Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 13(4), 2532-2545, 2023
Journal of the Institute of Science and Technology, 13(4), 2532-2545, 2023

ISSN: 2146-0574, eISSN: 2536-4618

Çevre Mühendisliği / *Environmental Engineering* **DOI: 10.21597/jist.1387681**

Araştırma Makalesi / *Research Article*

Geliş tarihi / *Received*: 08.11.2023 **Kabul tarihi / *Accepted*: 30.11.2023**

Atıf İçin: Tırınk, S. ve Aykaç Özen, H. (2023). Yükseköğretim Kurumlarında Karbon Ayak İzinin Belirlenmesi: Iğdır Üniversitesi Örneği. *Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 13(4), 2532-2545.

To Cite: Tırınk, S. & Aykaç Özen, H. (2023). Determination of Carbon Footprint at Institutions of Higher Education: The Case of the Iğdır University. *Journal of the Institute of Science and Technology*, 13(4), 2532-2545.

Yükseköğretim Kurumlarında Karbon Ayak İzinin Belirlenmesi: Iğdır Üniversitesi Örneği

Sevtap TIRINK[1*], Hülya AYKAÇ ÖZEN[2]

Öne Çıkanlar:

- Üniversite emisyonlarının en büyük kaynağını elektrik ve doğalgaz tüketiminin oluşturduğu tespit edildi.
- Sera gazı emisyonları 2022 yılında 3679.66 tCO_2e/yıl olarak hesaplandı.
- Kampüs karbon ayak izi $1.27x10^{-3}$ tCO_2e/m^2 olarak hesaplandı.

Anahtar Kelimeler:

- Karbon Ayak İzi
- Sera Gazı Emisyonları
- İklim Değişikliği
- Doğrudan Emisyon
- Dolaylı Emisyon

ÖZET:

Üniversite yerleşkeleri, bünyesinde her türlü sosyokültürel faaliyetin gerçekleştiği ve öğrencilerin eğitim hayatları boyunca zamanlarının büyük bölümünü geçirdikleri bir yaşam merkezidir. Bu faaliyetler sonucunda yerleşkelerdeki atmosferik sera gazı seviyelerinin artması kaçınılmazdır. Ortaya çıkan sera gazı emisyonlarının belirlenmesinde en yaygın yaklaşımların başında "karbon ayak izi" gelmektedir. Karbon ayak izi, bir organizasyon veya bireyin yaptığı faaliyetler sonucu atmosfere salınan karbon dioksit ve diğer sera gazlarının dolaylı gösterimidir. Bu makale, Iğdır Üniversitesi Şehit Bülent Yurtseven yerleşkesindeki faaliyetlerinden kaynaklanan karbon ayak izi hesaplama aşamalarını ve azaltmaya yönelik önerileri ele almaktadır. Yapılan hesaplamalar, yerleşkenin çeşitli faaliyetlerini kapsamakta ve genel olarak kabul gören emisyon kapsamlarını içermektedir. Yerleşkenin karbon ayak izi hesaplamasında DEFRA kılavuzu kullanılmış ve hesaplama için temel yıl 2022 seçilmiştir. Iğdır Üniversitesi'nin 2022 yılındaki toplam karbon ayak izi yıllık ve alansal bazda, sırasıyla, 3679.66 tCO_2e/yıl ve $1.27x10^{-3}$ tCO_2e/m^2 olarak hesaplanmıştır. Bu emisyonlar doğalgaz kullanımı, elektrik tüketimi, ulaşım, su tüketimi ve atık miktarı gibi faktörlerden kaynaklanmaktadır. En büyük emisyon kaynağı doğalgaz tüketimi (%37) olurken, minibüs taşımacılığı kaynaklı emisyonlar (%31) ikinci sırada yer almaktadır. Sonuç olarak, üniversiteler, farklı yetenek ve deneyimlere sahip insanları, gelişmiş araştırma olanakları ve kaynakları bir araya getirerek karbon ayak izinin ölçülmesi, kontrolü ve azaltmasına yönelik yenilikçi yaklaşımların belirlenmesinde önemli bir role sahiptir. Bu makale Iğdır Üniversitesi örneği üzerinden, bir üniversitenin sera gazı envanteri hazırlama sürecini, üniversitenin karbon nötrlüğe ulaşma olasılıklarını ve emisyon azaltma stratejilerini belirlenmesinde literatüre katkı sağlayacağı düşünülmektedir.

Determination of Carbon Footprint at Institutions of Higher Education: The Case of the Iğdır University

Highlights:

- The use of natural gas and electricity was shown to be the main contributor to emissions at university.
- Greenhouse gas emissions were calculated at 3679.66 tCO_2e/year in 2022.
- The campus carbon footprint was calculated as $1.27x10^{-3}$ tCO_2e/m^2.

Keywords:

- Carbon Footprint
- Greenhouse Gas Emissions
- Climate Change
- Direct Emission
- Indirect Emission

ABSTRACT:

University campuses are centers of living where all kinds of sociocultural activities take place and where students spend most of their time throughout their education life. As a result of these activities, it is inevitable that atmospheric greenhouse gas levels in campuses will increase. One of the most common approaches for determining greenhouse gas emissions is the "carbon footprint". Carbon footprint is an indirect representation of the carbon dioxide and other greenhouse gases released into the atmosphere as a result of the activities of an organization or individual. This article deals with the calculation stages of the carbon footprint resulting from the activities of Iğdır University Şehit Bülent Yurtseven campus and suggestions for reducing it. The calculations include various activities of the campus, and they contain generally accepted emission scopes. DEFRA guidance was used in the carbon footprint calculation of the campus and the base year for the calculation was 2022. The carbon footprint of Iğdır University in 2022 was calculated as 3679.66 tCO_2e/year and $1.27x10^{-3}$ tCO_2e/m^2 on annual and area basis, respectively. These emissions are caused by factors such as natural gas consumption, electricity consumption, transport, water consumption and waste amount. The largest emission source is natural gas consumption (37%), followed by emissions from minibus transportation (31%). In conclusion, universities have an important role to play in identifying innovative approaches to measuring, controlling, and reducing carbon footprints by bringing together people with different skills and experience, advanced research facilities and resources. This article is thought to contribute to the literature in determining the process of preparing a university's greenhouse gas inventory, the possibilities of the university to achieve carbon neutrality and emission reduction strategies through the example of Iğdır University.

[1] Sevtap TIRINK (**Orcid ID:** 0000-0003-0123-0054), Iğdır University, Vocational School of Health Services, Department of Medical Services and Techniques, Iğdır, Türkiye
[2] Hülya AYKAÇ ÖZEN (**Orcid ID:** 0000-0003-4990-6682), Ondokuz Mayıs University, Department of Environmental Engineering, Samsun, Türkiye
***Sorumlu Yazar/*Corresponding Author**: Sevtap TIRINK, e-mail: sevtaptirink@gmail.com

INTRODUCTION

The rapid increase in the world's population, industrialization, urbanization, and the increase in production and consumption as a result of urbanization has led to a rise in environmental problems, and today climate change and sustainability are at the top of the agenda of societies and governments (Truong & Saunders, 2022). These problems, which are caused by the rapid increase in the number of gases that cause the greenhouse effect in the atmosphere, pose a global threat such as the destruction of natural resources, desertification and reduction of biodiversity. Carbon dioxide (CO_2) gas, which is emitted into the atmosphere by human activities and especially by the use of fossil fuels (oil, coal, natural gas), is the leading greenhouse gas (Martínez-Zarzoso et al., 2007; Dewi et al., 2018). For this reason, studies on the calculation of the amount of CO_2 gas emitted have increased in recent years. One of the concepts of these issues is "carbon footprint". The term of carbon footprint has emerged as a tool developed to assess the environmental impacts of greenhouse gases and to reduce their amount (Wiedmann & Minx, 2008). Firstly, in the 1970s, scientists and environmental activists realized that fossil fuel consumption increased carbon dioxide levels in the atmosphere (Broecker, 1975). This realization increased further in the late 1980s when many countries started to monitor and report their greenhouse gas emissions (IPCC, 2007).

Carbon footprint calculation methods and standards started to develop in the mid-1990s and early 2000s (IPCC, 2006). During this period, many international organizations and research institutions conducted studies to standardize the calculation of carbon footprint (Wiedmann and Lenzen, 2018). For the first time in 2001, the International Standards Organization (ISO) defined carbon footprint calculation processes with ISO 14040 and ISO 14044 standards (ISO, 2006).

The concept of "footprint", developed by environmental scientists in the last decade, generally aims to quantify how much natural resources are used by humans (Gökçek et al., 2019). Environmental scientists measure footprints in three categories, namely, ecological footprint, carbon footprint and water footprint (Toröz, 2015). The carbon footprint concept was adopted by many commercial organizations and governments in the early 21st century, with many companies supporting sustainability efforts by calculating the carbon footprint of their products and services (Girod and De Haan, 2018). At the same time, international agreements and government policies have started to use carbon footprint data to set and monitor greenhouse gas emissions reduction targets (UNFCCC, 2015).

Carbon footprint is an indicator of environmental sustainability that measures the impact of humans on nature with quantitative data. This concept helps to understand the relationship between the resources consumed and the wastes produced by people throughout their lives and their relationship with natural resources. Due to climate change concerns, the assessment of emissions and calculation of carbon footprint is gaining interest, especially as a first point of action to reduce one's impact on CO_2 generation and ultimately achieve carbon neutrality. Efforts to reduce emissions and achieve carbon neutrality are being rapidly implemented by many organizations, institutions, countries and other associations at national and international level. The European Union has committed to decarbonization covering all sectors in the European Green Deal, with a commitment to achieve net zero emissions by 2050 (European Union, 2019). The United Nations Development Programmer (UNDP) and Turkey's Ministry of Environment, Urbanization, and Climate Change have started developing a long-term climate change strategy and action plan in accordance with this commitment.

There are various studies in the literature on carbon dioxide emissions and footprint change, which represent the effects of climate change and global warming. Smith et al. (2022) examined the effects of the use of renewable energy sources in the energy sector on carbon emissions. The study addressed how

the use of renewable energy sources instead of fossil fuel-based energy sources can reduce greenhouse gas emissions. Jones et al. (2021) evaluated various strategies aimed at reducing carbon emissions in the transport sector. Solutions such as the use of electric vehicles and optimizing public transport systems were presented. Williams et al. (2020) examined the impact of industrial processes on carbon footprint and investigated how improvements can be made through energy efficiency. Brown et al. (2019) addressed the impact of the agricultural sector on greenhouse gas emissions and discussed how sustainable agricultural practices can reduce these emissions. Chang et al. (2018) provided a critique of the methodologies and standards used in carbon footprint calculations and aimed to guide future research in this field. There are also studies that emphasize cooperation between companies, universities and governments for carbon footprint calculations (Wiedmann & Minx, 2008).

There are also a number of studies in the literature on the change in the institutional carbon footprint of universities. Davis et al. (2022) examined the energy use and carbon footprint reduction strategies of universities. The study addressed the feasibility of energy efficiency and renewable energy projects on campus. Thompson et al. (2021) investigated the impact of green construction projects on carbon emissions on university campuses. The study discussed how sustainable design can reduce energy consumption. Wang et al. (2020) evaluated the carbon footprint awareness of university students and the importance of education on this issue. The study conducted a series of surveys and experiments to understand whether educational programmers are effective. Kim et al. (2019) analyzed the impact of universities' transport systems on carbon footprint. In particular, the effects of cycling and public transport use were examined. Lee et al. (2018) analyzed the impact of university catering and waste management practices on carbon emissions. Food waste and waste minimization strategies are presented.

Carbon footprint is a fundamental identification tool for higher education institutions aiming for carbon neutrality. However, due to the lack of specific guidelines addressing the characteristics of universities, case studies are an important resource when deciding which methodology to use. A general methodology for assessing the emissions of higher education institutions is probably fairly well researched, but applied case studies accessible worldwide would help to further develop the methods and make the calculations clearer. They will also offer a new perspective beyond existing studies, thanks to discussions on appropriate effective mitigation measures, taking into account the characteristics of the institution. Higher education institutions in Turkey have published several studies, including the recommendation to act as pioneers for a sustainable future and realize carbon neutrality in 2053 (Yaka et al., 2015; Günerhan & Günerhan, 2016; Başoğul, 2018; Binboğa & Aylin, 2018; Ömer et al., 2017; Yüksel, 2017; Kumaş, et al., 2019a; Kumaş, et al., 2019b; Doğancılı et al., 2019; Gökçek et al, 2019; Karakaya, 2019; Seyhan & Çerçi, 2022; Sıleybi, 2023; Yavuz et al., 2023). Universities are educational and research institutions that offer appropriate ways to adopt new technologies and practices supported by their research and to raise awareness of younger generations on sustainability and climate-friendly actions.

The purpose of this paper includes the calculation and assessment of the carbon footprint at Iğdır University in Turkey. The carbon footprint of the university has been calculated for the base year, which includes various activities of the institution and is determined as the first step towards carbon neutrality. The assessment is based on common calculation methods and includes generally accepted emission scopes. Following the results obtained, the best options for mitigation measures and the possibilities for the campus to achieve carbon neutrality are discussed.

MATERIALS AND METHODS

The following topics are discussed in this section: (1) the definition of the study location, (2) the methodology applied to calculate the carbon footprint of the institution as a result of activities.

Material

Description of the study area

Iğdır University established on 22 May 2008 and located within the borders of Iğdır (Figure 1) in the Eastern Anatolia Region of Turkey. It continues its activities with 11 faculties, 1 institute, 4 vocational schools and 23 application and research centers. As of the 2022-2023 academic year, it has 13190 students, including 5415 associate degree, 5914 undergraduate, 1861 graduate students, 198 administrative staff, 464 academic staff and 188 auxiliary staff. Although Iğdır University has 3 campuses, education and training activities are carried out in two campuses. These campuses are Şehit Bülent Yurtseven Campus and Karaağaç Campus (Figure 2). Şehit Bülent Yurtseven Campus stands out as the largest campus of the university with an area of 2907 km^2. The campus, which is approximately 14 km away from the city center, is located overlooking the Ağrı Mountain. Most of the university activities are carried out in this campus.

Figure 1. Map of Turkey (Iğdır is shown in green color)

(a) (b)

Figure 2. Şehit Bülent Yurtseven campus (Anonymous, 2023a) (a) and Karaağaç campus (Anonymous, 2023b) (b) at Iğdır University

Method

Carbon footprint calculation methodology

There are many regulatory frameworks and international guidelines for calculating institutional carbon footprints, and documents such as the Greenhouse Gas (GHG) Protocol (WRI & WBCSD, 2004),

ISO 14064-1 Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals (ISO, 2018) and Department for Environment, Food and Rural Affairs (DEFRA) are used quite frequently (Kiehle, 2021; Valls-Val & Bovea, 2021). In this research, DEFRA conversion emissions were used to calculate the carbon footprint of the university. The base year for all data required for the calculation of greenhouse gas emissions in Şehit Bülent Yurtseven campus, the largest campus of Iğdır University, was chosen as 2022. The study boundaries of Iğdır University Şehit Bülent Yurtseven campus were determined includes the area from the main gate entrance of the campus to the last unit of the campus (Figure 3).

In order to calculate the greenhouse gas emissions associated with the activities of Iğdır University, direct or indirect emissions are taken into account. GHG emissions from activities on the campus are called direct emissions include emissions that are under the control of the university. Indirect emissions include emissions that are not under the control of the university, but are caused by its activities. In this study, direct and indirect GHG inventory was determined in four categories as follows.

Figure 3. Boundaries of the study area

Category 1 - Direct greenhouse gas emissions: It refers to direct greenhouse gas emissions (direct emissions resulting from heating and/or production activities) resulting from activities within the boundaries of the campus.

Category 2 - Energy-related indirect greenhouse gas emissions: It refers to the greenhouse gas emissions resulting from the electricity purchased and consumed by the campus.

Category 3 – Indirect greenhouse gas emissions: It refers to the fuels used by the university's rental vehicles and all emissions resulting from the commuting of employees.

Category 4 - Indirect GHG emissions resulting from purchased services.

Using these methodologies, the carbon footprint of Iğdır University was calculated, and the results were evaluated.

All data required for the calculation were obtained from the administrative offices of Iğdır University. In light of these definitions, the activities needed to determine the carbon footprint of Iğdır University are given in Table 1. The natural gas used by the university for heating purposes and the emissions generated by the vehicles belonging to the university were evaluated under Category 1, and the emissions arising from the electricity consumption of the university were evaluated under Category 2. Emissions from the transport of staff and students are considered under Category 3, emissions from water use and emissions from waste are considered under Category 4.

Table 1. A detailed categorization of emissions caused by IU Activity data source

Scope	Source	Emission	Source activity data
Category 1	Fuel	Natural gas emission used by the buildings in the campus for heating	Serhat Natural Gas Distribution Company
	Vehicles	Emissions from the use of vehicles owned by the university	Department of Administrative and Financial Affair
Category 2	Electricity	Emissions from the consumption of electricity purchased by the University	Department of Administrative and Financial Affairs
Category 3	Transport vehicle	Emissions caused by personal car	Department of Administrative and Financial Affairs Security Department
	Transport vehicle	Emissions caused by minibus	Iğdır Chamber of Minibus Drivers
Category 4	Medical Waste	Emissions from medical waste generated at the university	Department of Construction and Technical Affairs
	Water	Emissions from water use	Department of Construction and Technical Affairs

Natural gas consumption data: Natural gas consumption includes the consumption of all units in Şehit Bülent Yurtseven campus such as the Rectorate, all faculties, vocational schools, and residences. The total amount of natural gas consumed in Şehit Bülent Yurtseven campus in 2022 is 678510 Sm^3.

University vehicle fleet consumption data: The emissions created by the university's vehicle fleet are one of the leading activities that cause greenhouse gas emissions. In this context, vehicle data of the university were obtained in order to calculate greenhouse gas emissions. The total km driven by the university vehicles in 2022 is 255400 km.

Electricity consumption data: The electricity consumption data required for the calculation of greenhouse gas emissions from electricity consumption includes all units in Şehit Bülent Yurtseven campus, and the total electricity consumption of the campus in 2022 was determined as 3366070.74 kWh.

Transportation data: The numbers of personal vehicles and motorcycles driving in Iğdır University were determined at the Şehit Bülent Yurtseven main gate on a day when the student population is high. In 2022, the data required for emission calculation from personal vehicles and motorcycles are summarized in Table 2. It is assumed that vehicles travel an average of 6 km.

Table 2. Number of vehicles driving to Şehit Bülent Yurtseven campus and the distance travelled

Weekdays	**Personal Vehicles**	Number	124100
		Total km	744600
	Motorcycle	Number	3650
		Total km	21900
Weekend	**Personal Vehicles**	Number	40150
		Total km	240900
	Motorcycle	Number	1095
		Total km	6570

Minibus is another means of transport preferred by the passengers arriving at the campus. The number of trips and passenger capacities of minibus are based on the data obtained from Iğdır Minibus Chamber. The daily number of minibus vehicles in the campus is 55 and each minibus drives in and out of the campus 10 times a day. The distance taken by minibus within the campus is 14 km from the campus to the city center. The fuel type of the minibus is diesel.

Calculation

The greenhouse gas emission values of Şehit Bülent Yurtseven Campus were calculated using the data obtained from the university departments and foundation and the emission factors provided by international sources. The carbon footprint of the campus was calculated using the calculation methodology of the UK greenhouse gas conversion factors reports published by the UK Department for Environment, Food and Rural Affairs (DEFRA) in 2022. GHG emission calculations are based on the measured greenhouse gas activity data multiplied by greenhouse gas emission factors. Since the effect

of each of these gases on global warming is different from each other, the term Carbon dioxide equivalent (CO_2e) is used to indicate the effect of greenhouse gases on global warming in a single unit. The GHG emission values expressed in equivalent carbon dioxide constitute the carbon footprint of Şehit Bülent Yurtseven Campus.

The following formula was used for the calculation:

Carbon Footprint = Activity data x Emission factor (1)

RESULTS AND DISCUSSION

Carbon footprint calculation caused by heating: The university uses natural gas as fuel for its heating system. The emission factors required for the carbon footprint calculation resulting from the use of natural gas were calculated using the DEFRA approach calculation methodology. During the calculation, emission values were calculated by multiplying the natural gas data with the emission factors selected for natural gas. The CO_2, CH_4, N_2O, and equivalent CO_2 emissions of the Şehit Bülent Yurtseven Campus resulting from natural gas consumption calculated according to DEFRA are given in Table 3.

Table 3. Annual emission values of Şehit Bülent Yurtseven Campus caused by natural gas consumption

Location	Activity data (m^3)	Emission value (tCO_2e)			Total carbon footprint
		tCO_2	$t\ CH_4$	tN_2O	tCO_2e
Mosque and Complex Building	29797	59.9495	0.0816	0.0319	60.0630
Animal Hospital	9263	18.6365	0.0254	0.0099	18.6718
Workshop Building	30302	60.9655	0.0830	0.0324	61.0810
Vocational School Dining Hall	67	0.1348	0.0002	0.0001	0.1351
Vocational School	44244	89.0158	0.1212	0.0473	89.1844
Laboratory Building	18255	36.7278	0.0500	0.0195	36.7973
Indoor Sports Hall	47974	96.5203	0.1314	0.0513	96.7031
Medico Social Dining Hall	6564	13.2063	0.0180	0.0070	13.2313
Medico Social Building	65336	131.4515	0.1790	0.0699	131.7004
A3 Lodging	50559	101.7212	0.1385	0.0541	101.9138
B3 Lodging	55759	112.1832	0.1528	0.0597	112.3956
C3 Lodging	58263	117.2211	0.1596	0.0623	117.4431
Rectorate Building	89723	180.5164	0.2458	0.0960	180.8582
Faculty of Agriculture	159925	321.7579	0.4382	0.1711	322.3672
Rectorate Residence	8468	17.0370	0.0232	0.0091	17.0693
Nizamiye Building	4011	8.0699	0.0110	0.0043	8.0851
Total		**1365.1146**	**1.8591**	**0.7260**	**1367.6997**

According to these calculations, the equivalent carbon dioxide value of CO_2, CH_4 and N_2O greenhouse gases were calculated as 1365.1146 tCO_2e, 1.8591 tCO_2e, and 0.7260 tCO_2e, respectively. As a result, the carbon footprint caused by natural gas consumption at Iğdır University Şehit Bülent Yurtseven Campus is total 1367.6997 tCO_2e for the year 2022.

Carbon footprint calculation from transportation: In order to calculate the emissions from transportation at Iğdır University Şehit Bülent Yurtseven Campus, it is important which means of transport are used by students, academic personal and staff. In this study, emission calculation from transport is analyzed in two categories as direct and indirect emission. The direct emission source is the emissions caused by the vehicle fleet of the university. The data belong to the university's cars were taken from the departments and the emission values were calculated by multiplying the appropriate emission factors taken from DEFRA (2022). Greenhouse gas emission values and carbon footprint amounts calculated for the cars in the university vehicle fleet are given in Table 4. For the calculation of the carbon footprint caused by vehicle owned by the university, the emission factor is selected according to the motor capacity and fuel type.

Table 4. Emission values and carbon footprint of the cars in the university vehicle fleet

No	Type	Fuel type	Average km	Emission value (tCO_2e)			Total carbon footprint
				t CO_2	t CH_4	tN_2O	tCO_2e
1	Car	Diesel	10000	1.3801	0.000041	0.0188	1.3989
2	Car	Diesel	10000	1.3801	0.000041	0.0188	1.3989
3	Car	Diesel	15000	2.07015	0.000062	0.0282	2.0984
4	Car	Diesel	15000	2.07015	0.000062	0.0282	2.0984
5	Car	Gasoline	10000	1.3801	0.000041	0.0188	1.3989
6	Car	Diesel	10000	1.6612	0.000041	0.0188	1.6800
7	Car	Diesel	7000	0.96607	0.000029	0.01316	0.9793
8	Car	Diesel	8000	1.32896	0.000033	0.01504	1.3440
9	Car	Diesel	25000	4.153	0.000104	0.047	4.2001
10	Car	Diesel	10000	1.6612	0.000104	0.0188	1.6800
11	Pickup	Diesel	15000	2.4918	0.000062	0.0282	2.5201
12	Pickup	Diesel	15000	2.4918	0.000062	0.0282	2.5201
Total				**23.03463**	**0.000621**	**0.282000**	**23.3173**

In the emission calculation of vehicles such as buses, minibus and vans, which are called large vehicles and are generally used for freight transport, in- and out-of-university transport and other activities, emission factors were selected by taking into account the maximum load weights of the vehicles. The selected emission factors were multiplied by the current km data of the vehicles and emission values were calculated. Greenhouse gas emission values and carbon footprint amounts calculated for large vehicles in the university vehicle fleet are given in Table 5.

Table 5. Emission values and carbon footprint of large vehicles in the university vehicle fleet

No	Type	Fuel Type	Average km	Emission value (tCO_2e)			Total carbon footprint
				t CO_2	t CH_4	tN_2O	tCO_2e
1	Bus	Diesel	12000	13.4496	0.0024	0.14292	13.59492
2	Bus	Diesel	12000	8.48904	0.00144	0.08748	8.57796
3	Bus	Diesel	12000	8.48904	0.00144	0.08748	8.57796
4	Bus	Diesel	1000	0.70742	0.00012	0.00729	0.71483
5	Truck	Diesel	10000	7.0742	0.0012	0.0729	7.1483
6	Truck	Diesel	10000	7.0742	0.0012	0.0729	7.1483
7	Truck	Diesel	15000	10.6113	0.0018	0.10935	10.72245
8	Minibus	Diesel	6000	1.3782	-	0.01116	1.38936
9	Minibus	Diesel	3000	0.6891	-	0.00558	0.69468
10	Minibus	Diesel	1000	0.2297	-	0.00186	0.23156
11	Minibus	Diesel	10000	2.5295	-	0.0186	2.5481
12	Minibus	Diesel	12000	3.0354	-	0.02232	3.05772
13	Tractor	Diesel	600 lt	1.596804	0.000156	0.02232	1.61928
14	Tractor	Diesel	800 lt	2.129072	0.000208	0.02976	2.15904
Total				**67.482576**	**0.009964**	**0.69192**	**68.18446**

Accordingly, the carbon footprint caused by vehicles in Category 1 emissions of Iğdır University in 2022 was found to be 91.50176 tCO_2e.

The calculation of emissions from electricity consumption is a significant category in determining the carbon footprint of the campus. The carbon footprint of the campus resulting from electricity consumption in 2022 was calculated (Table 6).

Table 6. Emission values and carbon footprint from electricity consumption

Electricity Consumption Amount (kWh)	Emission value (tCO_2e)			Total carbon footprint
	t CO_2	t CH_4	tN_2O	tCO_2e
3366070.74	643.62639	2.69286	4.61152	650.93076

Accordingly, the contribution of electricity consumed in 2022 to the carbon footprint of the university is 650.93076 tCO_2e.

The calculation of emissions from minibus, personal vehicles and motorcycles, which are the vehicles used by academic-administrative staff and students for transportation to the campus, is very important and is classified as an indirect emission source. In order to calculate the emissions generated by these vehicles, information such as vehicle characteristics, the distance travelled in 2022, the number of trips and the number of passengers are needed.

Personal vehicles in and out of Iğdır University Şehit Bülent Yurtseven campus are important in the calculation of carbon footprint. The data were collected by determining the average number of vehicles at the main gate of Şehit Bülent Yurtseven by choosing a day with a high student density. In 2022, the number of personal vehicles on the campus on weekdays and weekends was obtained. After determining these data on an average annual basis, the carbon footprint resulting from the use of personal vehicles and motorbikes were calculated by multiplying the calculated km data with the emission factors from DEFRA (2022) (Table 7).

Table 7. Emission values and carbon footprint from personal vehicles

		Total km	Emission value (tCO_2e)			Total carbon footprint
			t CO_2	t CH_4	tN_2O	tCO_2e
Weekdays	Personal car	744600	126.1352	0.1266	0.8191	127.0809
	Motorcycle	21900	2.43922	0.03460	0.01292	2.48675
Weekend	Personal car	240900	40.8085	0.0410	0.2650	41.1144
	Motorcycle	6570	0.73177	0.01038	0.00388	0.74602
Total						**171.42807**

Transportation to the university by minibus is another emission source and is considered within the scope of indirect emissions. Table 8 shows the emissions emitted by minibus driving into the campus.

Table 8. Emission values and carbon footprint caused by minibus providing transportation to the university campus

	Total km	Emission value (tCO_2e)			Total carbon footprint
		t CO_2	t CH_4	tN_2O	tCO_2e
Weekdays	3819200	966.06664	0	7.103712	973.1704
Weekend	655200	165.73284	0	1.218672	166.9515
Total					**1140.1219**

The carbon footprint value caused by minibus, which are among the vehicles for transport in Şehit Bülent Yurtseven campus, at the university in 2022 was calculated as 1140.1219 tCO_2e.

Carbon footprint calculation from water consumption: The emission factor used for the calculation of the carbon footprint resulting from water consumption is multiplied by the water consumption data and the emission value and the carbon footprint resulting from water consumption are given in Table 9. The emission factor for water consumption is 0.149 kg of CO_2e per cubic meter (DEFRA, 2022).

Table 9. Carbon footprint of Şehit Bülent Yurtseven campus caused by water consumption

Water consumption (m^3)	Emission factor (kg CO_2e per unit)	Emission value (kg CO_2e)	Carbon footprint (tCO_2e)
314763.6	0.149	46899.78	**46.8998**

Carbon footprint calculation from wastes: For the determination of emissions from wastes, only the amount of medical waste of the campus in 2022 was obtained. The emission value used to calculate the carbon footprint resulting from medical waste is multiplied by medical waste data and the emission factor. In DEFRA's 2022 emission factors list, the emission factor of medical waste is 467.008 kg CO_2e per cubic meter (Defra, 2022). The quantity of medical waste generated and the carbon footprint resulting from the waste is given in Table 10.

Table 10. Carbon footprint of medical waste at Şehit Bülent Yurtseven Campus

Amount of waste (kg)	Emission factor (kg CO_2e per unit)	Emission value (kg CO_2e per unit)	Carbon footprint (tCO_2e)
452	467.008	211087.6160	211.0876

In 2022, the carbon footprint of the emission resulting from medical waste generated at the Şehit Bülent Yurtseven campus was calculated as 211.0876 tCO_2e.

This study under consideration focuses on the carbon footprint inventory of Iğdır University in Turkey and emphasizes the importance of reducing carbon footprint to mitigate the threats posed by global warming. It highlights that human-induced activities such as fossil fuel consumption, transportation, waste, water consumption increases greenhouse gas levels in the atmosphere, leading to global warming (Aladağ, 2023; Tırınk & Öztürk, 2023). The study, University Şehit Bülent Yurtseven Campus is calculated as 3679.66 tCO_2e/year in 2022. Considering the emissions of the university under categories-1,-2,-3, and-4 the following emission values are 1459.201 tCO_2e/year, 650.93076 tCO_2e/year, 1311.54997 tCO_2e/year, and 257.9864 tCO_2e/year, respectively.

Overall, the article provides valuable insights into the carbon footprint inventory of Iğdır University and the importance of reducing carbon footprint, aligning with existing literature on carbon footprint reduction, measurement methods, and the role of institutions in addressing carbon footprints.

CONCLUSION

In the carbon footprint calculation of Iğdır University Şehit Bülent Yurtseven Campus, emission-emitting activities such as natural gas use, electricity consumption, transportation, water consumption and waste amount were examined under four categories for 2022. The calculation of the carbon footprint and the evaluation of the results are important in terms of identifying measures to reduce the carbon footprint of the campus. Accordingly, the greenhouse gas emissions caused by the activities of Iğdır University Şehit Bülent Yurtseven Campus were calculated as 3679.66 tCO_2e/year in 2022. When the emissions of the university are analyzed as Category-1, Category-2, Category-3 and Category-4, 40% of the total equivalent CO_2 emissions are Category-1, 18% are Category-2, 35% are Category-3 and 7% are Category-4 emissions.

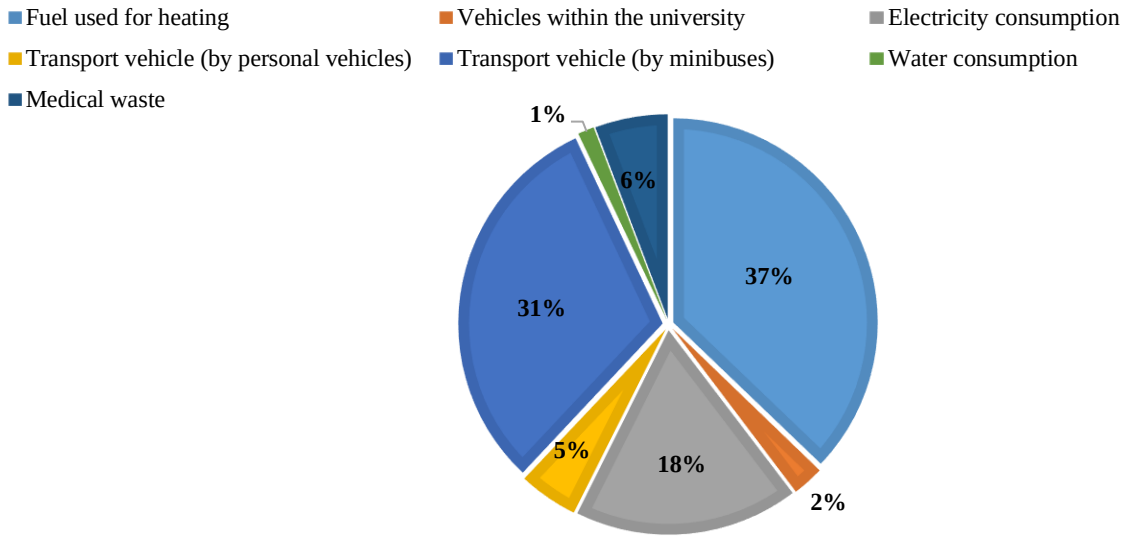

Figure 4. Carbon footprint of the activities performed at the university

Category 1 emissions occur from natural gas consumption and vehicles owned by the university. The total share of the carbon footprint resulting from natural gas consumption compared to other university-owned vehicles emission sources is 94%.

Category 2 emissions causing greenhouse gas emissions are emissions from electricity consumption. About 18% of the total greenhouse gas emissions produced by the Şehit Bülent Yurtseven campus come from the emission source of electricity usage.

Among the means of transport, the largest carbon footprint is caused by car transport. The carbon footprint from these vehicles' accounts for 13% of Category 3 emissions and 5% of the total carbon footprint. The main reason that individuals prefer personal vehicles instead of public transport. The total carbon footprint value from minibus that provide transportation on the campus is the second highest transportation emission source. The carbon footprint caused by the minibus used by the staff and students to reach the campus constitutes 31% of total emissions and 87% of Category 3 emissions. The study boundaries of Iğdır University Şehit Bülent Yurtseven campus were determined includes the area from the main gate entrance to the last unit of the campus. The amount of footprint per area was calculated by dividing the amount of carbon footprint by the area within the determined boundary. In 2022, the areal carbon footprint of Şehit Bülent Yurtseven campus is $1.27x10^{-3}$ tCO_2e/m^2.

The calculation and evaluation of the carbon footprint are essential for determining measures to reduce the carbon footprint of the campus. In light of the findings from the carbon footprint calculation at Iğdır University's Şehit Bülent Yurtseven Campus, various mitigation strategies can be proposed to reduce the university's carbon footprint. These recommendations can be consolidated into energy efficiency measures, adoption of renewable energy, transportation optimization, waste reduction and management, water conservation, green infrastructure and land use, behavioral change and education, carbon offsetting, investment and financing for sustainability, and continuous monitoring and reporting.

- For energy efficiency measures, an energy management system should be implemented to optimize energy usage. Therefore, a transition to LED lighting and energy-efficient appliances should be facilitated. Insulation and the improvement of heating, ventilation, and air conditioning (HVAC) systems are required to reduce the use of natural gas, a significant source of emissions.
- To adopt renewable energy, solar panels should be installed on campus buildings to produce clean energy and reduce dependence on non-renewable energy sources. The university currently has a solar energy plant, however, there is a need for more renewable energy sources.
- For transportation optimization, a green transportation plan should be developed to encourage public transportation, car-sharing, and non-motorized transit (bicycling, walking). Electric vehicle charging stations should be installed on campus to encourage the use of electric vehicles by staff and students. Additionally, a transition to electric or hybrid vehicles could be made in the university fleet.
- To reduce and manage waste, comprehensive recycling and composting programs could be implemented to decrease emissions caused by waste. Education campaigns on waste reduction and proper separation practices could be initiated.
- For water conservation, investments in water-saving fixtures and devices could be made. Rainwater harvesting and greywater recycling systems could be implemented throughout the university to reduce the water footprint.
- With the aim of green infrastructure and land use, increasing green areas on campus, which serve as carbon sinks, could be facilitated. This could be supported by using sustainable landscaping practices that require less maintenance and water.

- To promote behavioral change and education, workshops and training for staff and students could be organized to encourage eco-friendly behaviors. Sustainability and climate change should be incorporated as an integral part of the curriculum in all departments.
- For carbon offsetting, participation in carbon offset programs, preferably local environmental projects that provide community benefits, could be facilitated to compensate for unavoidable emissions.
- Regarding investment and financing for sustainability, funds could be allocated for the research and implementation of sustainability projects. Partnerships and grants, especially for carbon reduction initiatives, should be explored.
- For continuous monitoring and reporting, the campus's carbon emissions should be regularly monitored and reported to track the progress of the implemented measures.

It is vital to continuously develop and improve sustainability strategies based on the data collected. These strategies should be part of a comprehensive, integrated plan that provides a collaborative and sustainable approach to reducing the carbon footprint, aligning with the university's mission and resources.

Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Author's Contributions

The authors declare that they have contributed equally to the article.

REFERENCES

Agreement, P. (2015, December). Paris agreement. In report of the conference of the parties to the United Nations framework convention on climate change (21st session, 2015: Paris).

Aladag, E. (2023). The Influence of Meteorological Factors on Air Quality in the Province of Van, Turkey. Water, Air, & Soil Pollution, 234(4), 259.

Anonymous, (2023a). https://eskisite.Iğdır.edu.tr/alb%C3%BCm/2023-%C3%BCniversitemizden-bahar-g%C3%B6r%C3%BCnt%C3%BCleri. (Accessed on 10 October 2023).

Anonymous, (2023b). https://www.yurtlarburada.com/Iğdır-universitesi-hakkinda/. (Accessed on 10 October 2023).

Başoğul, Y. (2018). Akademisyen ve İdari Personelin Ekolojik Ve Karbon Ayak İzinin Belirlenmesi: Adıyaman Üniversitesi Mühendislik Fakültesi Örneği. *Mühendislik Bilimleri ve Tasarım Dergisi*, 6(3), 464-470.

Binboğa, G., & Aylin, Ü. (2018). Sürdürülebilirlik Ekseninde Manisa Celal Bayar Üniversitesi'nin Karbon Ayak İzinin Hesaplanmasına Yönelik Bir Araştırma. *Uluslararası İktisadi ve İdari İncelemeler Dergisi*, (21), 187-202.

Broecker, W. S. (1975). Climatic Change: Are We on the Brink of a Pronounced Global Warming? Science, 189(4201), 460-463.

Brown, C., Lee, M., & Kim, J. (2019). Sustainable Agriculture and Its Impact on Carbon Emissions. *Agriculture and Environmental Science*, 17(1), 90-105.

BSI, (2008). Publicly Available Specification PAS 2050:2008. Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. British Standards Institution, London

Chang, T., Wang, Y., & Lee, S. (2018). A Critique on Methodologies Used in Carbon Footprint Calculations. *Environmental Science & Technology*, 54(22), 13412-13420.

Davis, J., Smith, L., & Roberts, N. (2022). Energy Use and Carbon Footprint Reduction Strategies in Universities. *Journal of Environmental Management*, 34(2), 200-215.

DEFRA, (2022). Greenhouse gas reporting: conversion factors 2022. https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022. (Eşirim tarihi 10.10.2023)

Dewi, L., Wibowo, A., & Immanuel, N. (2018). E-census implementation: a case study in naikoten ii, kupang, indonesia. Matec Web of Conferences, 248, 05003. https://doi.org/10.1051/matecconf/201824805003

Doğancılı, O. S., Karaçar, E., & Korkmaz, N. (2019). Sinop Üniversitesi'nin Karbon Ayak İzini Ölçme Üzerine Bir Araştırma. 8 th International Vocational Schools Symposium. UMYOS'19 SİNOP, 11-13 June 2019 Türkiye

Eggleston, H. S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K. (2006). 2006 IPCC guidelines for national greenhouse gas inventories. https://www.ipccnggip.iges.or.jp/public/2006gl/index.html

European Union, (2019). European Union A European Green Deal. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

Fetting, C. (2020). The European green deal. ESDN report, 53.

Girod, B., & De Haan, P. (2018). Carbon Footprinting in Practice: Recent Trends and Insights. *Environmental Science & Technology*, 52(5), 2355-2366.

Gökçek, B., Bozdağ, A., & Demirbağ, H. (2019). Niğde Ömer Halisdemir Üniversitesi örneğinde karbon ayak izinin belirlenmesi. *Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi*, 8(2), 721-730.

Günerhan, S. A., & Günerhan, H. (2016). Türkiye için sürdürülebilir üniversite modeli. *Mühendis ve Makina*, 57(682), 54-62.

IPCC, (2006). Guidelines for National Greenhouse Gas Inventories: Volume 5 - Waste. Retrieved from https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

IPCC, (2007). Climate Change 2007: Synthesis Report. Retrieved from https://www.ipcc.ch/report/ar4/syr/

IPCC, I. (2014). Climate change 2014: Synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change.

IPM, (2021). İstanbul Politikalar Merkezi (İPM) (2021). Türkıye'nın Karbonsuzlaşma Yol Harıtası 2050'de Net Sıfır. https://ipc.sabanciuniv.edu/Content/Images/CKeditorImages/20211026-23105368.pdf

ISO (2006). ISO 14040:2006 - Environmental management - Life cycle assessment - Principles and framework. Retrieved from https://www.iso.org/standard/37456.html

ISO, (2018). International Organization for Standardization https://www.iso.org/search.html?q=14067. (Erişim 10.10.2023)

ISO, (2019). International Organization for Standardization https://www.iso.org/search.html?q=14064. (Erişim 10.10.2023)

Jones, L., Williams, M., & Gupta, R. (2021). Strategies for Reducing Carbon Emissions in Transportation. *Transportation Research*, 30(2), 150-167.

Karakaya, H. (2019). Enerji kaynaklı karbon ayak izinin hesaplanması: Batman Üniversitesi örneği. I. Uluslararası Harran Multidisipliner Çalışmalar Kongresi, 8-10 Mart 2019, Şanlıurfa, Türkiye

Kim, H., Choi, S., & Park, J. (2019). Impact of University Transportation Systems on Carbon Footprint. Transportation Research Part D, 28(3), 22-38.

Kumaş, K., Akyüz, A. Ö., Zaman, M., & Güngör, A. (2019a). Sürdürülebilir bir çevre için karbon ayak izi tespiti: MAKÜ Bucak Sağlık Yüksekokulu örneği. *El-Cezeri*, 6(1), 108-117.

Kumaş, K., Akyüz, A., & Güngör, A. (2019b). Burdur mehmet akif ersoy üniversitesi bucak yerleşkesi yükseköğretim birimlerinin karbon ayak izi tespiti. *Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi*, 8(2), 1277-1291.

Lee, S., Kim, M., & Park, H. (2018). Carbon Emissions from University Food Services and Waste Management: A Case Study. *Journal of Waste Management*, 44(12), 2409-2420

Martínez-Zarzoso, I., Bengochea-Morancho, A., & Morales-Lage, R. (2007). The impact of population on co2 emissions: evidence from european countries. Environmental and Resource Economics, 38(4), 497-512. https://doi.org/10.1007/s10640-007-9096-5

Ömer, E., Parlakay, O. P., Hilal, M., & Bozhüyük, B. (2017). Ziraat Fakültesi akademisyenlerinin ekolojik ayak izinin belirlenmesi: Mustafa Kemal Üniversitesi örneği. *Journal of Agricultural Faculty of Gaziosmanpaşa University (JAFAG)*, 34(2), 138-145.

Protocol, G. G. (2011). Greenhouse gas protocol. Sector Toolsets for Iron and Steel-Guidance Document.

Protocol, K. (1997). Kyoto protocol. UNFCCC Website. Available online: http://unfccc. int/kyoto_protocol/items/2830. php (accessed on 1 January 2011).

Protocol, M. (1987). Montreal protocol on substances that deplete the ozone layer. Washington, DC: US Government Printing Office, 26, 128-136.

Seyhan, A. K., & Çerçi, M. (2022). IPCC Tier 1 ve DEFRA Metotları ile Karbon Ayak İzinin Belirlenmesi: Erzincan Binali Yıldırım Üniversitesi'nin Yakıt ve Elektrik Tüketimi Örneği. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 26(3), 386-397.

Sıleybi, L. (2023). Harran Üniversitesi Osmanbey Kampüsü Karbon Ayak İzinin Hesaplanması. Harran Üniversitesi Fen Bilimleri Enstitüsü, Çevre Mühendisliği Anabilim Dalı (Yüksek Lisans Tezi). Şanlıurfa, Türkiye.

Smith, J., Miller, K., & Johnson, S. (2022). Renewable Energy Transition in Energy Sector: Implications on Carbon Emissions. *Journal of Environmental Studies*, 25(4), 320-335.

Thompson, M., Kelly, R., & Green, F. (2021). Green Construction in University Campuses and Its Impact on Carbon Emissions. *Journal of Sustainable Construction*, 19(1), 45-60.

Tırınk, S., & Öztürk, B. (2023). Evaluation of PM10 concentration by using Mars and XGBOOST algorithms in Iğdır Province of Türkiye. International Journal of Environmental Science and Technology, 20(5), 5349-5358.

Toröz, A., (2015). Gemi Kaynaklı Atıkları Alan ve Atık kabul tesisinde karbon ayak izinin belirlenmesi, İstanbul Teknik Üniversitesi Yüksek Lisans Tezi. İstanbul.

Truong, V. & Saunders, S. (2022). Guest editorial. Journal of Social Marketing, 12(1), 1-4. https://doi.org/10.1108/jsocm-12-2021-246

UNDP, (2021). https://www.undp.org/tr/turkiye/press-releases/undp-turkiyenin-2053-yilina-kadar-net-sifir-rotasi-cizmesine-destek-veriyor

UNFCCC (2015). Paris Agreement. Retrieved from https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

UNFCCC, (1992). Birleşmiş Milletler İklim Değişikliği Çerçeve Sözleşmesi, Rio de Janeiro, Brezilya

Wang, Y., Lin, T., & Liu, Z. (2020). Carbon Footprint Awareness Among University Students: An Experimental Study. *Journal of Environmental Education*, 31(4), 350-364.

Wiedmann, T., & Lenzen, M. (2018). Environmental and social footprints of international trade. *Nature Geoscience*, 11(5), 314-321.

Wiedmann, T., & Minx, J. (2008). A Definition of 'Carbon Footprint'. In Ecological Economics Research Trends, 1-11. Nova Science Publishers.

Williams, S., Clark, D., & Zhao, L. (2020). Industrial Processes and Carbon Footprint: An Efficiency Analysis. *Journal of Industrial Ecology*, 28(3), 410-422.

Yaka, İ. F., Koçer, A., & Güngör, A. (2015). Akdeniz üniversitesi sağlık hizmetleri meslek yüksekokulu karbon ayak izinin tespiti. *Makine Teknolojileri Elektronik Dergisi*, 12(3), 37-45.

Yavuz, A. B., Osman, K., & Yaniktepe, B., (2023). Karbon ayak izi tespiti: Osmaniye Korkut Ata Üniversitesi örneği. *Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi*, 12(4), 1-1.

Yüksel, Ş. B. (2017). Ankara Üniversitesi Tıp Fakültesi Çalışanlarının Karbon Ayak İzi Saptanması. Ankara Üniversitesi, Tıp Fakültesi. Aile Hekimliği Anabilim Dalı. Tıpta Uzmanlık Tezi. Ankara, Türkiye.