CALCULATING THE CARBON FOOTPRINT FOR ENVIRONMENTAL SUSTAINABILITY: THE CASE OF TED DİYARBAKIR COLLEGE (TÜRKİYE)

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Abstract

It is crucial to promote awareness, particularly throughout society, regarding a topic that holds significant importance for our environment. This study was undertaken with the intention of making a contribution to research on carbon footprint, driven by this motive. In this study, the carbon footprint calculation of TED Diyarbakır (Türkiye) College was made using the IPCC Tier approach. The carbon footprint of 3 different capabilities, namely scope 1 (Natural gas, gasoline, diesel, fire extinguishers), scope 2 (electric) and scope 3 (Water consumption, services), were calculated. When Scope 1, Scope 2 and Scope 3 are evaluated together, it is seen that the amount of carbon footprint originating from Scope 1 is higher. Sources of emissions from Scope 1 include natural gas consumption, diesel and gasoline fuel consumption, as well as fire extinguishers. When the emission sources in the college were compared, it was determined that the highest carbon footprint was due to natural gas consumption within scope 1 (97.98%). Subsequently, it was determined that the carbon footprint was caused by existing vehicle shuttle within scope 3 (1.917%). Finally, it has been determined that the carbon footprint is caused by the existing electricity consumption within scope 2 (0.1%). It is stated that there are 2 reasons for the low carbon footprint caused by electricity consumption. The first is that the equipment used in lighting is LED, and the second is that there is no need for lighting fixtures due to the long lighting time of the day in our geography.

Keywords: *Carbon footprint, environmental sustainability, greenhouse gas emissions, climate change*

1. Introduction

In the 19th century, the industrial revolution played a significant role in a number of factors, including population growth, technological advancements, competition in industrialization, an improvement in the quality of life, and an increase in the demand for energy. As a result, the concentrations of greenhouse gases in the atmosphere increased dramatically. The degradation of the natural ecosystem, global warming, desertification, and the progressive extinction of some biological species provide a significant threat [1]. It has been determined that the global surface air temperature has increased between 0.3°C and 0.6°C since 1800 [2].

Greenhouse gases generated by the use of fossil fuels, irregular use of soil and land are among the factors that cause climate change, and the reduction of forest areas reduces the carbon sequestration potential. According to data from the National Aeronautics and Space Administration (NASA), atmospheric CO_2 emissions increased from 315.71 ppm in 1956 to 398.78 ppm in 2014 and are projected to reach 450 ppm by 2040 [3].

With the second half of the twentieth century, global warming caused by industrialization, energy consumption, etc., has shown its effect, and it has been stated that if no precautions are taken, its effect will continue in the following periods and this effect will bring an irreparable situation.

The unconscious and inefficient use of fossil fuels causes an increase in greenhouse gases in the atmosphere, especially CO_2, the source of global warming. The main greenhouse gas emitted as a result of human activities is CO_2 with 76%, followed by CH_4 with 16%, NO_x with 6% and fluorinated gases with 2% [4] (Fig. 1).

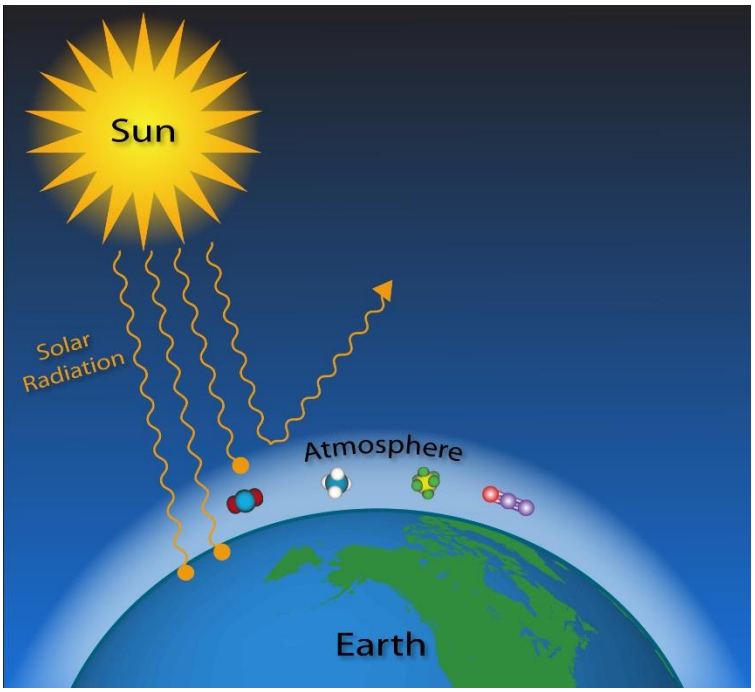

Figure 1. Accumulation of greenhouse gas emissions in our atmosphere
https://www.nps.gov/cajo/learn/nature/greenhouse-gasses.htm

A contract was needed because countries could not set targets for reducing greenhouse gas emissions and could not prepare the necessary infrastructure. Therefore, this situation was eliminated with the Kyoto Protocol, which entered into force in 2005. With the approaches proposed within the framework of the protocol, awareness has been created for countries on reducing carbon emissions and efforts to determine the carbon footprint have gained momentum [5].

The sum of greenhouse gases (GHG) emitted through direct or indirect actions produced by people, organizations, events and products is called the carbon footprint. To calculate the carbon footprint, it is necessary to know exactly the levels of pollution or GHG emissions that we produce each day. As seen in Figure 2, our business activities entail collecting data on the carbon footprint we leave directly and indirectly through electricity consumption, packaging use, materials, transportation, waste management, etc. The carbon footprint is measured in kg of CO2 equivalent (kgCO2e) or tonne of CO2 equivalent (tCO2e) and is calculated by multiplying activity data by emission factors [6].

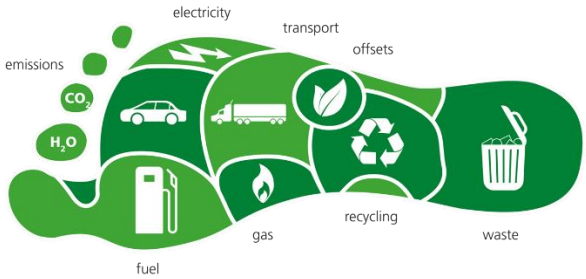

Figure 2. Parameters required to determine carbon footprint
https://www.siegwerk.com/en/sustainability/operations-and-supply-chain/carbon-footprint.html

Different studies have been conducted in the literature regarding the calculation of carbon footprint. Some of these studies are listed in Table 1 with their content.

Tablo 1. Basic studies related to the calculation of carbon footprint

Ref.	Where carbon footprint is calculated / Year(s)	Parameters	Outcomes
[7] Cano	Urban campuses of Universidad Nacional de Colombia, Medellín / 2019	Gaseous fue, liquid fuel, Electricity consumption, Transportation, Waste treatment/valorization /landflls, Internet network	The carbon footprint in 2019 was approximately 7250.52 tons CO2 eq, and 0.432 tons CO2 eq per person. The largest sources of greenhouse gas emissions were the transportation process (58.51%).
[8] Ridhosari	Universitas Pertamina (Indonesia) / 2017-2018	Electricity, transportation, and waste generation (solid waste disposal and waste transportation)	The results showed that electricity is the greatest contributor of carbon emissions at the university, at 92.3%, followed by transportation at 6.66% and waste generation at 1.04%.
[9] Aroonsrimorakot	Mahidol University Faculty of Environmental and Resource Studies /	Electricity and water consumption, amount of wastewater and garbage, amount of fuel	Most of the emissions come from electricity consumption
[10] Sippel	University of Applied Science in Konstanz (Germany) / 2017	Electricity, mobility (including private car use, public transport and aviation), food and other consumption.	The findings show average students' carbon footprint to be 10.9 tCO_2e/year and of the same order of magnitude as the German average.
[11] Sreng and Yiğit	Sakarya University Esentepe campus (Türkiye) / 2015	Including private car use, public transportand aviation and wastepaper	The emission is mostly caused by electricity consumption.
[12] Filimonau	Bournemouth University / 2019-2020	Natural gas, electricity, water and transportation	The change in carbon footprint during the COVID-19 quarantine was examined.

[13] Haseeb	University of the Punjab (Pakistan) / 2019-2020	Transportation, electricity, and waste generation	Electricity is the greatest contributor of CO2 emissions at 59%, followed by transportation at 36%, and waste generation at approximately 5%.

The carbon footprint determines the extent of people's share in global warming. In other words, a carbon footprint is the proportion of greenhouse gases released to nature from individuals, institutions or any product in the general total. Carbon footprint calculation includes many parameters such as the total distance traveled by vehicles, the amount of energy used for heating purposes, etc. In this regard, care should be taken when determining the primary and secondary traces of carbon. The carbon footprint consists of two parts: direct (primary) and indirect (secondary). The primary footprint is used to determine the CO_2 emissions that may occur with domestic energy consumption, transportation, and fossil fuel use, and the secondary footprint is used to determine the CO_2 released into the atmosphere until the production and final degradation of the products we use throughout our lives [14]. The main sources of greenhouse gases are given in Figure 3.

Figure 3. Sources that cause the accumulation of greenhouse gases
https://www.universityofcalifornia.edu/news/where-do-greenhouse-gas-emissions-come

It is crucial to promote awareness, particularly throughout society, regarding a topic that holds significant importance for our environment. This study was undertaken with the intention of making a contribution to research on carbon footprint, driven by this motive. In this study, the carbon footprint calculation of TED Diyarbakır (Türkiye) College was made using the IPCC Tier approach. Parameter values such as the college's total electrical energy consumption, fuel used

for heating purposes, daily transportation values of staff and students, and fuel types of vehicles used by the staff were used in the carbon footprint calculation.

2. Material and Method

2.1 Dataset

With an area of 20,000m^2, TED Diyarbakır (Türkiye) College began for business as the 35th school of the Turkish Education Association during the 2015–2016 academic year. The college offers programs for students in kindergarten, middle school, and high school. Three scopes were used to investigate greenhouse gas emissions, both direct and indirect. Table 2 contains the scope material.

Table 2. Greenhouse gas emission sources according to their scope

	Emission Source
Scope 1	Natural gas, gasoline, diesel, fire extinguishers
Scope 2	Electric
Scope 3	Water consumption, services

Natural gas is used to heat the building in the College. Electricity consumption is; It is caused by the lighting, air conditioning and classroom in the building, as well as the tools used in the laboratories. CO_2 emissions caused by waste gases caused by the vehicles used by the staff and students of the college were also taken into account in this study. In order to determine the emission values, the vehicles used by all the personnel in the units and the distances they travel daily were determined. For the public transportation vehicles used by the students, the distance between the district center and the College was accepted as average.

In addition to these data, it is assumed that all vehicles have the same engine volume, and the change in carbon footprint is calculated according to the IPCC (2006 guideline) Tier approach.

Table 3. Secondary class parameters of TED Diyarbakır College

Parameters	**Values**
Number of students	1044
Number of teachers	104
Number of staff	34
Closed area (m^2)	6.230 m^2
Type of fuel used for heating and kitchen at school	Natural gas
Number of personnel vehicles	72 (40 gasoline, 32 diesel)
Number of vehicles used for student shuttle service	19 (diesel)
Transportation distance of student shuttles (average)	6 km
Number of daily student shuttle services	38 / day
Fuel type of student shuttles	Diesel
Electricity consumption	600.000 kwh / year
Natural gas consumption	132.000 m^3 / year
Water Consumption	11.000 m^3 / year
Number of fire extinguisher	58 fire extinguishers were utilized in 1 year
Weight of fire extinguisher	5 kg

2.2 Intergovernmental Panel on Climate Change (IPCC) - Tier Approach

Emission calculation methods divided into various levels are called Tiers. When calculating CO_2 emissions, the following steps are applied [15].

- The amount of consumption of fuels is recorded,
- The energy content of the fuels used is calculated by multiplying the consumption values and the conversion factors in the IPCC guideline,
- The consumption amounts of fuels are multiplied by their lower calorific values,
- The resulting unit of energy is converted into the value of Terajoule (TJ), and
- The obtained value is multiplied by the emission factors to find the carbon dioxide content of the fuels.

The general formula for the Tier approach is shown in equation 1.

$$Carbon\ Emission\ =\ Activity\ data\ \times\ Emission\ factor \quad (1)$$

Within the scope of the study, it was accepted that the vehicles were gasoline and diesel. Current emission factors were used for the calculation. The relevant emission factors are given in Table 4.

Table 4. Emission Factors

Activity	Unit	Emission factor
Electric consumption	kg CO_2e/kwh	0.447
Water Consumption	kg CO_2e/m^3	0.149
Shuttle – diesel	kg CO_2e/km	0.17

The density value was 0.83 for diesel fuel, which is one of the direct greenhouse gas sources, and 0.735 for gasoline fuel. The lower calorific values of fuel types are given in Table 5. Emission factors of fuel types are given in Table 6. Global warming potential values are given in Table 7.

Table 5. Lower boundary of heating values for fuel types

Fuel type	Lower boundary of heating value
Natural gas	8100 kcal/m3
Diesel consumption	43 MJ/kg
Gasoline consumption	44.3 MJ/kg

Table 6. Emission factors of fuel types

Fuel type	CO_2 (kg/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)
Natural gas	56100	1	0.1
Diesel consumption	74100	3.9	3.9
Gasoline consumption	69300	25	8

Table 7. Global warming potential

Greenhouse gas	Global warming potential
CO_2	1

CH_4	21
N_2O	310

3. Results

The carbon footprints obtained as a result of the calculations are listed below according to their scope.

a) Carbon footprint from Scope 1

Natural gas consumption (CO2) = 250.7253 tCO2e

Natural gas consumption (CH4) = 0.0939 tCO2e

Natural gas consumption (N2O) = 0.1385 tCO2e

Natural gas consumption (Total) = 250.9577 tCO2e

Diesel fuel consumption (CO2) = 4.1133 tCO2e

Diesel fuel consumption (CH4) = 0.0045 tCO2e

Diesel fuel consumption (N2O) = 0.0671 tCO2e

Diesel fuel consumption (Total) = 4.1850 tCO2e

Gasoline fuel consumption (CO2) = 6.6312 tCO2e

Gasoline fuel consumption (CH4) = 0.0502 tCO2e

Gasoline fuel consumption (N2O) = 0.2373 tCO2e

Gasoline fuel consumption (Total) = 6.9187 tCO2e

Fire extinguishers = 0.0116 tCO2e

Carbon footprint amounts according to emission sources in Scope 1 are given in Table 8.

Table 8. Carbon footprint amounts from Scope 1

Activity	**Carbon footprint (tCO_2e)**
Natural gas consumption	250.9577
Diesel consumption	4.1850
Gasoline consumption	6.9187
Fire extinguishers	0.0116
Total	262.073

Carbon footprint percentages from Scope 1 are as follows: Natural gas consumption causes the highest carbon footprint with 95.76%. Following natural gas consumption, it has been observed that 2.64% is due to gasoline fuel consumption, 1.60% is due to diesel fuel consumption and approximately 0% is due to fugitive emissions from fire extinguishers.

b) Carbon footprint from Scope 2

Electricity consumption was calculated as the carbon footprint from Scope 2.

Electricity consumption = 0.268 tCO_2e

c) Carbon footprint from Scope 3

Water consumption = 1.6390 tCO_2e

Shuttle = 3.4884 tCO_2e

Carbon footprint amounts according to emission sources in Scope 3 are given in Table 9.

Table 9. Carbon footprint amounts from Scope 3

Activity	**Carbon footprint (tCO2e)**
Water Consumption	1.6390
Shuttle	3.4884
Total	5.1274

The carbon footprint percentages from Scope 3 are as follows: Vehicle service causes the highest carbon footprint with 68%. It was subsequently observed that water depletion causes a carbon footprint of 32%.

4. Conclusion

It is crucial to promote awareness, particularly throughout society, regarding a topic that holds significant importance for our environment. This study was undertaken with the intention of making a contribution to research on carbon footprint, driven by this motive. In this study, the carbon footprint calculation of TED Diyarbakır (Türkiye) College was made using the IPCC Tier approach.

The carbon footprint of 3 different capabilities, namely scope 1 (Natural gas, gasoline, diesel, fire extinguishers), scope 2 (electric) and scope 3 (Water consumption, services), were calculated and the obtained values are available in Table 10.

Table 10. Kapsamlara göre karbon ayak izi miktarları

Scope type	**Carbon footprint (tCO2e)**
Scope 1	262.073
Scope 2	0.268
Scope 3	5.1274
Total	267.4684

Carbon footprint amounts from scopes are given in Table 10. Carbon footprint percentages according to scopes are given in Figure 4.

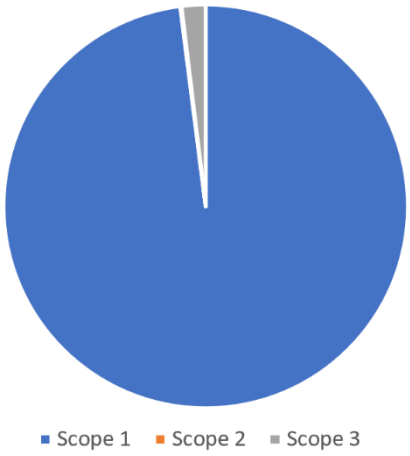

Figure 4. Carbon footprint percentages by scope

When Scope 1, Scope 2 and Scope 3 are evaluated together, it is seen that the amount of carbon footprint originating from Scope 1 is higher. Sources of emissions from Scope 1 include natural gas consumption, diesel and gasoline fuel consumption, as well as fire extinguishers. When the emission sources in the college were compared, it was determined that the highest carbon footprint was due to natural gas consumption within scope 1 (97.98%). Subsequently, it was determined that the carbon footprint was caused by existing vehicle shuttle within scope 3 (1.917%). Finally, it has been determined that the carbon footprint is caused by the existing electricity consumption within scope 2 (0.1%). It is stated that there are 2 reasons for the low carbon footprint caused by electricity consumption. The first is that the equipment used in lighting is LED, and the second is that there is no need for lighting fixtures due to the long lighting time of the day in our geography.

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Received: 19 May 2024.

Accepted: 4 June 2024