Journal of Food Health and Bioenvironmental Science (January - April 2025), 18(1): 51-60

Journal of Food Health and Bioenvironmental Science
Journal homepage : http://jfhb.dusit.ac.th/

Organizational Carbon Footprint: A Case Study of the University of Phayao

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Article info

Article history:
Received : 16 January 2025
Revised : 22 March 2025
Accepted : 26 March 2025

Keywords:
Carbon footprint, GHG protocol, Greenhouse gases, University

Abstract

This study evaluates the organizational contribution of a university to global warming by conducting a comprehensive CO_2 inventory in accordance with the Greenhouse Gas (GHG) Protocol. Organizational and operational boundaries were established under 3 emission scopes, and the university's carbon footprint was quantified using emission factors derived from Thailand's national databases and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Emissions for each scope were calculated in metric tons of CO_2 equivalent per year (tCO_2eq/year). Data were sourced from financial records, usage logs, and estimates for specific emission sources. The findings indicate that total GHG emissions increased from 9,897 tCO_2eq in 2021 to 10,944.55 tCO_2eq in 2022, with per capita emissions rising from 0.46 to 0.49 tCO_2eq/person. Electricity consumption (Scope 2) was the primary contributor, accounting for 61.84% and 56% of total emissions in 2021 and 2022, respectively. The study also highlights the impact of the COVID-19 pandemic on emission patterns, particularly in transportation and on-campus activities. Despite higher overall electricity consumption in 2022 compared to 2021, electricity-related emissions remained relatively stable due to the installation of a solar cell system, which mitigated the increase. While the university has implemented various emission reduction initiatives, ongoing carbon footprint assessments are essential for monitoring operational impacts and identifying further strategies to reduce emissions.

Introduction

Climate change and rising greenhouse gas (GHG) emissions resulting from human activities have become critical global challenges. Many countries recognize the severe impacts and potential damages associated with these environmental changes. According to Thailand's Fourth Biennial Update Report, the country's total GHG emissions were recorded at 372,716.86 $GgCO_2eq$, with the distribution of emissions illustrated in Fig.1 (DCCE., 2022). Thailand's CO_2 emissions have increased at an average annual rate of 25% (Ritchie & Roser, 2024). Despite contributing only 0.86% of global GHG emissions, Thailand is among the ten countries most severely affected by climate change (Eckstein et al., 2021).

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To address these challenges, national strategies for mitigating and limiting GHG emissions must be developed. A fundamental step in this process is the establishment of measurement, reporting, and verification (MRV) systems at all levels. In particular, the implementation of carbon footprint assessments at the organizational level—known as the Carbon Footprint for Organizations (CFO)—serves as a crucial mechanism for tracking and managing emissions effectively.

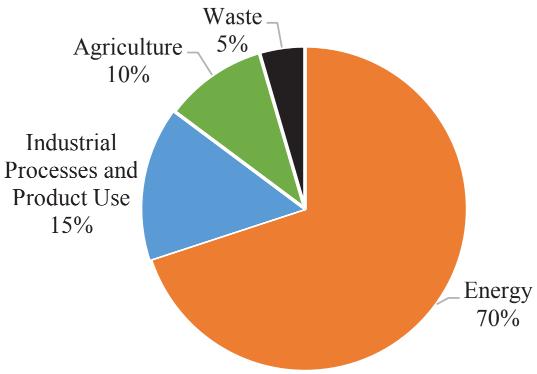

Fig. 1 Total GHG emissions by sector in Thailand 2019 (excluding LULUCF) 2019 (DCCE, 2022)

Thailand Greenhouse Gas Management Organization is a Public Organization (TGO) that aims to 1) promote and develop as well as provide technical knowledge to government and private sector agencies regarding GHG management, and 2) set the Thai criteria requirements for calculating and reporting an organization's carbon footprint adapted from ISO 14064-1 (2018), GHG Protocol (2001, 2004) as well as examples from ISO/TR 14069 (2013) (TGO., 2022).

The Carbon Footprint of an Organization (CFO) refers to the total quantity of greenhouse gas (GHG) emissions resulting from an organization's activities, expressed in tons or kg of carbon dioxide equivalent (CO_2eq). GHG emissions are classified into three scopes: Scope 1, which includes direct emissions from sources owned or controlled by the organization, such as stationary combustion, mobile combustion, fugitive emissions, and other on-site activities; Scope 2, which covers indirect emissions from imported energy consumption; and Scope 3, which encompasses other indirect emissions, including those from transportation and supply chain activities (GHG Protocol, 2024; TGO., 2024a).

GHG Protocol is guidance for companies and organizations accounting and reporting standards. The objective of GHG protocol is to help companies represent a true and fair accounting of their emissions, reduce the costs of compiling a GHG inventory, information for building management and reduction strategies, increase consistency and transparency in GHG accounting and reporting. GHG protocol accounting and reporting standard cover seven greenhouses gases covered by the Kyoto protocol such as carbon dioxide (CO_2), methane (CH_4), Nitrous oxide(N_2O) hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3)(World Resources Institute and World Business Council for Sustainable Development, 2004a).

A university, as an educational organization, play an important role in sustainable development and building awareness. The activities related to education in the university facilities create significant GHG emissions. Therefore, many universities evaluated their carbon footprint and apply the results for environmental impact control. Universities around the world have initiated reporting GHG emissions using standards based on the GHG protocol, offering valuable insights and practical approaches. Many institutions have begun assessing and reporting their carbon footprints using standardized protocols and identified their emission hotspot. These studies consistently identify electricity consumption as the primary contributor to university carbon footprints, followed by transportation-related emissions for instance; Diponegoro University (Syafrudin et al., 2020), American University of Sharjah (Samara et al., 2022), Suranaree University of Technology (Puttipiriyangkul, 2018) and Nan College Uttaradit Rajabhat University (Saphanthong, 2020). The variation in total emissions across institutions likely reflects differences in size, location, and operational practices. As a result, many universities now prioritize energy conservation and efficiency measures to reduce their carbon footprints.

The Carbon Footprint of an Organization (CFO) framework was used to assess the impact of greenhouse gas (GHG) emissions at various universities during the COVID-19 pandemic. A study conducted by the University of Bologna (Battistini et al., 2023) compared the institution's carbon footprint between 2018 and 2020 to evaluate the pandemic's effect on emissions. The findings indicated that emissions from water supply, special waste management, district heating, and natural gas remained relatively consistent between the two years. However, emissions from paper purchasing, gas oil consumption, and district cooling were higher in 2018, whereas emissions from student and employee commuting were significantly greater in 2018 compared to 2020.

These findings highlight the importance of universities not only in assessing their current emissions but also in implementing strategic measures to reduce their overall carbon footprint. Enhancing campus sustainability requires informed decision-making and the adoption of best practices in environmental management. To achieve this, the University of Phayao must adopt a systematic and sustainable approach that addresses the complex interactions between its activities and environmental impacts. Therefore, this study aims to: 1) Quantify and compare the University of Phayao's GHG emissions for 2021 and 2022, 2) Identify the primary sources of GHG emissions and potential reduction strategies and 3) Propose mitigation measures for university carbon management.

To assess the university's organizational GHG emissions, a CO_2 inventory was conducted by defining organizational and operational boundaries in accordance with the GHG Protocol (ISO 14064-1:2018, 2018). The university's carbon footprint was calculated using emission factors obtained from Thailand's national databases and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The emissions for each scope were quantified in metric tons of CO_2 equivalent per year (tCO_2eq/year). Data collection was based on financial records, usage records, and estimates for certain sources.

Materials and methods

1. Organizational boundary

Companies must select an approach for consolidating GHG emissions for purposes of accounting and reporting GHG emissions because of the difference of business operation, legal and organizational structure. For corporate reporting, two distinct approaches were the equity share and the control approaches (World Resources Institute and World Business Council for Sustainable Development, 2004b). In this study, the organization boundary consisted of the Administrative section and Academic section as shown in Fig. 2 and the corporate report was used for the control approach.

The University of Phayao, located in Phayao Province, Thailand, spans an estimated area of 9.12 km^2. Using the operational control approach, data were collected for the calendar years 2021 and 2022, covering the periods from January 1 to December 31 of each respective year. This data collection aimed to facilitate a comparative analysis of the impact of the COVID-19 pandemic on the university's greenhouse gas (GHG) emissions.

The university's operational area, which includes academic buildings and associated facilities, is illustrated in Fig. 3. Additionally, the number of students, staff,

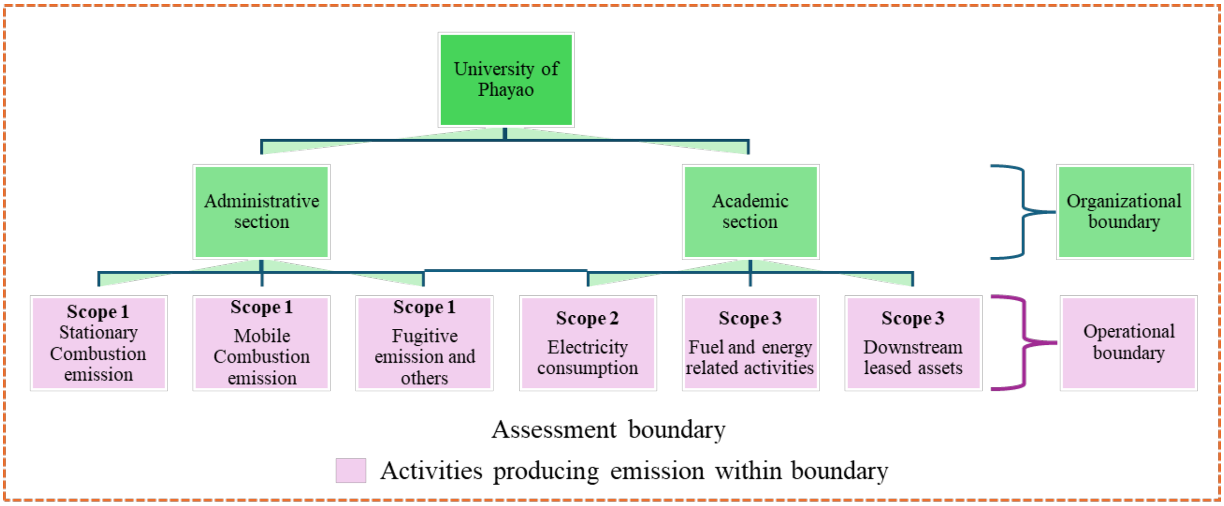

Fig. 2 Organizational boundary and operational boundary at University of Phayao

and business days, as presented in Table 1, was used to calculate the institution's Carbon Footprint of Organization (CFO).

Table 1 Number of students, staff, and business day for 2021 and 2022

Type of People	2021			2022		
	Online	Onsite	Days	Online	Onsite	Days
Staff, Academic Staff and Support personnel	-	1937	238	-	1974	232
Student	9,557	10,221	238	-	20,344	232

2. CO_2 emission calculation methodology

CO_2 equivalent (CO_2-eq) emissions serve as the universal unit of measurement for quantifying the global warming potential (GWP) of the seven major greenhouse gases (GHGs), expressed relative to the GWP of one unit of carbon dioxide.All data related to the Carbon Footprint of Organization (CFO) at the University of Phayao for 2021 and 2022 were collected and used to calculate CO_2 emissions based on Equation (1):

$$CO_2 \text{ emission } (kgCO_2\text{-eq}) = \text{Activity data} \times \text{Emission factor} \quad (1)$$

Where:

• Activity data represents the quantitative measure of an activity that results in GHG emissions.

• Emission factor (EF) is a coefficient that enables the estimation of GHG emissions per unit of activity data.

Emission factors were obtained from Thailand's national database, published by the Thailand Greenhouse Gas Management Organization (TGO) (TGO., 2022, 2024b), which is adapted from the Intergovernmental Panel on Climate Change (IPCC) Guidelines (IPCC., 2006a).

3. Reporting boundaries and sources of emission

The operational boundaries were established as shown in Fig. 2, categorizing greenhouse gas (GHG) emission sources in accordance with the GHG Protocol. These sources are classified into three scopes:

1. Scope 1: Direct emissions from sources owned or controlled by the organization, including stationary combustion, mobile combustion, fugitive emissions, and other direct sources.

2. Scope 2: Indirect GHG emissions from the generation of purchased electricity, heat, or steam consumed by the organization.

3. Scope 3: Other indirect GHG emissions associated with the university's operations.

The reporting scopes and corresponding activities for this study are summarized in Table 2.

Table 2 Scopes and GHG emission activity of University of Phayao in 2021 and 2022

Scope 1: Direct GHG emission	Scope 2: Energy indirect GHG emission	Scope 3: Other indirect emissions
Stationary combustion emission - Diesel consumption by generator and fire pump **Mobile combustion emission** - Diesel consumption by university vehicles - NGV consumption by bus - Gasoline consumption by brush cutters **Fugitive emission and others** - Leakage of R32, R410a and R134a refrigerant - Leakage of methane gas from septic tank - N_2O and CH_4 emission from solid waste management	- Electricity consumption	**Fuel-and energy related activities** - Diesel - Gasoline - Natural Gas for Vehicles (NGV) - Electricity **Downstream leased assets** - Electricity consuming by the leaser

4. Data collection

The diesel and gasoline consumption data were collected from financial expenditure. The electricity consumption, measured in kWh per month, was obtained from the usage record from the bill and the data recorded by division of building and facilities, University of Phayao. Assumptions and calculations were applied to estimate NGV consumption, refrigerant leakage from chillers and air conditioning systems, and GHG emissions from the University waste operations (including septic tanks and solid waste).

There were three operation routes of the University bus services. NGV usage of the University buses was calculated from the trip distance using the consumption rate of 11.905 km/L (TGO., 2022)

Leakage of R32, R410a, and R134a refrigerant were calculated using onsite survey nameplate data and the percentage of equipment leakage. The calculation method was adapted from IPCC Guidelines for National GHG Inventories (2006), Volume 3: Industrial Processes Use (IPCC., 2006b)

The University of Phayao solid waste management system used mechanical biological treatment (MBT) system. The MBT contained 3 steps. Firstly, the mechanical pre-treatment process removed recyclable waste from mixed waste and decreased the size of waste. The next step was the biological process where the waste was contacted with the air by turning the garbage over

1	School of information And Communication Technology	16	School of Law
2	Demonstration School, University of Phayao	17	School of Business and Communication Arts
3	Phraya Ngam Mueang Auditorium	18	School of Education
4	Office of the President	19	School of Liberal Arts
5	School of Environmental and Engineering	20	CU – UP Book Center
6	School of Engineering	21	Souvenir Up Shop
7	School of Dentistry	22	University of Phayao Hospital and School of Medicine
8	School of Allied Health Sciences	23	Library and Learning Center
9	School of Architecture and Fine Arts	24	Sports field
10	School of Pharmaceutical Sciences	25	Swimming Pool
11	School of Agriculture and Natural Resources	26	Student dormitory
12	School of Medicine	27	Student dormitory
13	School of Nursing	28	University Buddha statue
14	School of Medical Sciences	29	99^{th} Anniversary Phra Upali Kunupamachan Building
15	School of Sciences		

Fig. 3 University of Phayao map

for aerobic biodegradation and eliminating the moisture. The final step was the mechanical separation that separated large solid waste into refuse derived fuel (RDF) for sale and other waste that cannot be used as fuel. That other waste was dumped into the landfill where methane is emitted from the anaerobic process. Therefore, the GHG emission from solid waste management assumes that all biodegradable waste will be converted to N_2O and CH_4. The waste quantity and composition data were collected from the data from the University's buildings and facilities division.

This study assumed that all students and staff used the University toilet when they came onsite. This toilet waste was then transferred into septic tanks. The data of the number of students and personnel and the number of work and study days were used for methane emission calculation using the method from IPCC Guidelines Volume 5, Chapter 6, 2006) (IPCC., 2006c). The 2021 academic year was held both onsite and online due to COVID-19 situation whereas the 2022 academic year was held only onsite. In 2021, staff worked full-time and most of the students studied online except for Master degree students and Doctoral degree students who studied on site. In 2022, all staff and students worked and studied full time onsite.

The organization must identify other indirect sources of GHG emissions (Scope 3) that will be included in the GHG inventory. This process must specify the significance assessment criteria used in the determination. The reporting data in this study for scope 3 was selected based on availability of sources of GHG and EF. Thus, there are 2 categories reported in this study; 1) Fuel related activities and 2) Downstream leased and asset. Since the source of data and emission factors are varied, the data uncertainty is considered. Overall, there is slight uncertainty, and the quality of the data is moderate.

Results and discussion

The summary of the total GHG emissions of University of Phayao for 2021 and 2022 are shown in Table 3 and the carbon footprint in 2021 and 2022 distributions are presented in Fig. 4. As shown in Table 3, the total GHG emissions of the University of Phayao increased from 9,397 tCO_2eq in 2021 to 10,944 tCO_2eq in 2022. The emission per person increased from 0.46 tCO_2eq/person in 2021 to 0.49 tCO_2eq/person in 2021.

Scope 1 (direct emissions)

Scope 1 emissions showed a significant increase in mobile source emissions from vans, rising from 211.99 tCO_2eq in 2021 to 289.17 tCO_2eq in 2022. Similarly, fugitive emissions from septic tanks increased substantially from 791.06 tCO_2eq in 2021 to 1,200.94 tCO_2eq in 2022. In contrast, diesel consumption from pickup trucks and cars remained relatively stable between the two years.

A notable shift in the primary emission sources within Scope 1 was observed. In 2022, the highest proportion of Scope 1 emissions originated from refrigerant leakage of R410a from chillers (39.74%), followed by methane emissions from septic tanks (37.62%) and diesel consumption from vans (10.08%). In 2021, however, methane emissions from septic tanks accounted for the largest share (46.69%), followed by refrigerant leakage of R410a (32.47%) and diesel consumption from vans (11.27%). Several factors contributed to these variations in emission distribution:

1. Increased business travel post-COVID-19: The resumption of business travel following the end of the COVID-19 pandemic in 2022 led to a rise in staff travel, resulting in higher diesel consumption. Consequently, emissions from van usage increased by 77.18 tCO_2eq in 2022 compared to 2021.

2. Reduced natural gas vehicle (NGV) consumption: NGV consumption by buses decreased in 2022 by 31.27 tCO_2eq compared to 2021 due to the implementation of shorter bus routes, as detailed in Table 3.

3. Increase in waste-related emissions: The return to full-time onsite learning in 2022 resulted in a higher student population compared to 2021, which led to an increase in solid waste generation. This contributed to greater emissions from waste management processes, including N_2O and CH_2 emissions from solid waste management and CH_2 emissions from septic tanks.

A similar trend has been observed in previous studies. For instance, the University of Bologna compared emissions between 2018 and 2020 to assess the impact of the COVID-19 pandemic. In 2018, 74% of total emissions were attributed to student and employee commuting (Battistini et al., 2023). This pattern aligns with the findings of the present study, where transportation-related emissions from academic staff, support personnel, and students were significantly affected by the pandemic, despite differences in transportation infrastructure and policies between the two universities.

Scope 2 (indirect emission from imported energy)

In both 2021 and 2022, Scope 2 emissions represented the largest share of the University of Phayao's greenhouse gas (GHG) inventory, accounting for approximately 60% of total emissions. Emissions from purchased electricity remained relatively stable, increasing slightly from 6,144 tCO_2eq in 2021 to 6,173 tCO_2eq in 2022. Notably, the university initiated solar energy implementation in 2022. Despite the transition back to full on-campus operations after the COVID-19 pandemic, the overall difference in GHG emissions between the two years was minimal. This stability can be attributed to the installation of a 2.997 MW solar power system in 2022, which generated 2,156,957.54 kWh of electricity, effectively reducing emissions associated with grid electricity consumption to zero for that portion of energy use (Fig. 4).

Scope 3 (other indirect emission)

Scope 3 emissions were higher in 2022 compared to 2021, showing an upward trend in energy-related activities. Diesel-related emissions increased by 7.84 tCO_2eq, while emissions from outsourced energy consumption rose by 106.92 tCO_2eq. Additionally, downstream electricity emissions nearly doubled, increasing from 203.64 tCO_2eq in 2021 to 406.67 tCO_2eq in 2022.

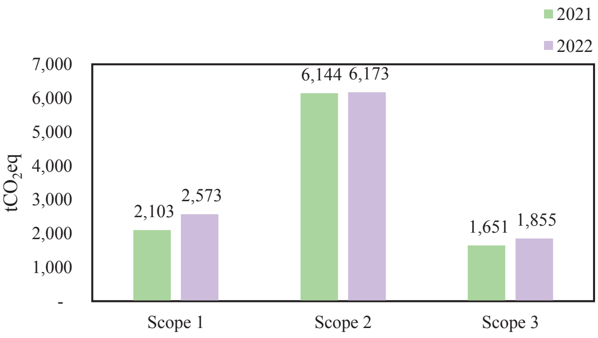

Fig. 4 Carbon footprint in 2021 and 2022

Total greenhouse gas (GHG) emissions in 2022 were higher than in 2021, despite both years sharing the same organizational boundary. The emission distribution trends remained consistent, with electricity consumption under Scope 2 identified as the primary emission hotspot. This finding aligns with previous studies conducted at Diponegoro University (Syafrudin et al., 2020), the American University of Sharjah (Samara et al., 2022), Suranaree University of Technology (Puttipiriyangkul, 2018), and Nan College at Uttaradit Rajabhat University (Saphanthong, 2020), all of which reported that electricity consumption was the dominant contributor to university carbon footprints, followed by transportation-related emissions.

A key difference between the two years was the inclusion of solar-generated electricity in the 2022 reporting boundaries, which was not accounted for in 2021 as the solar power system had not yet been installed. Additionally, in 2021, some university activities were conducted online due to the COVID-19 pandemic, which likely contributed to lower emissions compared to 2022.

A positive correlation between population size and GHG emissions is generally observed, though this trend does not hold universally across all universities. For example, the American University of Sharjah, with a smaller population than the University of Talca, emitted higher GHG levels. Additionally, the duration of the data collection period plays a significant role in influencing GHG emissions. The University of Ibadan, for instance, reported lower emissions compared to other institutions, likely due to its shorter data collection period of six months (January to June), whereas other universities collected data over a full 12-month period.

When comparing emissions across different studies, it is essential to express values in terms of emissions per capita. In 2022, the University of Phayao's emissions were 0.49 tCO_2eq per person. This figure is higher than that of the University of Bologna, the University of Ibadan, and Nan College at Uttaradit Rajabhat University (Adeyeye et al., 2022; Battistini et al., 2023; Saphanthong, 2020), but lower than the emissions reported by the American University of Sharjah, Clemson University, Eastern Asia University, Diponegoro University, Autonomous Metropolitan University, Suranaree University of Technology, University of Talca, and Chaiyaphum Rajabhat University (Clabeaux et al., 2020; Maimun et al., 2018; Mendoza-Flores et al., 2019; Samara et al., 2022; Sudha & Hirun, 2019; Syafrudin et al., 2020; Puttipiriyangkul, 2018; Yañez et al., 2020).

However, direct comparisons between studies can be challenging due to various influencing factors, including differing population sizes, emission factor values based on national contexts, the range of activities included, and the duration of the study period.

Conclusion

The University of Phayao's carbon footprint study for 2021-2022 revealed that post-COVID recovery in 2022 increased GHG emissions, with electricity consumption (Scope 2) consistently being the largest contributor (61.84% in 2021, 56% in 2022). A 2.997 MW

Table 3 Total GHG emission of University of Phayao for 2021 and 2022

Source / activity	unit	Activity data		Emission (tCO_2eq)		+ / - (tCO_2eq)
		2021	2022	2021	2022	(2022-2021)
Scope 1						
Stationary source						
- Diesel consumption by generator and Fire pump	L	1,360.51	0	3.68	0	-3.68
- Gasoline consumption by brush cutters	L	241.40	0	0.53	0	-0.53
Mobile source						
- Diesel consumption by van	L	77,349.45	105,511.68	211.99	289.17	77.18
- Diesel consumption by pick-up and cars (on road)	L	6,027.79	5,955	16.52	16.32	-0.20
- NGV consumption by bus	kg	43,944.41	30,110.94	99.35	68.08	-31.27
- Diesel consumption by front load (off road)	L	4,220.21	4,072.21	12.57	12.13	-0.44
- Gasoline consumption by other vehicles	L	0	3,228.70	0	8.00	8.00
Fugitive emissions						
- Leakage of methane gas from septic tank	$kgCH_4$	28,252.25	42,890.72	791.06	1,200.94	409.88
- N2O emission from solid waste management	kgN_2O	24.98	37.55	6.62	9.95	3.33
- CH4 emission from solid waste management	$kgCH_4$	333.09	500.64	9.33	14.02	4.69
- Leakage of R32 refrigerant from air conditioner	kg	28.28	28.28	19.15	19.15	0
- Leakage of R410a refrigerant from chiller	kg	434.45	434.45	835.66	835.66	2.2
- Leakage of R134a refrigerant from chiller	kg	74.25	74.25	96.53	96.53	0
Scope 2						
-Purchased electricity	kWh	12,289,545	12,349,129	6,144	6,173	29.33
-Solar cell	kWh	0	2,156,957	0	0	0
Scope 3						
Fuel-and energy related activities						
- Diesel	kg	74,457.81	96,706.05	26.22	34.06	7.84
- Gasoline	kg	179.84	811.26	0.07	0.33	0.26
- NGV	kg	43,944.41	30,110.94	50.80	34.18	-16.62
- Electricity	kWh	12,892,952	13,976,149	1,272.53	1,379.45	106.92
Downstream leased assets						
- Electricity	kWh	603,407	813,510	301.64	406.67	105.03
Total				**9,897**	**10,944.55**	

Table 4 The comparison of carbon footprint (CF) organization between University of Phayao and other universities

University	Years	Population	CF (tCO_2eq)	CF Distribution (%)			CF Per Capital (tCO_2eq/ Person)	Reference
				Scope 1	Scope 2	Scope 3		
1. Diponegoro University	2018	11,000	16,345.83	0.5	85.4	14.1	1.50	(Syafrudin et al., 2020)
2. Autonomous Metropolitan University (UAM)	2016	2,750	2,956.3	4	24	72	1.07	(Mendoza-Flores et al., 2019)
3. American University of Sharjah	2018	5,122	94,553	0.37	61.12	38.51	15.7	(Samara et al., 2022)
4. University of Ibadan	2019 (Jan-June)	41,743	5,271	4	90	6	0.11	(Adeyeye et al., 2022)
5. University of Talca	2016	7,643	5,472.89	5	35	60	0.72	(Yañez et al., 2020)
6. Clemson University	2014	21,857	92,762	19.5	41.7	38.8	4.2	(Clabeaux et al., 2020)
7. University of Bologna	2020	85,000	16,467	43	36	21	0.19	(Battistini et al., 2023)
8. Eastern Asia University	2016	3,454	5553.17	20.27	78.94	0.79	1.61	(Maimun et al., 2018)
9. Chaiyaphum Rajabhat University	2013	6,090	3,469.14	29.70	52.62	17.68	0.57	(Sudha & Hirun, 2019)
10. Nan College, Uttaradit Rajabhat University	2015	120	138.477	40.33	56.87	2.80	1.154	(Preecha Saphanthong, 2020)
11. Suranaree University of Technology	2016	18,411	13,319	27	66	6	0.73	(Wichayanee Puttipiriyangkul, 2018)
12. University of Phayao	2022	22,318	10,943.55	24	56	20	0.49	This study
	2021	21,715	9,897	21	62	17	0.46	This study

solar cell installation in 2022 helped mitigate electricity-related emissions, while the pandemic significantly affected emission patterns through changes in transportation and on-campus activities (Scope 1). Scope 3 emissions, particularly from fuel and energy activities, represented a substantial portion of the university's carbon footprint, suggesting the need for a broader emissions reduction approach. Comparing the university's emissions with other institutions proved challenging due to methodological differences, highlighting the need for standardized reporting in university carbon footprint assessments. The study emphasized the importance of regular carbon footprint monitoring to understand and manage environmental impact, especially during operational changes and external disruptions like the pandemic.

The University of Phayao's carbon footprint study offers essential insights for developing targeted emission reduction strategies, particularly focusing on energy efficiency, renewable energy adoption, and addressing indirect emissions. Practical mitigation suggestions include installing building management systems to monitor energy usage, applying sunlight films on windows, transitioning to LED lighting, and increasing tree planting across campus. Future research on university GHG emissions should examine long-term emission trends across multiple academic years to identify patterns related to enrollment, operations, and policy changes; evaluate the effectiveness and cost-benefit ratio of various emission reduction interventions; investigate behavioral factors influencing energy consumption among different campus stakeholders; and explore how green infrastructure and campus design can contribute to emissions mitigation, all supporting the university's journey toward sustainability.

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