literature both scientifically and socially in terms of being in YTU, one of the largest universities in Istanbul and one of the largest universities in Turkey.

2. Materials and Methods

2.1 The study area

The Davutpaşa Campus of YTU, which continues its educational activities with 9 faculties, 2 institutes, a school of foreign languages, and more than 25,000 students, was chosen as the study area. The boundary of the campus included in the study is given in Figure 1 (p. 14). Technopark, student dormitory, restaurants, cafes, and lodgings located on the Davutpaşa Campus are not included in the study. A total of 26,842 students including 19,157 undergraduate and 7,685 graduate students are present at the Davutpaşa Campus.

2.2. The calculation method

In this study, the university's direct and indirect greenhouse gas emissions are grouped under three headings. A schematic representation of the emission sources evaluated under 3 headings is given in Figure 2 (p. 15). Emissions originating from the university itself and causing direct greenhouse gas emissions are under heading 1, emissions that are a result of energy consumption and indirectly emitted to the atmosphere are under heading 2, and emissions originating from university activities but not under the control of the university are grouped under heading 3 (Wiedmann et al., 2010). The consumption of natural gas used as fuel in YTU, Davutpaşa Campus, and emissions from vehicles belonging to the rectorate are evaluated under heading 1, and emissions from electricity consumption are under heading 2. Emissions arising from the vehicles belonging to both administrative, academic staff, and students, and buses traveling within the border of the campus, the water consumption of the university, and the emissions from domestic wastes are evaluated under heading 3.

The calculation method of GHG emissions provided by the IPCC was used in the study (Wiedmann et al., 2010). To make the calculations, it is necessary to determine the emission sources and emission factors related to these sources. The carbon footprint of each source was calculated by multiplying the data on emission sources and emission factors (WRI/WBCSD, 2004). IPCC (2006) (Eggleston et al., 2006) guidelines and DEFRA (2016) (WRI/WBCSD, 2004) sources were used for emission factors. The amount of emissions arising from the electricity consumption purchased by YTU, which is evaluated under heading 2, is calculated by multiplying the monthly electricity consumption data obtained from the YTU Rectorate with the emission factors obtained from DEFRA (DEFRA, 2016) and TUIK (TUIK, 2012). Emission factors taken from DEFRA

(DEFRA, 2016) were used to calculate the amount of fuel-related emissions. To calculate the carbon footprint from the fuel, the amount of fuel used was multiplied by the emission factors obtained for N_2O, CH_4, and CO_2. Emission amounts and carbon footprint values due to water consumption were calculated by multiplying water consumption data and the emission factor obtained by Sawant et al. (2015). While calculating the emissions for the vehicle fleet belonging to the YTU Rectorate, passenger vehicles are categorized as large vehicles. Engine volume and fuel type were considered in the calculation of the carbon footprint of passenger vehicles while engine volume, fuel type, and weight was used in the calculation for large vehicles (DEFRA, 2016). Emission values were calculated by multiplying the selected emission factors with the annual average km of the vehicles. Table 1 (p. 21) and Figure 3 (p. 16) show the natural gas, electricity, and water consumption data of YTU Davutpaşa Campus for 2019 and 2020.

3. Results and Discussion

In Table 2 (p. 22) and Table 3 (p. 23), carbon footprint values based on electricity consumption data of Davutpaşa Campus for 2019 and 2020 are given. The schematic representation of the carbon footprint values is given in Figures 4 and 5 (p. 17). The calculated emission values are the carbon footprint resulting from the electricity consumption of the campus and are expressed as t of CO_{2e}.

Under heading 1, fuel consumption for heating purposes and vehicle emissions belonging to the Rectorate of YTU Davutpaşa Campus were evaluated. Natural gas is used as fuel for heating purposes on the campus. Based on the DEFRA (DEFRA, 2016) values, the data obtained for the Davutpaşa Campus for 2019 and 2020 are given in Table 4 (p. 24) and Table 5 (p. 25). In Figure 6 (p. 18), carbon footprint values based on natural gas consumption data of the Davutpaşa Campus are given.

Based on the emission factors taken from the IPCC (Eggleston et al., 2006), the emission of natural gas used for heating was calculated. The CO_2 emission factor used in the calculations is 56.10 kg CO_2/GJ and the unit of natural gas consumed is m^3. Unit conversion is required for the calculation. To convert billion m^3 to GJ, it is necessary to multiply by 37,681,200 GJ/billion m^3. The emission amounts calculated for 2019 and 2020 based on the IPCC (Eggleston et al., 2006) emission factors are given in Table 6 (p. 26) and Table 7 (p. 27), and the schematic representation of the values is given in Figure 7 (p. 18). It can be seen from the tables that the emission values are directly related to the amount of consumption.

Therefore, the use of systems such as isolation and automation will reduce the amount of carbon footprint. Tables 2-5 show that the carbon footprint values calculated using the DEFRA (DEFRA, 2016) and IPCC (Eggleston et al., 2006) emission factors are close to each other. The carbon footprint of YTU Davutpaşa Campus resulting from monthly water consumption in 2019 and 2020 is given in Table 8 (p. 28) and Table 9 (p. 29), and the schematic representation of the values is given in Figure 8 (p. 19).

Another source of CO_2 emission is food consumption. Since calculating the emissions from food consumption is complex, it is necessary to narrow the scope. Therefore, in this study, five groups, namely bread, vegetables, fish, red meat, and chicken, were determined for the types of food consumed to calculate the carbon footprint resulting from food consumption. Emission factors used in the calculation of emission values due to food consumption and the amount of consumed food are given in Table 10 (p. 30), and the calculated emission amounts are given in Table 11 (p. 30). The schematic representation of the emission values from food consumption is given in Figure 9 (p. 19).

The amount of emissions due to domestic waste is calculated by multiplying the amount of waste generated on campus by the emission factor. There are 25 containers on the Davutpaşa campus. The volume of a container is 770 liters and garbage is collected 6 days a week, except Sunday. It is assumed that the unit volume weight of solid wastes is 0.5 kg/L and the fill rate of the containers is 90 %. Using these data, the amount of waste on campus is calculated as 2494800 kg per year. The carbon footprint was determined by multiplying this calculated amount with the emission factor. Accordingly, the amount of carbon footprint caused by domestic waste was calculated as 52.4 t of CO_{2e}.

Emission values calculated for passenger and large vehicles in the vehicle fleet of the Rectorate are given in Table 12 (p. 31). The total CO_{2e} emission value of the Rectorate's vehicle fleet is 43.95 t per year. In addition to the vehicle fleet of the Rectorate, 13 gasoline Toyota brand vehicles with 1500 engine capacity were rented. The CO_{2e} value of rental vehicles, calculated using the DEFRA (DEFRA, 2016) emission factors, is 2 t per vehicle, and the total emission value of 13 vehicles is 26 t. The total emission value of the vehicle fleet is 69.95 t of CO_2 per year and 5.83 t per month.

In YTU Davutpaşa Campus, the number of vehicles with stickers is 1435, and the number of personal vehicles belonging to academic and administrative staff is calculated as 1722 considering vehicles that do not have stickers. It is assumed that 10 % of these vehicles belong to the staff living in the lodgings and that

vehicles coming from outside the campus travel an average of 35 km per day, and vehicles located within the campus travel 3 km per day. The number of academic and administrative staff working at YTU is 2386. If it is accepted that 720 people from the total staff use the staff service vehicle and 360 people provide transportation by public transportation (15 %), the number of vehicles entering the campus from outside can be considered as 1306. A gasoline vehicle consumes 10.7 L/100 km of gasoline in the city and generates 254.7 g CO_2/km emissions. A vehicle using LPG consumes 11.2 L/100 km of gas and generates 266 grams of CO_2/km emissions. A diesel vehicle consumes 9.8 L/100 km of diesel in the city and causes 233 grams of CO_2/km emissions (EPA, 2001). It is assumed that 45 % of the personal vehicles belonging to academic and administrative staff are gasoline, 45 % diesel, and 10 % LPG. Considering that there are 20 workdays per month, the monthly distance traveled by vehicles coming from outside the campus was calculated as 914200 km, and the monthly distance covered by the vehicles located on the campus is calculated as 10320 km. The total distance traveled is 924520 km. The emission value from gasoline vehicles is 105672 kg, the emission value from diesel vehicles is 92562 kg and the emission value from LPG vehicles is 24592 kg. The total emission resulting from the transportation of academic and administrative staff to the campus using their vehicles was calculated as 222826 kg CO_2 per month. Assuming that 500 student vehicles enter the campus per day, these vehicles travel 35 km per day and arrive at campus 4 days a week, the total distance covered is 280000 km per month. The total emission value was calculated as 68040 kg per month. While calculating the annual emission amount, it was taken into account that the academic year is 180 days, but the academic and administrative staff enter and leave throughout the year.

The number of YTU staff service vehicles is 40, the urban diesel consumption amount of the buses is 35 L/100 km and the emission amount is 1034.61 g CO_2/km (EPA, 2001). Assuming that the distance traveled by the service vehicles is 35 km per day, the total distance traveled is 28000 km per month. The amount of emissions from service vehicles is 28969 kg per month. 5 vehicles perform 60 ring trips a day from Cevizlibağ, and 2 vehicles complete 10 ring trips a day to the Beşiktaş campus. The distance traveled for the Cevizlibağ expedition is 9.7 km, and the distance covered for the Beşiktaş expedition is 36 km. The total distance covered daily is 942 km and 18,840 km per month. The total emission value caused by ring services is 19492 kg per month. The 41AT-coded bus of the IETT conducts 53 trips per day to Davutpaşa Campus. The buses, which travel 3 km on the campus, cover a total of 159 km per day and 3180 km per month. The total emission value from public buses entering the campus is

3290 kg per month. 26842 students receive education at Davutpaşa Campus. It is assumed that 7 % of these students do not attend school, among attending students 15 % attend 5 days a week, 15 % two days a week, 40 % four days a week, and 30 % three days a week. It is accepted that the students who come to the school travel an average of 35 km per day. According to these assumptions, 3750 of the approximately 25000 students attending Davutpaşa Campus come to school five days a week, 3750 students two days a week, 10000 students four days a week, and 7500 students three days a week. Assuming that students use buses to come to school and a bus takes 50 passengers, buses travel 62125 km per week and 248500 km per month. For 2019, 2236500 km covered in 9 months means 2313.9 t of CO_2 emissions per year while 497000 km covered for 2020 means 514.2 t CO_2 emissions. The transportation-related emissions of the Davutpaşa Campus are given in Table 13 (p. 32). Emission amounts from sources under headings 1, 2, and 3 are summarized in Table 14 (p. 32) and a schematic representation is given in Figure 10 (p. 20).

YTU Davutpaşa Campus has a total area of 1250000 square meters and a forest area of 220000 square meters. When it is assumed that one tree falls per 10 m^2 in the forest area, it is concluded that there are 22000 trees. Considering that each tree absorbs 25 kg of CO_2 per y, 22000 trees absorb 550 t of CO_2 in a year. While there is 12952.3 t of CO_2 emissions in 2019 and 6701.1 t of CO_2 emissions in 2020 in YTU Davutpaşa Campus, only 550 t of this emission can be absorbed by trees. The remaining part reaches the atmosphere. In Table 15 (p. 33), the studies carried out at various university campuses in Turkey and YTU Davutpaşa Campus are given. Emission values calculated for campuses are close to each other, and it is essential to reduce this value for all campuses.

4. Conclusions and Recommendations

In this study, the carbon footprint of Yildiz Technical University Davutpaşa Campus for 2019 and 2020 was calculated. The results of the study showed that the largest component of the CO_2 emission in the Davutpaşa campus in 2019 was transportation followed by electricity consumption. In 2020, the largest component was electricity consumption. The reason why the emissions from transportation and the emission value obtained for 2020 corresponds to approximately half of the value obtained for 2019 is that online education started in March 2020 due to the pandemic. The carbon footprint of the YTU Davutpaşa Campus is similar to the results of studies conducted on other university campuses. However, it should be noted that the results obtained do not show an exact amount. Because there is a lack of data on some resource consumption and

calculations were made by making various assumptions. The measures and suggestions to be taken to prevent climate change due to global warming and support sustainable life by reducing the carbon footprint of universities, which should lead the society in matters such as sustainability and efficient use of natural resources, are given below:

- Educational seminars should be organized and projects should be conducted at the universities to raise awareness about environmental problems, global climate change, and zero waste.
- Elective courses covering environmental issues, nature protection, global climate change, and sustainable use of natural resources should be included in the course plans of all departments of the university and the selection of these courses should be encouraged.
- Studies that provide savings in water, electricity, heating, and transportation and projects that will form a basis for these studies should be carried out to reduce the carbon footprint.
- Waste management plans should be made to ensure waste minimization and separation of wastes at the source, and encouraging steps should be taken especially regarding recycling and recovery.
- Studies on the use of renewable energy (i.e., wind and solar energy) within the scope of sustainability should be increased and it should be aimed that the university produces its energy.
- Regular afforestation studies should be carried out every year to reduce the carbon footprint.
- Savings and awareness should be created by conducting projects for the reuse of rainwater and gray water.
- Heat loss should be prevented by performing insulation in buildings.
- Emission-reducing measures should be taken regarding transportation to the university.
- A large number of studies and projects are currently carried out at the university to find solutions to sustainable development, global climate change, and other environmental problems. Our university, which has been working on afforestation since its establishment, has been rapidly advancing towards becoming a sustainable campus by adopting a new environmental policy in recent years. Sustainable campus studies are expected to contribute to a significant decrease in carbon footprint values over time.

Yıldız Technical University is rapidly advancing towards becoming a sustainable campus by adopting the green campus approach. For this purpose, studies are carried out to create ecological awareness in many areas such as energy conservation, waste management, and water sustainability. This study covers the years 2019-2020. The studies and measures taken in line with this goal as of these years are given below to set an example for other campuses:

- Preferring the use of energy-efficient appliances at points where the use of electrically consuming appliances is necessary, monitoring the energy consumption throughout the campus, renewing electronic appliances with new generation equipment with less energy consumption during renovation and maintenance works (natural lighting windows designed to make maximum use of daylight in the buildings. Smart systems such as LED lighting, automatic doors, and automatic lighting systems in all buildings throughout the campus to be used during dark hours, air-conditioning systems with high energy efficiency "inverter" technology, energy-efficient devices with "Class A" certificate in areas such as laboratories and faculty kitchens, 20-30 % Energy-Star certified computers and printers that consume less energy.
- To reduce waste, all official correspondence of our university is made electronically, and all document signing and paperwork is carried out over the electronic system at the university, thus saving on stationery costs and waste generation.
- Designing waste containers, special purpose containers, and creating a temporary waste storage area to help students, staff, and guests separate waste effectively and simply on YTU campuses.
- To maintain the water cycle, green area arrangement to protect natural drainage areas, use of drought-resistant or low-water maintenance plants in water management in landscaped areas, improvement of soil drainage, correct design and implementation of irrigation system.
- The use of a tank/rain harvest tank to collect the rainwater flowing from the roof gutters to reduce the tap water used in the landscaping areas on the campus, the use of the water in the rain harvest tank for irrigation of open green areas with economic and smart systems with sensors.

While this study reveals the current situation in YTU as an important data source in terms of the period it was carried out, it will shed light on similar studies to be carried out in other universities in Turkey and around the world. Following this

study, it is planned to conduct a more comprehensive study covering both pre-pandemic and post-pandemic spanning a wider period. In this way, the effects of the studies and measures taken to reduce the carbon footprint will be revealed, and the data to be obtained will be an example for other universities.

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Note about Figures and Tables

Figures and Tables can be downloaded from the respective separate pdf files at this link: http://dx.doi.org/10.13135/2384-8677/7317

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Competing Interests

The authors declare that they have no conflict of interest.

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Appendix 1 – Figures

Figure 1. The boundary of YTU, Davutpaşa Campus (adopted from Google Maps)

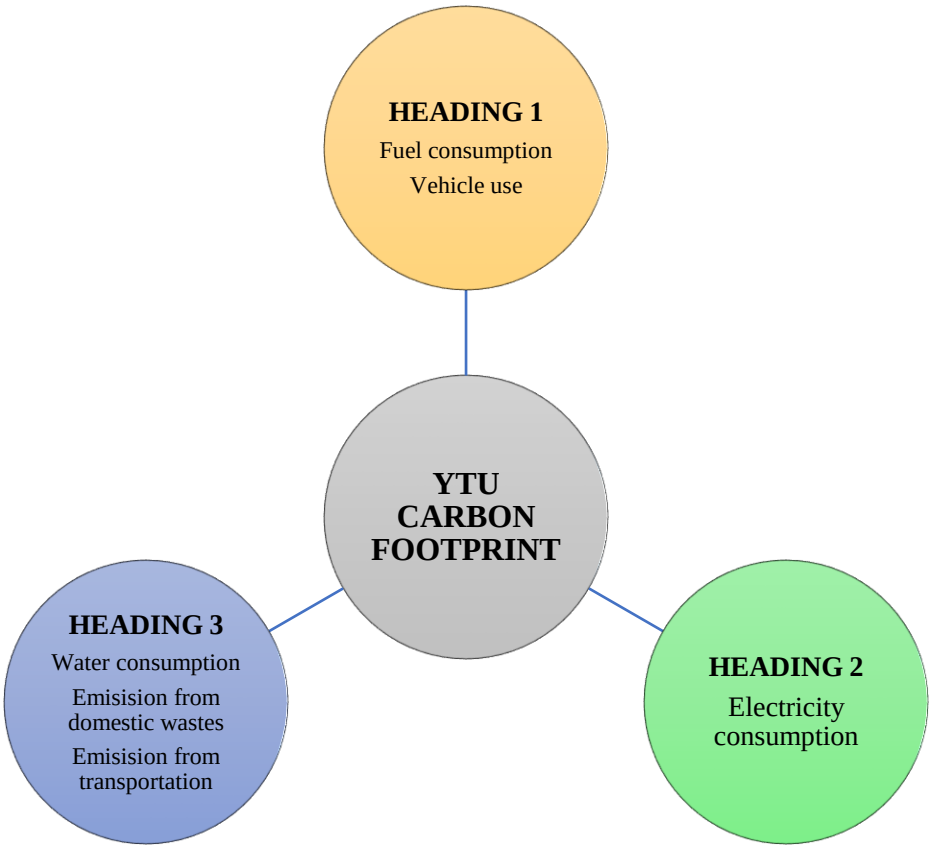

Figure 2. Schematic representation of greenhouse gas emission sources of YTU Davutpaşa Campus

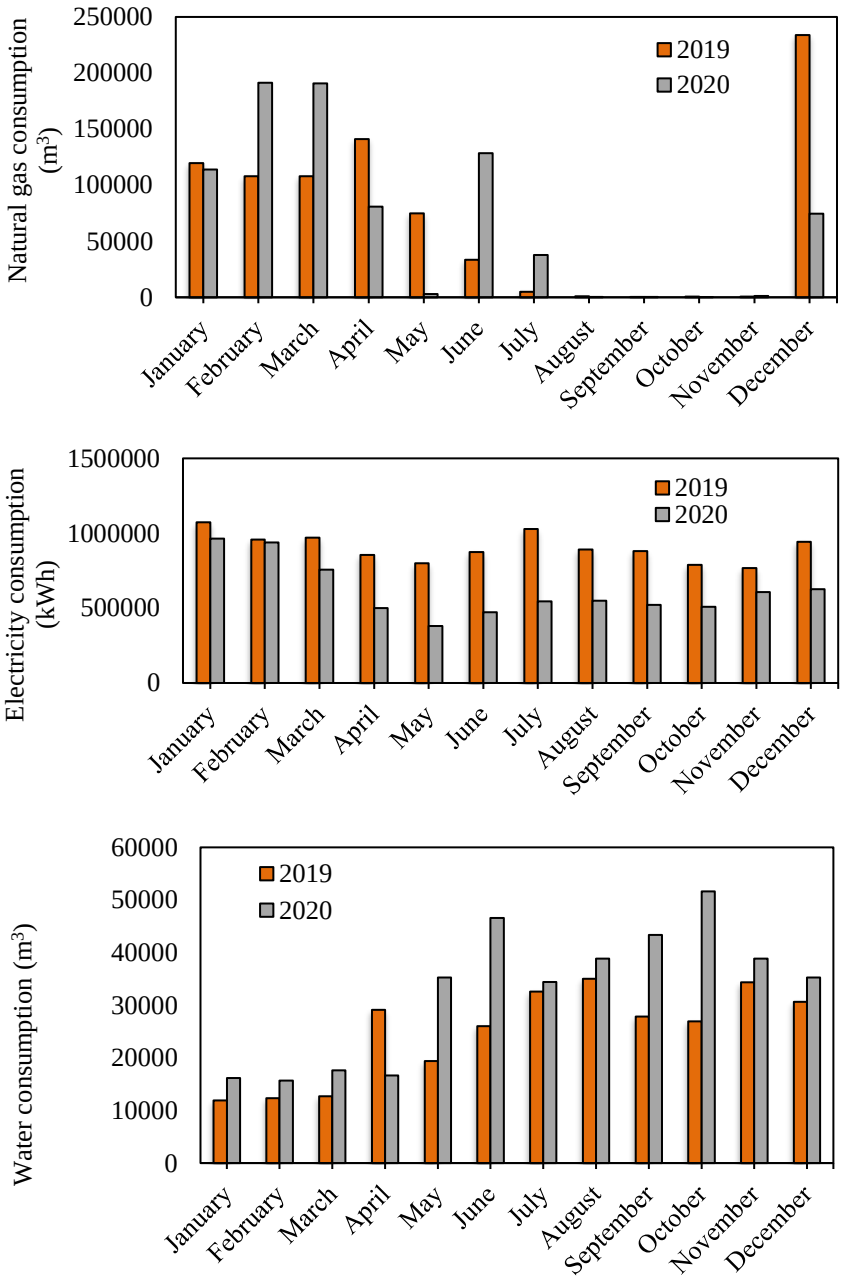

Figure 3. Consumption data for 2019 and 2020 Davutpaşa Campus

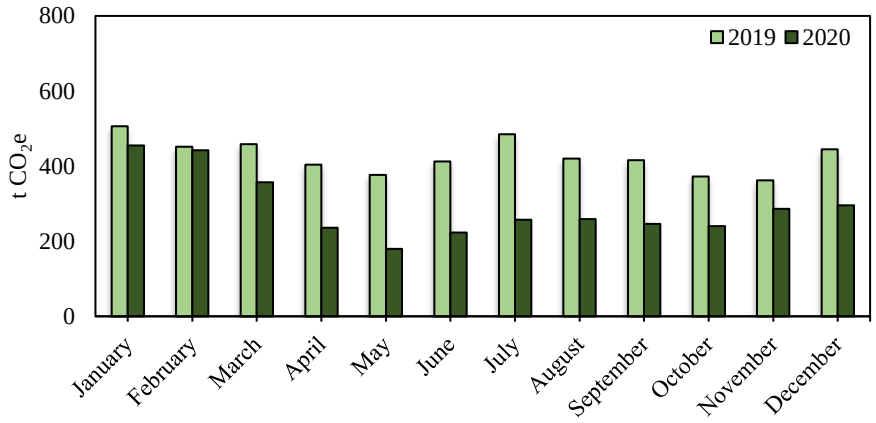

Figure 4. The carbon footprint values of Davutpaşa Campus based on electricity consumption data (DEFRA)

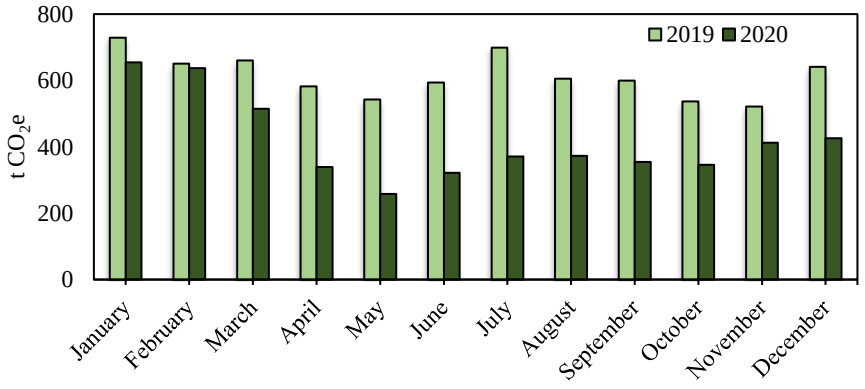

Figure 5. The carbon footprint values of Davutpaşa Campus based on electricity consumption data (DEFRA)

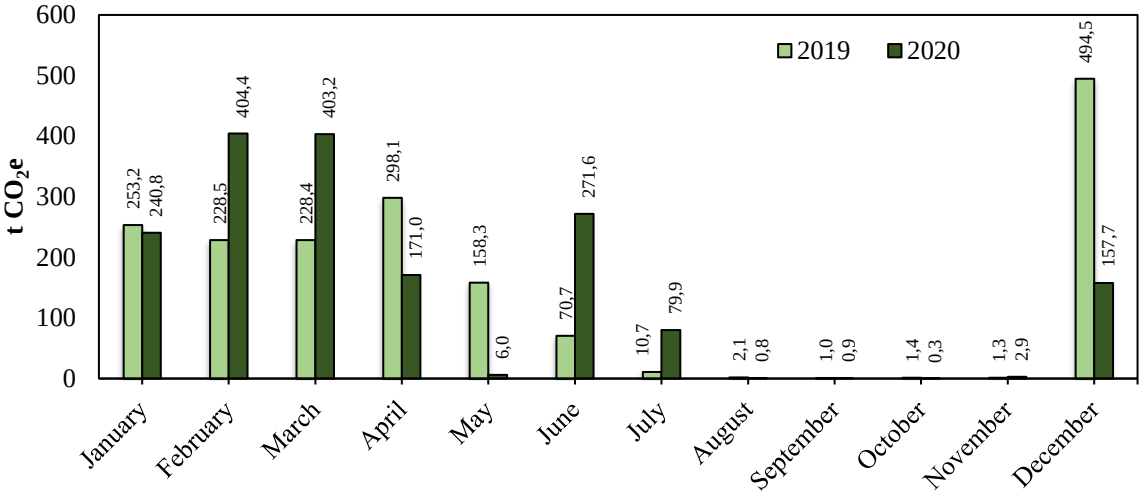

Figure 6. The carbon footprint values of Davutpaşa Campus based on natural gas consumption data.

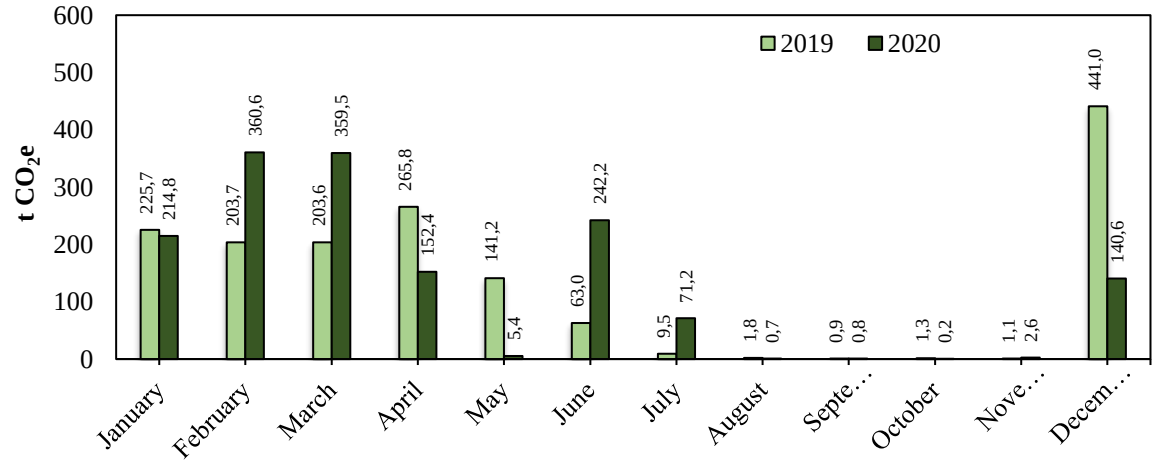

Figure 7. Carbon footprint values due to natural gas consumption of Davutpaşa Campus (IPCC)

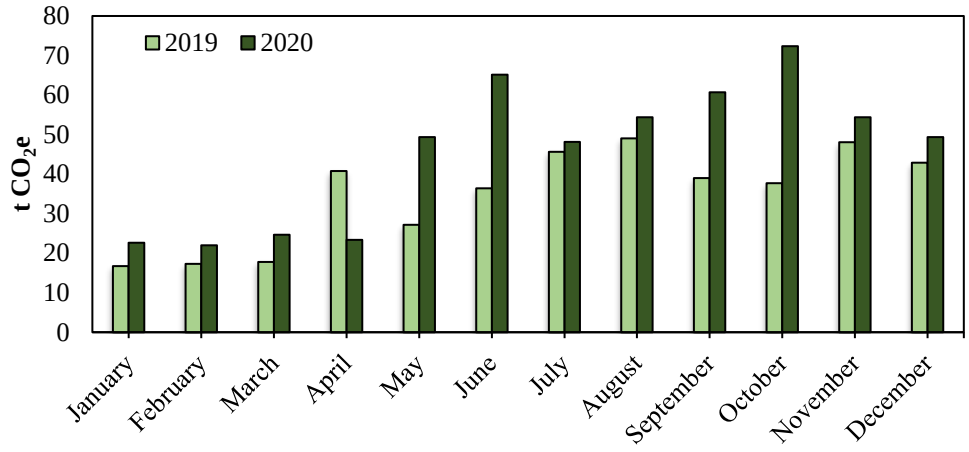

Figure 8. Carbon footprint values due to water consumption of Davutpaşa Campus

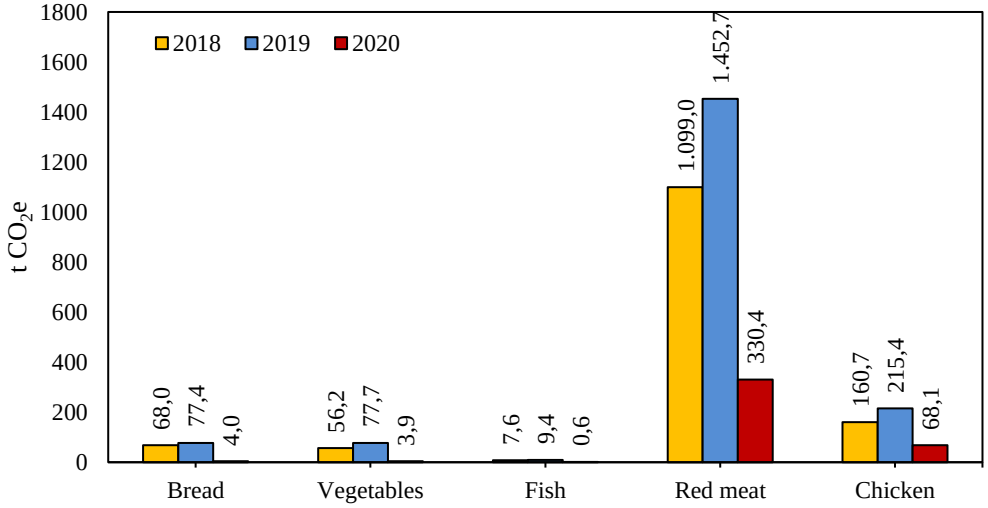

Figure 9. The emission amounts of YTU Davutpaşa Campus due to food consumption

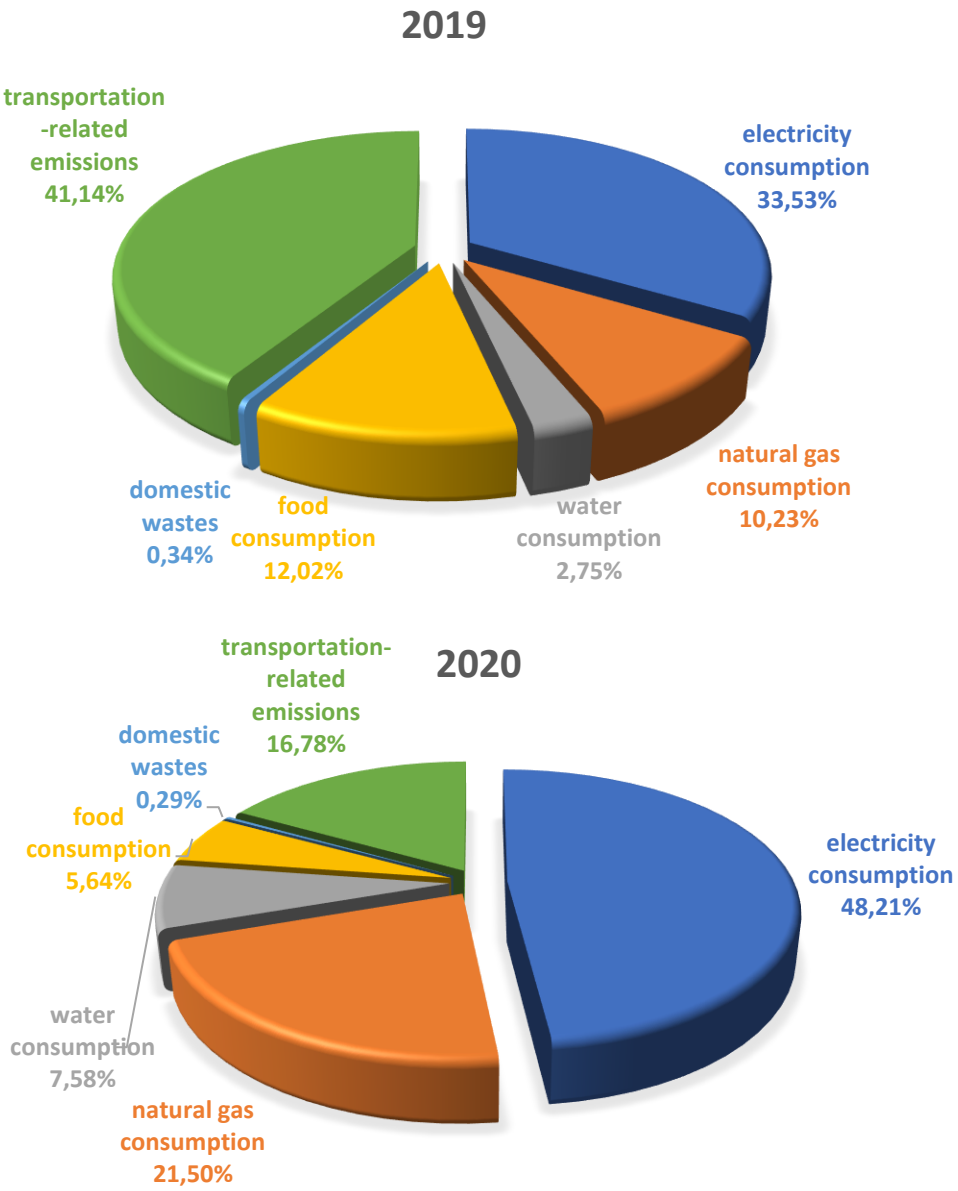

Figure 10. The total emission values of the Davutpaşa Campus

Appendix 2 – Tables

Table 1. Natural gas, electricity, and water consumption data for Davutpaşa Campus

	Natural gas consumption (m^3)		**Electricity consumption (kWh)**		**Water consumption (m^3)**	
	2019	2020	2019	2020	2019	2020
January	119,757.356	113,927.000	1072,549.8	963,233.1	11,928.00	16,183
February	108,079.050	191,284.000	957,230.1	937,751.4	12,325.00	15,697.00
March	108,030.437	190,741.000	971,554.5	756,771.3	12,723.00	17,643.00
April	141,028.155	80,870.000	855,696.6	499,346.1	29,100.00	16,670.00
May	74,881.906	2,847.000	798,668.1	380,238.3	19,409.00	35,273.00
June	33,431.305	128,494.000	873,664.2	472,932.9	25,996	46,564.00
July	5,060.000	37,783.000	1027,423.8	544,886.1	32,583.00	34,397.00
August	980	396	890,451.9	548,363.7	35,039.00	38,871.00
September	467.000	446.000	881,343.9	521,495.1	27,833.00	43,346.00
October	675	131	789,622.2	508,785.3	26,958.00	51,664.00
November	609.000	1,354.000	767,079.9	607,006.8	34,357.00	38,871.00
December	233,946.350	74,595.000	942,760.8	626,550.3	30,657.50	35,273.00
Total	**826,945.56**	**822,868.00**	**10,828,045.8**	**7,367,360.40**	**298,908.50**	**390,452.00**

Table 2. Carbon footprint values due to electricity consumption of Davutpaşa Campus in 2019

2019	Electricity consumption (kWh)	Emission factor (DEFRA 2016) (kg CO_2/kWh)	Emission factor (TUIK 2012) (kg CO_2/kWh)	Emission value (DEFRA 2016) (kg CO_2)	Emission value (TUIK 2012) (kg CO_2)	Carbon footprint (DEFRA 2016) (t CO_{2e})	Carbon footprint (TUIK 2012) (t CO_{2e})
January	1,072,549.8	0.472	0.68	506,243.5	729,333.9	506.2435	729.3339
February	957,230.1	0.472	0.68	451,812.6	650,916.5	451.8126	650.9165
March	971,554.5	0.472	0.68	458,573.7	660,657.1	458.5737	660.6571
April	855,696.6	0.472	0.68	403,888.8	581,873.7	403.8888	581.8737
May	798,668.1	0.472	0.68	376,971.3	543,094.3	376.9713	543.0943
June	873,664.2	0.472	0.68	412,369.5	594,091.7	412.3695	594.0917
July	1,027,423.8	0.472	0.68	484,944	698,648.2	484.944	698.6482
August	890,451.9	0.472	0.68	420,293.3	605,507.3	420.2933	605.5073
September	881,343.9	0.472	0.68	415,994.3	599,313.9	415.9943	599.3139
October	789,622.2	0.472	0.68	372,701.7	536,943.1	372.7017	536.9431
November	767,079.9	0.472	0.68	362,061.7	521,614.3	362.0617	521.6143
December	942,760.8	0.472	0.68	444,983.1	641,077.3	444.9831	641.0773
Total	**10,828,045.8**	**0.472**	**0.68**	**5,110,838**	**7,363,071**	**5110.838**	**7363.071**

Table 3. Carbon footprint values due to electricity consumption of Davutpaşa Campus in 2020

2020	Electricity consumption (kWh)	Emission factor (DEFRA 2016) (kg CO_2/kWh)	Emission factor (TUIK 2012) (kg CO_2/kWh)	Emission value (DEFRA 2016) (kg CO_2)	Emission value (TUIK 2012) (kg CO_2)	Carbon footprint (DEFRA 2016) (t CO_{2e})	Carbon footprint (TUIK 2012) (t CO_{2e})
January	963,233.1	0.472	0.68	454,646	654,998.5	454.646	654.9985
February	937,751.4	0.472	0.68	442,618.7	637,671	442.6187	637.671
March	756,771.3	0.472	0.68	357,196.1	514,604.5	357.1961	514.6045
April	499,346.1	0.472	0.68	235,691.4	339,555.3	235.6914	339.5553
May	380,238.3	0.472	0.68	179,472.5	258,562	179.4725	258.562
June	472,932.9	0.472	0.68	223,224.3	321,594.4	223.2243	321.5944
July	544,886.1	0.472	0.68	257,186.2	370,522.5	257.1862	370.5225
August	548,363.7	0.472	0.68	258,827.7	372,887.3	258.8277	372.8873
September	521,495.1	0.472	0.68	246,145.7	354,616.7	246.1457	354.6167
October	508,785.3	0.472	0.68	240,146.7	345,974	240.1467	345.974
November	607,006.8	0.472	0.68	286,507.2	412,764.6	286.5072	412.7646
December	626,550.3	0.472	0.68	295,731.7	426,054.2	295.7312	426.0542
Total	**7,367,360.4**	**0.472**	**0.68**	**3,477,394.2**	**5,009,805**	**3,477.394**	**5,009.805**

Table 4. Emission amounts due to natural gas consumption of Davutpaşa Campus in 2019

2019	Natural gas consumption (m^3)	t N_2O (emission factor:0.00017)	t CH_4 (emission factor: 1.88496)	t CO_2 (emission factor: 1.88500)	t CO_{2e} (emission factor: 1.88500)
January	119,757.356	0.020359	225.7378	225.7426	225.7426
February	108,079.050	0.018373	203.7247	203.729	203.729
March	108,030.437	0.018365	203.6331	203.6374	203.6374
April	141,028.155	0.023975	265.8324	265.8381	265.8381
May	74,881.906	0.01273	141.1494	141.1524	141.1524
June	33,431.305	0.005683	63.01667	63.01801	63.01801
July	5,060.000	0.00086	9.537898	9.5381	9.5381
August	980	0.000167	1.847261	1.8473	1.8473
September	467,000	7.94E-05	0.880276	0.880295	0.880295
October	675	0.000115	1.272348	1.272375	1.272375
November	609,000	0.000104	1.147941	1.147965	1.147965
December	233,946.350	0.039771	440.9795	440.9889	440.9889
Total	**826,945.56**	**0.140581**	**1558.759**	**1558.792**	**1558.792**

Table 5. Emission amounts due to natural gas consumption of Davutpaşa Campus in 2020

2020	**Natural gas consumption (m^3)**	**t N_2O (emission factor:0.00017)**	**t CH_4 (emission factor: 1.88496)**	**t CO_2 (emission factor: 1.88500)**	**t CO_{2e} (emission factor: 1.88500)**
January	113,927.000	0.019368	214.7478	214.7524	214.7524
February	191,284.000	0.032518	360.5627	360.5703	360.5703
March	190,741.000	0.032426	359.5392	359.5468	359.5468
April	80,870.000	0.013748	152.4367	152.44	152.44
May	2,847.000	0.000484	5.366481	5.366595	5.366595
June	128,494.000	0.021844	242.2061	242.2112	242.2112
July	37,783.000	0.006423	71.21944	71.22096	71.22096
August	396	6.73E-05	0.746444	0.74646	0.74646
September	446.000	7.58E-05	0.840692	0.84071	0.84071
October	131	2.23E-05	0.24693	0.246935	0.246935
November	1,354.000	0.00023	2.552236	2.55229	2.55229
December	74,595.000	0.012681	140.6086	140.6116	140.6116
Total	**822,868.00**	**0.139888**	**1551.073**	**1551.106**	**1551.106**

Table 6. Carbon footprint values due to natural gas consumption of Davutpaşa Campus in 2019 (Eggleston et al. 2006)

2019	**Natural gas consumption (m^3)**	**Natural gas amount (GJ)**	**Emission amount (kg)**	**Emission amount (t)**
January	119,757.356	4,512.601	253,156.9	253.1569
February	108,079.050	4,072.548	228,470	228.47
March	108,030.437	4,070.717	228,367.2	228.3672
April	141,028.155	5,314.11	298,121.6	298.1216
May	74,881.906	2,821.64	158,294	158.294
June	33,431.305	1,259.732	70,670.95	70.67095
July	5,060.000	190.6669	10,696.41	10.69641
August	980	36.92758	2,071.637	2.071637
September	467.000	17.59712	987.1985	0.987199
October	675	25.43481	1,426.893	1.426893
November	609.000	22.94785	1,287.374	1.287374
December	233,946.350	8,815.379	494,542.8	494.5428
Total	**826,945.56**	**31,160.3**	**1,748,093**	1,748.093

Table 7. Carbon footprint values due to natural gas consumption of Davutpaşa Campus in 2020 (Eggleston et al. 2006)

2020	**Natural gas consumption (m^3)**	**Natural gas amount (GJ)**	**Emission amount (kg)**	**Emission amount (t)**
January	113,927.000	4,292.906	240,832	240.832
February	191,284.000	7,207.811	404,358.2	404.3582
March	190,741.000	7,187.35	403,210.3	403.2103
April	80.870.000	3,047.279	170,952.3	170.9523
May	2,847.000	107.2784	6,018.317	6.018317
June	128,494.000	4,841.808	271,625.4	271.6254
July	37,783.000	1,423.709	79,870.06	79.87006
August	396	14.92176	837.1105	0.837111
September	446.000	16.80582	942.8062	0.942806
October	131	4.936237	276.9229	0.276923
November	1,354.000	51.02034	2,862.241	2.862241
December	74,595.000	2,810.829	157,687.5	157.6875
Total	822,868.00	31,006.65	1,739,473	1,739.473

Table 8. Carbon footprint values due to water consumption of Davutpaşa Campus in 2019

2019	Water consumption (m^3)	Water consumption (L)	Emission factor	Emission amount (kg CO_{2e})	Emission amount (t CO_{2e})
January	11,928.00	11928000	0.0014	16,699.2	16.6992
February	12,325.00	12325000	0.0014	17,255	17.255
March	12,723.00	12723000	0.0014	17,812.2	17.8122
April	29,100.00	29100000	0.0014	40,740	40.74
May	19,409.00	19409000	0.0014	27,172.6	27.1726
June	25,996	25996000	0.0014	36,394.4	36.3944
July	32,583.00	32583000	0.0014	45,616.2	45.6162
August	35,039.00	35039000	0.0014	49,054.6	49.0546
September	27,833.00	27833000	0.0014	38,966.2	38.9662
October	26,958.00	26958000	0.0014	37,741.2	37.7412
November	34,357.00	34357000	0.0014	48,099.8	48.0998
December	30,657.50	30657500	0.0014	42,920.5	42.9205
Total	**298,908.50**	**2.99E+08**	**0.0014**	**418,471.9**	**418.4719**

Table 9. Carbon footprint values due to water consumption of Davutpaşa Campus in 2020

2020	Water consumption (m^3)	Water consumption (L)	Emission factor	Emission amount (kg CO_{2e})	Emission amount (t CO_{2e})
January	16,183	16183000	0.0014	22656.2	22.6562
February	15,697.00	15697000	0.0014	21975.8	21.9758
March	17,643.00	17643000	0.0014	24700.2	24.7002
April	16,670.00	16670000	0.0014	23338	23.338
May	35,273.00	35273000	0.0014	49382.2	49.3822
June	46,564.00	46564000	0.0014	65189.6	65.1896
July	34,397.00	34397000	0.0014	48155.8	48.1558
August	38,871.00	38871000	0.0014	54419.4	54.4194
September	43,346.00	43346000	0.0014	60684.4	60.6844
October	51,664.00	51664000	0.0014	72329.6	72.3296
November	38,871.00	38871000	0.0014	54419.4	54.4194
December	35,273.00	35273000	0.0014	49382.2	49.3822
Total	**390,452.00**	**3.9E+08**	**0.0014**	**546632.8**	**546.6328**

Table 10. The amounts of food consumed and associated emission factors

Year	Bread, (kg) (emission factor:0.84 kg CO_2/kg bread)	Vegetables, (kg) (emission factor:0.25 kg CO_2/kg vegetables)	Fish, (kg) (emission factor:3.30 kg CO_2/kg fish)	Red meat, (kg) (emission factor:23.97 kg CO_2/kg red meat)	Chicken, (kg) (emission factor:2.82 kg CO_2/kg chicken)
2018	80900	224,705	2289	45,850.70	56,974.14
2019	92200	310,808	2843	60,605.65	76,387.54
2020	4800	15,510	169,25	13,782.81	24,144.90

Table 11. Annual CO_2 emission amounts (kg CO_{2e})

Year	Bread	Vegetables	Fish	Red meat	Chicken
2018	67956	56176.25	7553.7	1099024.5	160666.68
2019	77448	77702	9381.9	1452701.85	215411.34
2020	4032	3877.5	558.525	330354.54	68086.08

Table 12. The emission values of the Rectorate's vehicle fleet

Rank	Vehicle type	Fuel type	Current km	Monthly average km	Engine volume	Weight	CO_{2e} (t)	CO_2 (t)	CH_4 (t)	N_2O (t)
1	Automobile	Diesel	283,280	990	1968	2110	2.67	2.65	0.00012	0.023
2	Automobile	Diesel	321,460	900	1968	2110	2.43	2.41	0.00011	0.021
3	Automobile	Diesel	322,689	950	1968	2170	2.56	2.54	0.00011	0.021
4	Automobile	Diesel	119,335	900	1598	2070	2.43	2.41	0.00011	0.021
5	Automobile	Diesel	210,275	450	1461	945	0.96	0.95	0.000054	0.01
6	Automobile	Diesel	250,000	400	1461	945	0.85	0.84	0.000048	0.009
7	Automobile	Diesel	230,782	450	1461	945	0.96	0.95	0.00054	0.01
8	Automobile	Diesel	235,516	400	1461	945	0.85	0.84	0.000048	0.009
9	Automobile	Diesel	240,000	425	1461	945	0.9	0.89	0.000051	0.0097
10	Automobile	Diesel	311,000	435	1461	945	0.93	0.92	0.000052	0.0099
11	Automobile	Diesel	266,050	440	1461	945	0.94	0.93	0.000052	0.01
12	Automobile	Diesel	258,008	950	1461	1170	2.02	2	0.00011	0.021
13	Automobile	Diesel	320,486	900	1968	2170	2.43	2.41	0.00011	0.021
14	Automobile	Diesel	42,545	250	1600	985	0.6	0.59	0.001	0.0015
15	Minibus	Diesel	250,888	400	2402	3300	1.368	1.36	0.00008	0.0086
16	Minibus	Diesel	196,681	425	2402	3300	1.45	1.44	0.00008	0.0092
17	Minibus	Diesel	251,500	450	2402	3300	1.54	1.53	0.00008	0.0097
18	Minibus	Diesel	415,241	430	2.5 T	2004	1.47	1.46	0.00008	0.0093
19	Minibus	Diesel	160,157	200	2461	2025	0.68	0.67	0.00004	0.0043
20	Pickup	Diesel	366,532	400	1461	1860	1.37	1.36	0.00008	0.0086
21	Pickup	Diesel	69,305	350	2771	3500	1.2	1.19	0.00007	0.0076
22	Pickup	Diesel	134,201	340	4334	3500	1.16	1.15	0.00007	0.0073
23	Pickup	Diesel	94,645	500	2143	3050	1.71	1.7	0.00009	0.0108
24	Pickup	Diesel	130,829	350	2402	3300	1.2	1.19	0.00007	0.0076
25	Pickup	Diesel	239,568	250	-	2300	0.86	0.85	0.00005	0.0054
26	Bus	Diesel	262,254	400	5193	6936	2.49	2.46	0.00008	0.0086
27	Bus	Diesel	168,663	300	5193	6936	1.87	1.84	0.00006	0.0064
28	Bus	Diesel	134,837	320	4570	5292	1.99	1.96	0.00006	0.0069
29	Bus	Diesel	130,791	330	4570	5292	2.06	2.02	0.00006	0.0071

Table 13. The transportation-related emissions of Davutpaşa Campus

2019 (t CO_{2e})		**2020 (t CO_{2e})**	
Rectorate's vehicle fleet	69.95	Rectorate's vehicle fleet	11.66
Personal vehicles of the staff	2673.9	Personal vehicles of the staff	445.652
Staff services	347.628	Staff services	57.938
Ring buses	233.9	Ring buses	39.88
Personal vehicles of the students	612.36	Personal vehicles of the students	136.1
Public buses	29.6	Public buses	6.57
Transportation of the students	2313.9	Transportation of the students	514.2
Total emission	**6281.24**	**Total emission**	**1211.97**

Table 14. The total emission values of the Davutpaşa Campus

Emission values	**2019 (t CO_2)**	**2020 (t CO_2)**
The emissions due to electricity consumption	5110.84	3477.4
The emissions due to natural gas consumption	1558.8	1551.1
The emissions due to water consumption	418.5	546.6
The emissions due to food consumption	1832.6	406.9
The emissions due to domestic wastes	52.4	20.96
The transportation-related emissions	6281.24	1211.97
Total emission	**15254.4**	**7214.97**

Table 15. Comparison with studies conducted in other universities in Turkey

University	Number of Students and Staff	Emission value (t CO_{2e}/y)	Reference	Method
METU (2000-2014)	26500 students	56036.5 (2014)	(Turanlı 2015)	IPCC (2006)
Sakarya University, Esentepe Campus (2015)	79708 students 2018 staff	12330.73	(Sreng and Yiğit 2017)	IPCC (2006)
Manisa Celal Bayar University (2016)	46525 students 2968 staff	8953.906	(Binboğa and Ünal 2018)	IPCC (2006)
Çankırı Karatekin University (2017)	12856 students 1241 staff	5633.13	(Üreden 2019)	IPCC (2006)
Çanakkale 18 Mart University, Terzioğlu Campus (2016)	23285 students 2232 staff	10122.154	(Özçelik 2017)	IPCC (2006) /DEFRA (2016
YTU Davutpaşa Campus (2019-2020)	34138 students 2386 staff	15244.4 (2019) 7213.3 (2020)	This study	IPCC (2006)/ DEFRA (2016)