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Determination of Carbon Footprint: Düzce University Konuralp Campus

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Abstract

Climate change, one of the most important problems of our age, is a problem that needs an urgent solution as soon as possible. Mathematical models of climate support this idea. With the results of mathematical models related to climate change, it is aimed to predict effects such as increase in the average surface temperature of the planet, rise in sea level, more frequent and intense natural disasters, decrease in water resources, and imbalances in ecosystems. This study was carried out with the aim to emphasize the possible effects of climate change with mathematical models and encouraging people to take action on this issue and to take appropriate measures to minimize the negative consequences. For this reason, this study was presented to calculate the carbon footprint of Düzce University Konuralp Campus with the IPCC methodology Tier1 approach. The amount of carbon footprint was found to be 4.781.841 tons of CO_2. As a result of this analysis, the investment cost of solar energy usage has been calculated since the solar energy availability in the region is appropriate. This study was conducted to draw attention to sustainable campuses and to lead the transition from sustainable campuses to sustainable cities.

Keywords: Carbon footprint, Climate change, IPCC, Sustainability

1. Introduction

Climate change has a general definition as long-term and slow-moving changes in climatic conditions that have universal and important local effects, regardless of the cause [1]. The concentrations of anthropogenic greenhouse gas emissions such as Carbon dioxide (CO_2), Methane (CH_4), Nitrousoxide (N_2O) in the atmosphere are greatly increasing due to the use of fossil fuels since the pre-industrial period, industrialization, increasing population, unplanned urbanization, improper use of lands, deforestation, wastes harmful to nature. Despite the climate change from the first moment of the Earth's existence until today, is occurring faster than it should be due to anthropogenic reasons today. The 5th Assessment report of the Intergovernmental Panel on Climate Change (IPCC) also proves that the increase in global temperature is anthropogenic [2].

As a result of various mathematical climate models, it is concluded that the changes that started in the climate will continue in the future. As a result of this; Floods, drought and drought-related desertification, catastrophic storms, biological outbreaks are some of these problems. These and potential problems will continue to spread to wider regions and will be seen more frequently [3]. Due to these effects, the United Nations Framework Convention on Climate Change was first discussed at the Earth Summit in 1992 in order to prevent the greenhouse gas concentration in the atmosphere from reaching levels that would endanger the atmosphere. In the third conference held, the Kyoto Protocol was signed, in which the countries were envisaged to reduce their absorption rates by at least 5 percent of the 1990 absorption rate [4]. With the Kyoto Protocol, an emission quota was introduced to the responsible countries in order to calculate the carbon emission amounts, and the greenhouse gas emissions should not exceed the quota. It was stated that the carbon footprint of the emission causing the greenhouse gas should be made and a greenhouse gas inventory should be created. As a result of these studies, awareness on reducing emissions has been created for organizations and investors and carbon footprint calculation studies are carried out in different sectors [5]. In 2019, the European Union announced the European Green Deal, in which it stated that EU aims to become a climate neutral continent in 2050, which the industry will have a new growth strategy and will be

reshaped according to climate change. Following this agreement, countries such as South Korea, China and Japan, which have an important place in international trade, began to announce their goals regarding green transformation. Thailand, Sweden, Canada, Norway and Chile are among other countries that have declared net zero emissions [6].

The green agreement action plan was announced in our country in 2021. It is planned that greenhouse gas emissions will decrease by 41% in 2023 by 2030 and the net zero target in greenhouse gas emissions will be achieved by 2053. Studies are being carried out in our country for this purpose [7].

Figure 1 shows the amount of emissions per capita in countries for 2022.

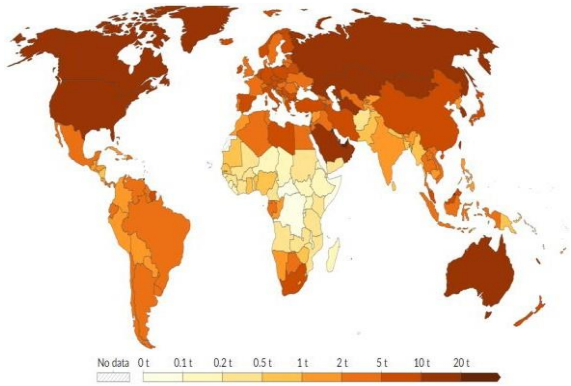

Figure 1. Per capita CO_2 emissions, 2022 [8]

In addition, the most up-to-date method to determine the amount of greenhouse gases caused by human activities is the calculation of carbon footprint.

Carbon footprint is a measure of the total carbon dioxide emissions that result directly or indirectly from a process of individuals, communities, governments, industry sectors, etc. and that a product produces over its entire life cycle [9]. Examining the carbon footprint is also important for monitoring climate change by measuring greenhouse gas emissions of individuals, households, sectors, organizations and cities. In this way, it creates a road map that governments can follow and supports international accountability [10]. While calculating carbon footprint, examinations are made with two main headings as primary and secondary carbon footprint. The primary carbon footprint is a measure of CO2 emissions directly from the combustion of fossil fuels, including household energy and transportation. The secondary carbon footprint is a measure of indirect CO2 emissions throughout the entire life cycle of the products used [11]. Carbon emission amount calculations were made using different approaches and criteria in the literature review.

Since cattle farming in Colombia accounts for approximately 15% of greenhouse gas emissions, González-Quinter et al. in their study measured the carbon footprint (CF) of 82 dairy farms with the survival analysis evaluation technique using IPCC data and determined that Acacia Decurrens, Baccharis Latifolia and Sambucus Peruviana. They investigated its contribution to milk production increase and greenhouse gas reduction potential and examined gas emissions [12]. This study revealed that emissions from municipal solid waste have a significant share in China's efforts to reduce carbon emissions. They examined the production and emissions of municipal solid waste in Yunnan Province under four different waste classification scenarios. In the research, municipal solid waste production was predicted with the STIRPAT model and carbon emissions from municipal solid waste were calculated with the methodologies recommended by IPCC [13]. In this research, He et al. used the IPCC methodology to evaluate the carbon emissions produced by China's Electrical and Electronic Equipment (EEE) emissions between 2012 and 2020 and included the grey model to estimate emissions for that year [14]. In this research, Ezhilkumar et al. estimated the amount and distribution of greenhouse gas emissions at Nile University in Abuja, Nigeria. They calculated the main emission sources at the site, such as energy production, transport, horticulture and cooking fuels, using IPCC guidelines [15].

Binboğa and Ünal conducted a study on calculating the carbon footprint of Manisa Celal Bayar University from a sustainability perspective. Using the IPCC Tier 1 methodology, they determined that the university's primary carbon footprint was 8,953.906 tons of CO2 emissions for the year 2016 [16]. Kumaş, Akyüz, and Güngör Annex 2014 conducted a study on the carbon footprint detection of higher education units at Burdur Mehmet Akif Ersoy University Bucak Campus. They calculated the total carbon footprint of three different colleges as 959,585 CO2 per year [5]. Seyhan and Çerçi investigated the determination of the carbon footprint using IPCC Tier 1 and DEFRA methods, focusing on the fuel and electricity consumption of Erzincan Binali Yıldırım University. Using both methods, they calculated the amount of emissions for the pandemic years 2020 and 2021. They found that the emission amount in 2020 was 21% less than in 2021 [17]. Gökçek, Bozdağ, and Demirbağ conducted a study on the determination of carbon footprint using Niğde Ömer Halisdemir University as an example. They used SPSS statistics application to find the consumption habits statistics of the students and analyzed the spatial distribution of the data using ArcGIS 10.2 software [18]. Yaka, Koçer, and Güngör conducted a study on the detection of carbon footprint at Akdeniz University Vocational School of Health Services. They calculated the carbon footprint of the college using the Annex 2014 method [19]. Atabey conducted a study as part of his master's thesis, focusing on calculating the carbon footprint for Diyarbakır. He used both Tier 1 and Tier 2 approaches in his calculations [11].

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Carbon footprint studies are carried out by various institutions and organizations in different countries. It was decided to contribute to our country's 2053 zero emission targets and to make this contribution at the university, which is the pioneer of scientific developments. Calculating the carbon footprint on campus provides many important benefits such as environmental sustainability, combating climate change, energy efficiency, awareness and education, corporate image and competitive advantage. In this study, Konuralp campus of Düzce University, which has specialized in the field of environment and health, was chosen as the study area. The aim of this study is to lead the transition from sustainable campuses to sustainable cities. Due to the increasing use of solar energy systems on roofs and fields, especially in Düzce, a cost analysis of solar energy installation was also made. The Green Deal action plan also aims to increase the costs of carbon regulations in sectors covered by border carbon regulations and consider aid such as EU ETS state aid as an alternative [6]. In this study, this was calculated for Düzce University and it was aimed to contribute to other studies.

In terms of originality, it is aimed to provide an original contribution locally and regionally, as it is one of the limited number of studies conducted on the carbon footprint of university campuses in Turkey.

In addition, this study does not only analyze the current situation, but also offers concrete suggestions that can be implemented in order to achieve sustainability goals. It is aimed to be a scientific resource by evaluating the environmental impacts of university campuses in a similar way to other higher education institutions in order to develop sustainability strategies with the data obtained.

2. Materials and Methods

2.1. Sources of information and study area

In this study, the carbon footprint was calculated for Düzce University Konuralp campus. As it can be seen Figure 2, there are faculties, central classrooms, Rectorate, training and research hospital, experimental laboratory research center, indoor sports hall in the campus. Monthly electricity and natural gas usage data of these centers for 2022 were calculated by Düzce University Construction and Technical Department. Table 5 gives the monthly electricity consumption of the campus and the hospital within the campus, and Table 6 gives the monthly natural gas consumption of different buildings on the campus.

Transportation data was obtained by calculating the average monthly numbers of trips and the average distance traveled by the lines to the university.

Figure 2. General view of Düzce University [20]

First of all, the natural gas and electricity consumptions of these buildings vere obtained from the official records registred by the university. The transportation data is calculated by using the daily average of trips and average of trip distances.

2.2. Methods

Calculations were made using the emission factors given for the Tier 1 approach in the IPCC 2006 guideline. The steps of this method are as follows:

1) Equation 1 is used to find the consumption values of fuels. The energy consumption values are obtained by multiplying the conversion values in the IPCC guideline given in Table 1 with the fuel consumption values [16].

Table 1. The Net Calorific Values of Fuels [16]

Fuel Types	Net Calorific Value (TJ/Gg)
Natural Gas	48.0
Diesel	43.0
Gasoline	44.3

$$\text{Energy Consumption (TJ)} = \text{Fuel Consumption (t)} \times \text{Net Calorific Values } \left(\frac{\text{TJ}}{\text{Gg}}\right) \quad (1)$$

2) Equation 2 is used to find the total carbon content in the fuel. The average values of the carbon emission factors in the IPCC guide in Table 2 are selected and calculated. The energy consumption and carbon emission factor are multiplied to find the amount of carbon content [16].

Table 2. The Emission Factors of Fuels [21]

Fuel Types	Emission Factors
Diesel	20.20
Gasoline	18.90
Natural Gas	5.30

$$\text{Carbon Content (t C)} = \text{Emission Factor } \left(\frac{\text{t C}}{\text{TJ}}\right) \times \text{Energy Consumption}_i \text{ (TJ)} \quad (2)$$

3) Equation 3 is used to calculate the carbon emission. The oxidation percentages (combustion efficiency) values in Table 3 given by the IPCC are multiplied by the carbon content and the amount of carbon that is completely involved in combustion is found [16].

Table 3. Oxidation Ratio of Fuels [21]

Fuel Types	Oxidation Ratio
Diesel	0.990
Gasoline	0.990
Natural Gas	0.995

$$\text{Carbon Emission (Gg C)} = \text{Carbon Content (Gg C)} \times \text{Carbon Oxidation Ratio} \quad (3)$$

4) As a final step, Equation 4 is used to find the net carbon value of CO2. The molecular weight of carbon is 44/12. When the carbon emission is multiplied by the molecular weight of the carbon, the CO2 emission is obtained [16].

$$\text{CO2 Emission (Gg CO2)} = \text{Carbon Emission (Gg C)} \times (44/12) \quad (4)$$

3. Findings

The total amount of electricity consumed in the campus is given in Table 5. When the consumption data is examined, the amount of electricity consumption in the campus is less in June, July, August and September compared to other months. As seen in Figure 3, the total amount of electricity consumed in the hospital is approximately twice the amount of electricity consumed on campus.

Table 5. Electrical Energy Consumption Values (kWh)

MONTHS	CAMPUS	HOSPITAL
JANUARY	438.253,500	619.523,40
FEBRUARY	378.278,700	549.854,10
MARCH	453.033,300	606.137,40
APRIL	342.495,300	537.213,30
MAY	286.833,000	548.060,10
JUNE	271.314,900	639.084,90
JULY	252.740,100	635.062,20
AUGUST	288.392,400	737.858,40
SEPTEMBER	264.414,900	585.451,20
OCTOBER	364.182,000	533.977,20
NOVEMBER	388.173,300	555.339,60
DECEMBER	448.168,800	601.141,80
TOTAL (kWh)	**4.176.280,20**	**7.148.703,60**
OVERALL TOTAL (kWh)	**11.324.983,80**	

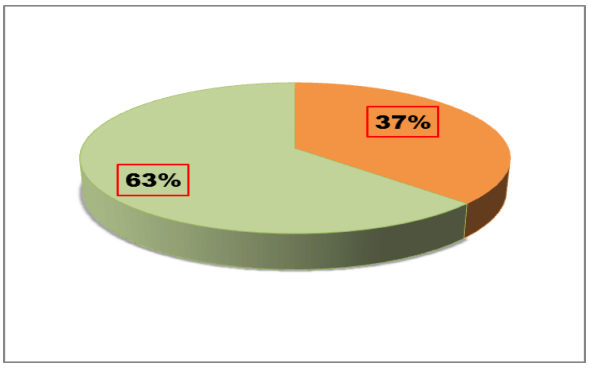

Figure 3. Electrical Energy Consumption Distribution

The natural gas consumption data is on Table 6. Since natural gas is mostly used for heating purposes, natural gas consumption is zero in many buildings in June, July, August and September. When calculations were made using the data, the data in Table 7 of the CO_2 emission were obtained.

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Table 6. Natural Gas Consumption Data (m^3)

Months	Heating Center	Hospital	Rectorate	Faculty of Science & Literature (A-B)	Foreign Languages School	Transportation	New Central Amphitheatre	Central Laboratory	Experimental Research Laboratory	Faculty of Medicine E Block
January	115.620	104.432	27.715	25.319	9.948,52	1.298,70	15.966,56	0,0	0,0	10.860,35
February	92.328	93.667	19.243	12.553	4.982,72	837,38	8.358,49	4.073,30	0,0	6.706,64
March	115.455	109.332	22.058	13.404	5.970	764,0	12.339	4.276,38	2.158	7.859,83
April	55.925	32.757	7.854	5.210	1.668,54	259,72	3.980,82	688,79	1.394	3.356,40
May	129	50.258	121	0,0	0,0	34,76	0,0	0,0	773,35	0,0
June	0,0	15.178	0,0	0,0	0,0	49,97	0,0	0,0	0,0	0,0
July	0,0	17.131	0,0	0,0	0,0	77,46	0,0	0,0	0,0	0,0
August	0,0	15.688	0,0	0,0	0,0	82,44	37,08	0,0	0,0	0,0
September	0,0	16.190	0,0	0,0	0,0	95,0	0,0	0,0	0,0	0,0
October	32.196	53.301	6.290	3.230	1.509	426,0	2.720	0,0	845	1.895
November	72.295	68.185	10.045	7.283	2.604	459,0	4.059	0,0	1.480	2.860
December	89.761	84.028	7.309	7.741	1.808	298,0	5.455	1053	1.003	2.285
Total (m^3)	**573.709**	**660.147**	**100.635**	**74.740**	**28.490,77**	**4.682,43**	**52.915,9**	**10.091,47**	**7.653,35**	**35.823,22**
Overall Total (m^3)				**1.548.888,19**						

Table 7. CO_2 Emission Values

	Tons CO_2	%
Electrical Energy	5.447,32	0.12
Natural Gas	3.319.700,00	69.42
Transportation (Diesel)	1.456.694,32	30.46
Total	**4.781.841,64**	**100**

When Table 7 and Figure 4 are examined, it is concluded that the CO_2 emission amount is caused by natural gas consumption with a rate of approximately 70 percent. Transportation comes next with 30 percent. The amount of emissions from electricity is much lower than the others.

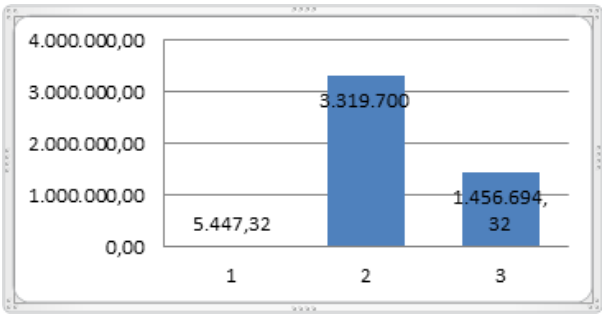

Figure 4. CO_2 Emission Values

In our country, there is no legal obligation to reduce emissions, since the emission values are not yet at a dangerous level. Therefore, our country cannot do carbon trade. Figure 5 shows how the carbon trading certificate works. However, although there is no obligation, projects are actively carried out in voluntary markets [22]. In these projects, if 35 million tons of CO_2 is processed, certified and converted into carbon trade, the value is 200 million dollars.

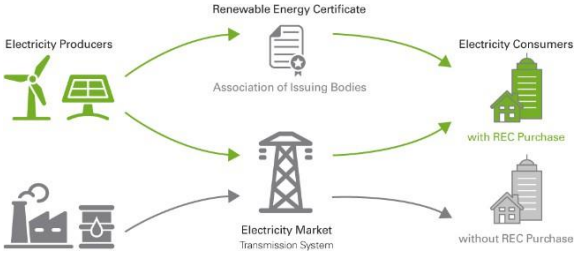

Figure 5. Renewable energy certificate system[23]

In case of carbon trading, the certificate value calculation was made for the amount of carbon originating from electricity consumption for Düzce University. For this, the electrical energy must be completely met by the energy obtained from solar energy. The following steps were followed for the calculation [24].

1) Initially, it is calculated how many solar panels will meet the electrical energy demand. For this reason, in Equation 5, the total amount of electricity consumed annually is divided by the

total amount of hours in 1 year, and the amount of kWh used is found as a result of this process. Solar panel preference is panels with 250 watts of power. For this reason, the amount in kW in Equation 6 is converted into watts.

2) The number of solar panels needed is obtained when the converted value is divided by 250 watts in Equation 7. In order to meet the electrical energy consumed at the university, 5,172 solar panels with a power of 250 watts are needed.

$$\frac{11.324.983,800\ \frac{kWh}{Year}}{8760\ \frac{Hours}{Year}} = 1.292,80\ kW \quad (5)$$

$$1.292,80\ kW = 1.292.806,37\ w \quad (6)$$

$$\frac{1.292.806,37\ watt}{250\ watt} = 5.172\ Panels \quad (7)$$

3) Solar panel installation cost is calculated. Solar energy cost per watt varies between $0.40 and $0.80 [13]. The cost was assumed as an average value and taken in the calculations $ 0.60. When the cost per watt is calculated in Equation 8, the cost is $775.683,822.

$$1.292.806,37 \times 0.60\ \$ = 775.683,822\ \$ \quad (8)$$

4) It is €10 per ton in carbon emission trade. In Table 7, the emission amount due to electricity consumption is 5,447.3168 tons CO_2. In Equation 9, the amount to be obtained from carbon sales is calculated by multiplying the amount of emissions per ton in carbon trade. If the amount of electricity could be certified and sold, € 54,473 would have been obtained.

$$447,3168 \times 10\ € = 54.473\ € \quad (9)$$

5) The expense arising from the annual electricity consumption in the case where the solar energy panel is not installed is calculated in Equation 10. The unit price of 1 kW of electricity is $45 . When we convert it into dollars with the June'23 dollar rate of 20.68, we have a cost of 509.624.271 dollars

$$11.324.983,80 \times 45 = 509.624.27\$ \quad (10)$$

According to the analysis, when we take into account the annual electricity cost and the carbon we would sell if we could participate in the carbon emission trade, the system pays for itself in a short period of about 1 year.

4. Results And Discussion

A campus carbon footprint calculation is an important tool for a university or educational institution to determine its greenhouse gas emissions and guide its reduction efforts. Finding the carbon footprint allows determining what the organization's greenhouse gas emissions are from and how much it is. This information helps the organization to understand its environmental impact and set future goals. Carbon footprint calculation is an important step in the struggle against climate change. Institutions can make contribution for minimizing the effects of climate change by reducing greenhouse gas emissions. Carbon footprint calculation provides a starting point for determining emissions and developing reduction strategies. By analyzing energy consumption data, organizations can identify opportunities for energy savings and develop energy management strategies. This helps to both create a more environmentally sustainable campus and lower energy costs. Sustainability-focused institutions gain reputation and competitive advantage among students, staff and potential students. The carbon footprint calculation provides an opportunity to declare the sustainability goals of the organization and support them with concrete actions.

For this purpose, carbon footprint analysis was carried out in Konuralp Campus of Düzce University. As a result of this analysis, the investment cost has been calculated since solar energy availability in the region is sufficient. In Düzce, the annual sunshine duration and the intensity of the sun's rays are at levels suitable for the use of solar energy systems.

As a result of the study, the amount of carbon footprint was found to be 4.781.841 tons of CO_2. Some effort can be organized to reduce this expanse.

- Since most of the carbon footprint comes from natural gas, thermal insulation can be controlled.
- Information and studies on global climate change and sustainable campus can be increased.
- The use of environmentally friendly and fully recyclable items can be increased.
- Employing electric buses widespread. Encouraging the use of micro-mobility vehicles such as bicycles and electric scooters in individual transportation.
- The use of renewable energy should be increased. The university should be made to meet its own needs.
- The number of trees and ornamental plants suitable for Düzce vegetation can be increased.

- Newly designed buildings can produce in accordance with green building concept.

Turkey is the country with the highest potential to produce thermal energy in Europe - excluding the countries with a coast on the Mediterranean. Electricity generation with solar energy is one of the most important energy policies. After the conversion of solar energy to thermal energy, it has recently started to be popularized with small steps such as traffic lights, park and garden lighting [25].

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Author's Contributions

İrem Düzdar: analytical analysis on the structure, supervised the experiment's progress, result interpretation and manuscript preparation.

Rabia Yıldız: Drafted and wrote the manuscript, performed the experiment and result analysis.

Ethics

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

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