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ARTICLE

Carbon Footprint of the National University of Juliaca: Establishing a Baseline for Future Management in an Emerging and Developing Institution

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ABSTRACT

This study aimed to quantify the carbon footprint of the National University of Juliaca (UNAJ) for the year 2023, in order to identify the main sources of greenhouse gas (GHG) emissions and provide a foundation for implementing sustainable policies. The methodology was based on the greenhouse gas inventory approach outlined in ISO 14064-1, applying the operational control method to measure both direct and indirect emissions. Data on energy consumption, transportation, and purchased goods and services were collected using digital tools and surveys, and emissions were calculated in metric tons of CO_2 equivalent (tCO_2e). The results indicate that UNAJ's total carbon footprint in 2023 was 1,461.03 tCO_2e, with per capita emissions of 0.47 tCO_2e per person. The main sources of emissions were transportation, accounting for 75.88% of total emissions, followed by the consumption of goods and services (14.29%) and energy use (5.12%). Despite limitations in solid waste management, the study makes a valuable contribution to the development of sustainability strategies, emphasizing the urgent need for sustainable mobility policies, energy efficiency measures, and the adoption of responsible procurement practices. Furthermore, it highlights the importance of achieving carbon neutrality at UNAJ as a key objective in mitigating its environmental impact. The findings provide relevant insights from

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the Peruvian context and offer a basis for analyzing emissions at local universities, with practical implications for enhancing environmental management in higher education institutions.

Keywords: Carbon Footprint; Greenhouse Gases; Higher Education Institutions; University; ISO 14064-1

1. Introduction

Global warming, caused by greenhouse gas (GHG) emissions and responsible for the extreme weather events experienced in recent years, has increasingly attracted the attention of governments and scientists worldwide [1]. These gases include carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4), among others [2]. Although these compounds are naturally emitted through biogeochemical processes [3], the Industrial Revolution and the widespread use of fossil fuels are essential contributors to the increasing atmospheric concentrations of GHG [4]. It is well known that all human activities and services generate GHG emissions, including those from higher education institutions (HEIs), which produce substantial amounts due to student [5] and staff[6] mobility, as well as intensive energy [7] and water [8] consumption on campus. Despite promoting sustainability as part of their educational and research missions, universities continue to be significant contributors to the global GHG problem [9], highlighting the urgent need for comprehensive and sustainable solutions within these environments.

Higher education institutions (HEIs), as major energy consumers due to their expansive campuses and the necessity to support educational and research activities, generate considerable GHG emissions. These emissions are mainly driven by electricity consumption, which is used to light, heat, cool, and power electronic devices in buildings such as classrooms, laboratories, and administrative offices [10,11]. In addition, transportation, including that of students, faculty, and staff, besides university-owned vehicles, represents one of the principal sources of emissions, ranking as the second most significant contributor within universities [12]. Furthermore, emissions stem from procurement and construction operations, and activities are not fully considered because they are underestimated [13]. Additionally, waste generation and disposal, including office materials, academic supplies, and food waste, contribute to indirect emissions. These factors illustrate that, although universities play a vital role in education and research, their environmental impact is substantial, particularly regarding emissions not directly under institutional control, such as transportation and waste disposal [14]. Therefore, university campuses constitute heterogeneous ecosystems for social, economic, energy-related, and personal mobility planning, with substantial impacts on the cities and regions in which they are embedded [15].

The lack of awareness regarding GHG emissions and the impact of human activities on climate change is a significant barrier to the adoption of sustainable practices that could effectively reduce emissions [16]. In addition, the absence of accurate emissions data hinders the identification of principal pollution sources, complicating the design of appropriate intervention measures and the targeting of effective mitigation efforts [17]. Without a reliable data foundation, there are no clear incentives for individuals and organizations to take meaningful action, as the impact of such actions cannot be measured or verified.

There is a growing academic consensus that higher education institutions (HEIs) have the responsibility to become leaders in climate-conscious practices and should strive for sustainability in their infrastructure and operations, aiming to achieve carbon neutrality [18]. Effectively addressing climate change requires achieving carbon neutrality by ensuring a balance between emissions and carbon sequestration, in line with the objectives of international climate agreements [19]. Consequently, HEIs pursuing carbon neutrality often use the carbon footprint as a GHG emissions inventory tool to establish a baseline [20]. Moreover, the carbon footprint is a highly valuable decision-making tool that enables organizations, including universities, to exercise greater control over their environmentally impactful activities [21]. Carbon accounting, the first step in carbon management and emissions reduction, involves a range of activities related to carbon emissions, such as measurement, calculation, reporting, and verification [22].

HEIs have a crucial role in the world; they are well-positioned to leverage their resources more broadly and to lead initiatives that benefit not only their campuses but also local communities and beyond [9]. Through the transfer of skills and knowledge across industry, government, and the public, universities play a vital role in educating future leaders who are responsible for shaping a globally sustainable system [14]. By quantifying GHG emissions, HEIs can lead by example, serving as models for other organizations by adopting sustainable practices and committing to carbon neutrality [23,24]. These demonstrate that analyzing GHG sources and managing emissions reductions are fundamental strategies for climate change mitigation [3]. Furthermore, achieving carbon neutrality, ensuring a balance between emissions and carbon sequestration, is essential and aligned with international climate agreements [25].

In Latin American countries, carbon footprint reporting remains limited and underdeveloped [26], as most current research on university carbon footprints has focused on campuses in developed countries such as the United Kingdom, the United States, Australia, and Canada [27]. Since beginning operations in 2013, the National University of Juliaca (UNAJ) has experienced significant growth in its academic offerings, resulting in increased infrastructure, student enrollment, personnel, transportation units, and the consumption of natural resources and electricity. These factors suggest a simultaneous rise in GHG emissions. In line with its commitment to social responsibility and the Sustainable Development Goals, UNAJ has set out to reduce its environmental impact. Achieving this objective requires, first and foremost, the quantification of emissions, which is essential for implementing effective reduction measures and ultimately obtaining carbon neutrality. In this context, this study aims to quantify the carbon footprint of the National University of Juliaca in accordance with ISO 14064, in order to provide accurate data that will facilitate the identification of the main GHG emission sources. By measuring the carbon footprint, this study will generate a solid foundation for informed decision-making and foster sustainable policies within and beyond the institution.

2. Materials and Methods

2.1. Study Area

The National University of Juliaca (UNAJ) is in the province of San Roman, in the department of Puno, Peru (**Figure 1**). It is located 839 kilometers from the country's capital, at an average altitude of 3,824 meters above sea level. An extreme climate, with marked thermal amplitudes characterize the city of Juliaca. Daytime temperatures are moderate but accompanied by extremely high solar radiation, while nighttime temperatures drop significantly [28]. The average annual temperature is 18°C, and the mean annual precipitation is 619.1 mm [29]. UNAJ was established in 2007 and formally began its academic activities in 2013. Despite being a relatively young institution, it has experienced rapid growth in recent years. During the 2023 study period, according to data from the university's administration, UNAJ operated three campuses: the administrative headquarters (La Capilla), the academic campus (also in La Capilla) located in the city of Juliaca, and the Ayabacas campus situated in the rural area of Ayabacas. The university comprises three faculties (the Faculty of Engineering Sciences, the Faculty of Industrial Process Engineering, and the Faculty of Management and Business Entrepreneurship) and ten undergraduate programmes. Furthermore, according to data provided by the Office of Academic Records and Human Resources, the university had a population of 2,860 undergraduate students, 168 professors, and 78 administrative staff. It is important to note that, at the time of the study, the university did not offer postgraduate programmes.

2.2. Calculation Approach of Carbon Footprint

This research is based on the GHG inventory approach in accordance with the Huella Carbono Perú Technical Guide and the ISO 14064-1:2018 standard. This standard specifies the requirements for the design, development, management, and reporting of GHG inventories, enabling the identification and quantification of the direct and indirect emissions generated by the university's activities [30].

2.3. Organizational and Operational Boundaries

The UNAJ's carbon footprint was calculated using the operational control approach, which includes emissions from activities under the university's direct control. This approach encompassed emissions generated across the three operational campuses, accounting for the direct emissions (Category 1) and the indirect emissions (Categories 2, 3, and 4) (**Figure 2**).

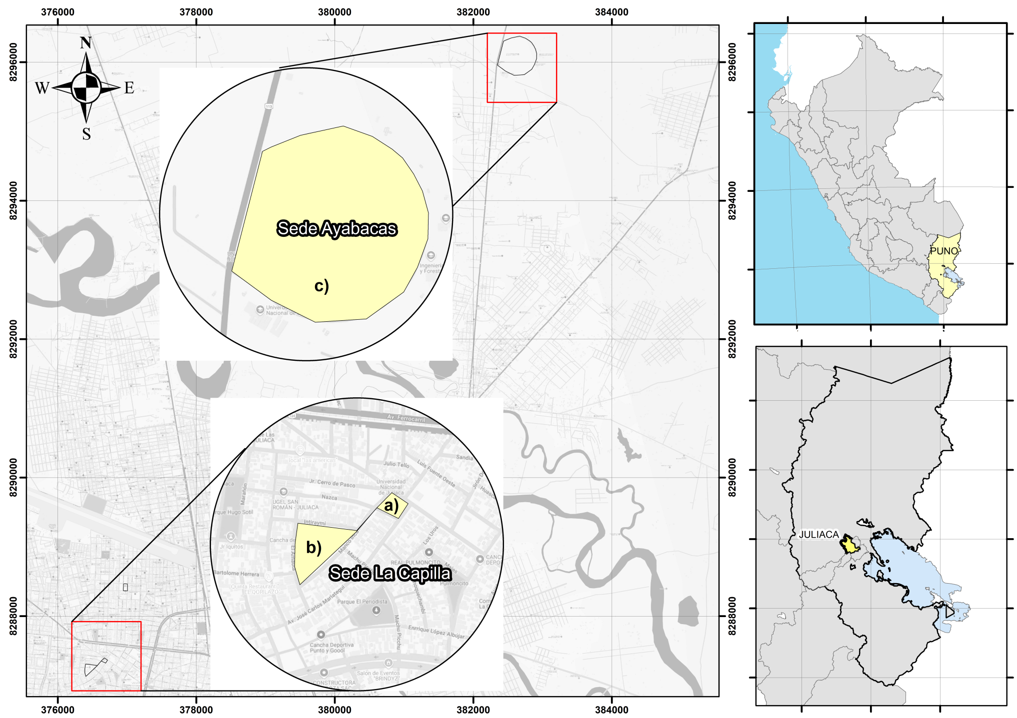


Figure 1. Location of the campuses of the UNAJ (a) La Capilla campus – Administrative area, (b) La Capilla campus – Academic area, (c) Ayabacas campus.

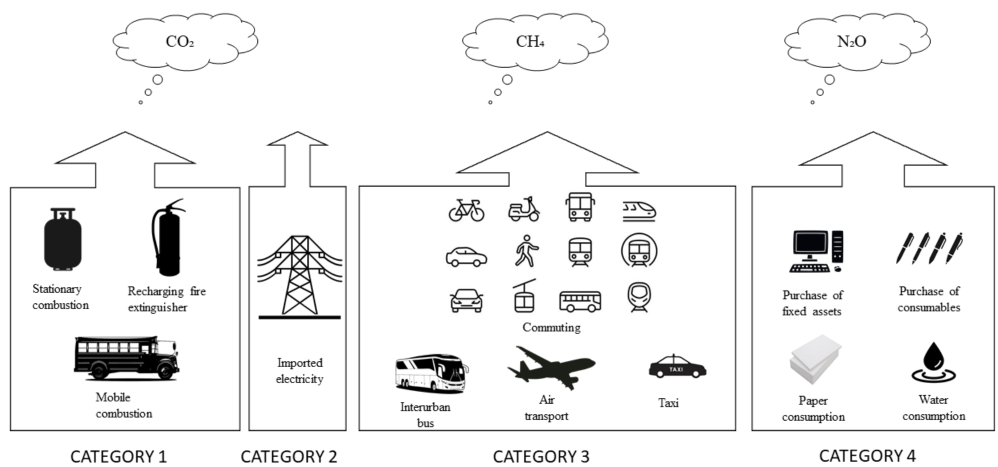


Figure 2. Operational boundaries and emission sources by category for the calculation of the carbon footprint at the UNAJ.

2.4. Data Collection

Relevant information was requested from various administrative offices to quantify the university's carbon footprint. However, adequate data validation was achieved through the Integrated Administrative Management System (SIGA), a software tool used for managing administrative processes in public institutions in Peru. This system facilitated the centralization and rigorous verification of data obtained from different offices, thereby ensuring the accuracy and consistency of the calculations. Data related to home-to-university transportation were collected through a structured questionnaire designed explicitly for this purpose. In contrast, the quantification of emissions associated with solid waste could not be completed due to the absence of a formal strategy within the university for collecting and measuring such data. Likewise, the consumption of liquefied petroleum gas (LPG) and carbon dioxide used in laboratory practices was excluded, given their limited use in university activities.

The emission factors used to calculate the carbon footprint were obtained from the official platform Huella de Carbono Perú, developed and managed by the Ministry of Environment (MINAM). This free digital platform enables both public and private organizations to measure, report, and manage their greenhouse gas (GHG) emissions (https://huellacarbonoperu.minam.gob.pe).

Complementarily, emission factors from internationally recognized sources were used, such as DEFRA (2018, 2023), IDEMAT 2024, and Ecoinvent 3.10, aligning with the Peruvian Technical Standard NTP ISO 14064-1, which establishes the requirements for the quantification and reporting of GHG emissions at the organizational level [31,32] (**Table 1**).

Table 1. Information sources by category.

Category	Emission Source	Information Source	Activity Data	Source of Emission Factors
		Direct emission sources		
Category 1	Combustion of mobile sources	Organization reports and invoices.	gal/year	CF Peru
	Combustion of stationary sources	Reports and invoices from the organization were used. To convert the total LPG consumed, it was considered that one gallon equals 3.785 liters and that the density of LPG is 0.56 kg/liter.	gal/year, kg/year	CF Peru
	Fire extinguisher refilling	An inventory of fire extinguishers from all campuses was conducted, considering only CO_2 extinguishers. The conversion from pounds to kilograms was performed using a factor of 0.453592.	kg/year	CF Peru
		Indirect emission sources		
Category 2	Electricity consumption	Consumption records: Electricity supplied by the Regional Public Electricity Service Company, Electro Puno S.A.A.	kWh/year	CF Peru
Category 3	Air travel	Total number of reported air travels. Distances were calculated using: https: //www.prokerala.com/travel/airports/distance/	km/year	DEFRA 2018
	Contracted taxis	Travel reports. Conversion of monetary units (Peruvian Soles) to kilometers was carried out using: https://ta.es.aboutlist.org/taxi-precios/pe/lima-district.	km/year	DEFRA 2018
	Land transportation	Travel reports. Distances were calculated using Google Maps software.	km/year	CF Peru
	Home-university transportation	Data obtained through survey (20% of the surveyed population).	km/year	CF Peru
Category 4	Paper consumption	A4 paper consumption was assumed to be equivalent to the total amount purchased.	kg/year	CF Peru
	Water consumption	Supplier payment receipts. Only potable water supplied by a Service Provider Company (EPS from Spanish language: Empresa Prestadora de Servicios) in the city was considered, excluding water from underground sources.	m^3	DEFRA 2018
	Assets	Accounting records of acquired assets during the year, based on purchase invoices and inventory records.	kg-units	IDEMAT 2024 V2.3, DEFRA 2023
	Consumables	Accounting records of acquired assets during the year, based on purchase invoices and inventory records.	kg-units	IDEMAT 2024 V2.3, DEFRA 2023, Ecoinvent 3.10

2.5. Criteria for GHG Emission Estimation

The quantification of GHG emissions was carried out in two steps. First, GHG emissions were calculated in metric tons using specific activity data and the corresponding emission factors [Equation (1)][30].

$$\text{GHG Emissions (t GHG)} = \text{Activity data} \times \text{Emission factor} \tag{1}$$

To convert GHG emissions (in metric tons) into carbon dioxide equivalent (tCO_2e), the following Equation (2) was employed.

$$\text{Emissions } (tCO_2e) = \text{Emission Data} \times \text{Global Warming Potential (GWP)} \tag{2}$$

For this calculation, Global Warming Potential (GWP) values based on a 100-year time horizon were used, in accordance with the Fifth Assessment Report (AR5) of the IPCC. This procedure enabled the standardization of emissions in terms of CO_2e, thus facilitating comparison and analysis by international guidelines.

2.6. Uncertainty Calculation

In order to assess the uncertainty associated with the carbon footprint measurement of the UNAJ for the year 2023, a qualitative analysis was conducted. This approach was adopted because the majority of emissions originate from indirect sources, and the emission factors and activity data used do not provide sufficient detail to support a rigorous quantitative uncertainty analysis The analysis was carried out following the guidelines established in the Manual of Greenhouse Gas Emissions Calculation Methodologies – Technical Guide by the Ministry of the Environment of Peru (MINAM), which proposes a qualitative classification of uncertainty based on three levels for activity data[31] (**Table 2**).

Table 2. Qualitative classification of uncertainty.

Type of Uncertainty	Activity Data	Emission Factors
Low	Reliable documentation is available, allowing for accurate data collection.	Emission factors are derived from national sources, such as the Ministry of the Environment.
Medium	Documentation is available, but the data must be estimated. For example, taxi expenses are documented, and total kilometers are estimated based on the expenditure.	Emission factors are taken from international databases that provide country-specific values for Peru.
High	No documentation or official reports are available; data must be estimated using secondary or bibliographic sources.	Emission factors are based on regional or global averages from international literature.

Source: Adapted from Guidelines for the Operation of the Carbon Footprint Peru, November 2020.

2.7. Emissions Verification

The GHG inventory prepared by the National University of Juliaca for the year 2023 was verified by an independent third party in accordance with the requirements of ISO 14064-3:2019. The audit was conducted by the Colombian Institute of Technical Standards and Certification (ICONTEC), applying a reasonable assurance level, corresponding to a confidence level greater than 95%.

During the verification process, the activity data, the appropriateness and application of emission factors, the defined organizational and operational boundaries, as well as the methodological consistency with ISO 14064-1:2018, were thoroughly reviewed.

3. Results

3.1. Activity Data from UNAJ

Activity data corresponding to direct emission sources are represented within Category 1 (**Table 3**). This category comprises activities related to the combustion of mobile and stationary sources, as well as the refilling of CO_2 fire extinguishers. The activities described in this section result in direct GHG emissions.

Activity data related to indirect emission sources are represented in Categories 2, 3, and 4. These categories include activities such as electricity consumption (Category 2) (**Table 4**), land and air transportation (Category 3) (**Table**

5), and the use of materials and consumables (Category 4) (**Table 6**).

Table 3. Activity data from direct emission sources: category 1.

Emission Source	Activity Data	Total Consumption	Units
Combustion of mobile sources	Petrol	825.0	gal
	Diesel	6,373.0	gal
	LPG	0.0	gal
Combustion of stationary sources	LPG	70.8	gal
	Acetylene	9.0	kg
Recharging fire extinguishers	CO_2	173.0	kg

Table 4. Activity data of indirect emissions caused by imported energy: category 2.

Emission Source	Activity Data	Total Consumption	Units
Electricity consumption	Electricity consumption	349,863.2	kWh

Table 5. Activity data of indirect emissions caused by transportation: category 3.

Emission Source	Activity Data	Total Consumption	Units
Air travel	less than 1600	90,619.5	km
Contracted taxis	kilometers traveled	4,879.0	km
Land transportation	Interprovincial transport	64,349.2	km
House-university transportation	private Diesel car	715,318.2	km
	private petrol car	1,489,766.9	km
	private car with LPG	771,906.4	km
	private electric car	468.0	km
	bicycle	702,219.9	km
	busses	592,121.8	km
	walking	80,477.6	km
	combi o custer	2,595,136.1	km
	motorcycle	1,114,001.5	km
	motorcycle taxi	10,846.3	km
	electric scooter	6,327.0	km
	taxi	129,703.2	km
	public transport vehicle	1,719,049.4	km

Table 6. Activity data of indirect emissions caused by products used by the organization: category 4.

Emission Source	Activity Data	Total Consumption	Units
Paper consumption	A4 DIN paper	8,370.8	kg
Water consumption	drinking water	6,702.0	m^3
Assets	steel	2,460.1	kg
	computer	120.0	units
	large electrical equipment	46.7	kg
	small electrical equipment	211.2	kg
	IT equipment	14.1	kg
	wood	480.2	kg
	melamine	2,184.4	kg
	metal	16,101.2	kg
	monitor	120.0	units
	high-density polyethylene	323.4	kg
	polypropylene	67.0	kg
	PVC	18.0	kg
	keyboard	8.3	kg
Consumables	vegetal oil	694.1	kg
	acrylic	2.9	kg
	bottled water	4,183.5	kg
	almonds	71.0	kg

Table 6. *Cont.*

Emission Source	Activity Data	Total Consumption	Units
Consumables	rice	1,510.0	kg
	oats	906.0	kg
	sugar	1,026.0	kg
	coffee	4.5	kg
	sweets	5.2	kg
	cardboard	2.6	kg
	laminated cardboard	558.9	kg
	chocolate	1.6	kg
	disinfectant	567.8	kg
	detergent	300.0	kg
	biscuits	151.7	kg
	soda	1,371.1	kg
	paper sheets	78.3	kg
	eggs	372.0	kg
	soap	535.2	kg
	juice	29.8	kg
	pen	143.0	kg
	evaporated milk	724.8	kg
	legumes and other grains	1,811.0	kg
	bleach	200.0	kg
	wood	10.2	kg
	peanut	12.3	kg
	butter	280.0	kg
	apple	24.0	kg
	metal	19.5	kg
	bread	1,550.0	kg
	toilet paper	0.4	kg
	banana	109.2	kg
	maker	178.8	kg
	polypropylene	34.9	kg
	cheese	15.0	kg
	caustic soda	30.0	kg
	liquid ink	22.8	kg
	toner	54.1	unit
	yoghurt	627.6	kg

3.2. Carbon Footprint of UNAJ

The carbon footprint of UNAJ, calculated based on various identified emission sources across four main categories during the 2023 period, as is detailed in **Table 7**, amounted to 1,461.03 t CO_2e, corresponding to a per capita contribution of 0.47 t CO_2e. The following section provides a breakdown of emissions by activity category, along with the relative contribution of each to the total emissions.

Table 7. Total GEI emissions of the UNAJ for 2023.

Emission Source	Total Emissions (tCO_2e)	General Contribution
Category 1	**68.77**	**4.71%**
Mobile combustion	68.10	4.66%
Stationary combustion	0.50	0.03%
Fire extinguishers	0.17	0.01%
Category 2	**74.76**	**5.12%**
Energy consumption	74.76	5.12%
Category 3	**1108.70**	**75.88%**
Air travel	27.03	1.85%
Land transport	7.73	0.53%
Taxis	0.75	0.05%
House-to-work transport	1073.19	73.45%
Category 4	**208.80**	**14.29%**
Paper consumption	8.00	0.55%
Water consumption	2.31	0.16%
Fixed assets	162.00	11.09%
General consumables	36.49	2.50%
Total emissions	**1461.03**	**100.00%**

Overall, the National University of Juliaca's total emissions exhibit a markedly uneven distribution across categories. Category 3 (emissions from transportation) is the most significant contributor, within this category, the specific activity with the greatest impact was home-to-university transportation, accounting for 73.45% of total emissions (1,073.19 tCO_2e). This activity includes the daily commuting of students, faculty, and administrative staff from their homes to the university campuses, underscoring the urgent need to implement more sustainable mobility policies. Meanwhile, Category 2 (emissions from imported energy) and Category 4 (emissions from products used by the organization) are additionally significant contributors to the institutional carbon footprint, highlighting key areas to implement targeted mitigation strategies.

3.3. Uncertainty Calculation

The qualitative uncertainty assessment of UNAJ's GHG inventory indicates a relatively high overall level of uncertainty, as the most significant emission sources, primarily those related to transportation, exhibit medium-level uncertainty in their activity data (**Table 8**). This classification aligns with the indirect nature of these emissions and reflects the inherent limitations of data collection methods within emerging institutional contexts.

Table 8. Uncertainty analysis.

Type of Uncertainty	Activity Data	Emission Factors
Mobile combustion	Low	Low
Stationary combustion	Low	Low
Fire extinguishers	Low	Low
Energy consumption	Low	Low
Air travel	Low	Medium
Land transport	Low	Medium
Taxis	Medium	Medium
House-to-work transport	High	Medium
Paper consumption	Low	Medium
Water consumption	Low	Low
Fixed assets	Medium	High
General consumables	High	High

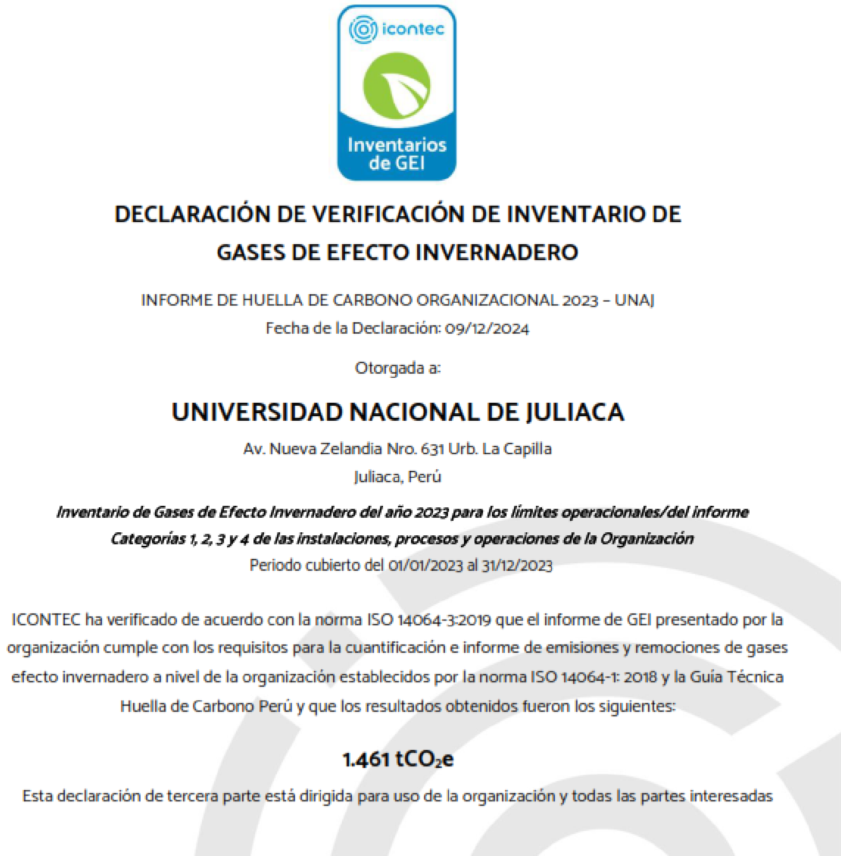
3.4. Emissions Verification

To ensure the reliability of the results, a verification was conducted by the Colombian Institute of Technical Standards and Certification (ICONTEC), validating the proper use of emission factors, the data traceability, and the consistency of the defined organizational and operational boundaries. As a result, a 'Greenhouse Gas Inventory Verification Statement' certificate was issued, as shown in **Figure 3**.

4. Discussion

The National University of Juliaca has enabled the development of a detailed understanding of the impact of institutional activities on GHG emissions. With a total carbon footprint of 1,461.03 metric tons of CO_2e for 2023, the university demonstrates a significant contribution to climate change in its first few years of operation. This emissions analysis not only identifies the most relevant GHG sources but also highlights critical areas where strategic interventions are urgently needed.

The emissions breakdown reveals an uneven distribution across the various emission source categories. Category 3, which encompasses emissions from transportation, accounts for 75.88% of total emissions, highlighting the predominant influence of internal and external mobility involving students, teaching, and administrative staff. Specifically, commuting between home and the university represents 73.45% of these emissions, underscoring the urgent need for policies that promote sustainable mobility. This finding aligns with evidence from the National University of Colombia, where transportation was also identified as one of the primary sources of GHG emissions, accounting for 58.51%[14]. Similarly, approximately 97% of emissions are indirectly generated, primarily due to the daily commuting of students[33]. These findings indicate that, in Latin American public universities, the transportation component, especially segments not directly managed by the institution, represents a critical and persistent source of emissions. This is largely due to a high dependence on motorized vehicles, the absence of sustainable mobility policies, and the peripheral or dispersed location of university campuses. Although emissions from energy consumption and business travel are relatively straightforward to quantify, estimates based on commuting surveys are limited in accuracy due to low response rates and the constant turnover of the student population [34]. This limitation may affect the results, especially considering that mobility patterns vary significantly among different groups. Given that the transportation sector remains one of the most challenging to decarbonize, it is imperative to implement innovative solutions that promote low-emission mobility, such as the use of electric transportation, the encouragement of bicycle use, and the integration of environmentally friendly public transportation alternatives.



icontec
Inventarios de GEI

DECLARACIÓN DE VERIFICACIÓN DE INVENTARIO DE GASES DE EFECTO INVERNADERO

INFORME DE HUELLA DE CARBONO ORGANIZACIONAL 2023 – UNAJ
Fecha de la Declaración: 09/12/2024

Otorgada a:

UNIVERSIDAD NACIONAL DE JULIACA

Av. Nueva Zelandia Nro. 631 Urb. La Capilla
Juliaca, Perú

Inventario de Gases de Efecto Invernadero del año 2023 para los límites operacionales/del informe Categorías 1, 2, 3 y 4 de las instalaciones, procesos y operaciones de la Organización
Periodo cubierto del 01/01/2023 al 31/12/2023

ICONTEC ha verificado de acuerdo con la norma ISO 14064-3:2019 que el informe de GEI presentado por la organización cumple con los requisitos para la cuantificación e informe de emisiones y remociones de gases efecto invernadero a nivel de la organización establecidos por la norma ISO 14064-1: 2018 y la Guía Técnica Huella de Carbono Perú y que los resultados obtenidos fueron los siguientes:

1.461 tCO_2e

Esta declaración de tercera parte está dirigida para uso de la organización y todas las partes interesadas

Figure 3. UNAJ carbon footprint verification certificate, 2023.

On the other hand, emissions associated with energy consumption (Category 2) account for 5.12% of total emissions, underscoring the critical role of energy efficiency in mitigation efforts. The universities, like other large institutions, are responsible for substantial energy consumption due to their extensive infrastructure. Optimizing energy use through the installation of efficient technologies, such as photovoltaic systems, LED lighting, and equipment modernization, could lead to a significant reduction of GHG emissions. Moreover, initiatives such as social marketing campaigns aimed at reducing energy consumption among students and faculty [35] have been implemented. In addition, the implementation of energy-saving inventories [36] would not only enhance environmental sustainability but also potentially reduce long-term operational costs.

Likewise, Category 4, which relates to the consumption of goods and services, represents 14.29% of total emissions. Like other institutions, UNAJ relies on different products in its daily operations, ranging from office supplies such as paper to electronic equipment and fixed assets. Although these procurement-related materials constitute a relatively minor portion of total material throughput, they have a substantial environmental impact, particularly on products such as electronics, furniture, stationery, catering food, and similar items [37]. Consequently, emissions associated with these products can be substantially reduced through sustainable procurement practices that prioritise low-impact goods and promote recycling and material reuse.

For contrasting institutional realities, total and per capita emissions of university members (students, faculty, and administrative staff) were considered, resulting in a value of 0.47 tCO_2e per person. This figure falls within the range reported by similar studies conducted at other higher education institutions.

Variations in the carbon footprint among universities can be attributed to a range of interrelated factors that reflect the intrinsic characteristics of each institution and strategic decisions related to resource management and sustainability. An analysis of the data presented in **Table 9** shows, for instance, that the American University of Sharjah reports the highest total carbon footprint (94,553.30 tCO_2e), along with a similarly elevated per capita value of 15.65 tCO_2e/person. This high per capita footprint indicates that each member of the university contributes significantly to overall emissions, reflecting an intensive use of resources in institutional activities. In contrast, the University of Oulu reports a total footprint of 19,072.00 tCO_2e and a per capita footprint of 1.13 tCO_2e/person, suggesting a considerably lower individual contribution despite the institution's relatively high overall emissions.

Table 9. Per capita and total carbon footprint in different universities worldwide.

Institution	Country	Year	Total (tCO_2e)	Per Capita (tCO_2e/per)	Source
Technological University of Pereira	Colombia	2017	8,969.00	0.4	Varón-Hoyos et al. [33]
Bologna University	Italy	2020	16,467.00	0.18	Battistini et al. [15]
National University of Colombia	Colombia	2019	7,250.52	0.43	Cano et al. [14]
EAN University	Colombia	2018	2,082.70	0.25	García-Alaminos et al. [26]
Oulu University	Finland	2019	19,072.00	1.13	Kiehle et al. [38]
American University of Sharjah	United Arab Emirates	2018/2019	94,553.30	15.65	Samara et al. [39]
University Jaime I	Spain	2019	4,720.73	0.30	Valls-Val et al. [40]
Pontifical Bolivarian University	Colombia	2019/2020	4462.00	0.28	Osorio et al. [23]
University of Technology	Jamaica	2021/22	4,150.43	0.36	Baker et al. [41]
Debre Markos University	Ethiopia	2022	66420.4	0.23	Admas et al. [42]
Rafael Landívar University	Guatemala	2019	2488.16	0.069	Gálvez-Campos et al. [43]
National University of the Altiplano	Peru	2023	4,721.20	0.23	Peralta et al. [44]
National University of Juliaca	Peru	2023	1,461.03	0.47	This study

In contrast, institutions such as the National University of Juliaca (1,461.03 tCO_2e and 0.47 tCO_2e per capita) and the National University of Altiplano (4,721.20 tCO_2e and 0.23 tCO_2e per capita) report low total carbon footprints, although their per capita values differ. In the case of UNAJ, despite its relatively low total footprint, the higher per capita t suggests that each member of the university community contributes more significantly to emissions compared to larger institutions. This phenomenon may be linked to the efficiency of resource management or the nature of the university's activities. Helmers[34] further notes that smaller universities and those located in urban areas may more easily achieve lower carbon footprints due to reduced impacts from infrastructure and transportation.

It is important to note that indirect emissions are not directly comparable due to the lack of standardization[14]. Furthermore, decisions regarding which operations are conducted on campus and which emissions are included or excluded from the assessment significantly influence the results, highlighting the need for caution on the part of those conducting the calculations[38]. Additionally, there are notable differences among existing tools used to calculate the carbon footprint of organizations in general and universities in particular[40].

The observed differences in total and per capita carbon footprints can be partly explained by several factors that directly influence resource consumption and GHG emissions. Firstly, the size of the university and the number of students, faculty, and administrative staff play a critical role. Universities with larger populations, such as the American University of Sharjah and the University of Oulu, tend to generate higher emissions due to increased demand for energy, transportation, and other services that require intensive resource use. In comparison, smaller universities, such as UNAJ, exhibit lower overall emissions owing to reduced demand.

Moreover, academic and administrative activities are key determinants of an institution's carbon footprint. Universities offering academic programs with high energy demands, such as those in engineering, technology, and applied sciences, tend to have a greater environmental impact due to the specialized infrastructure and equipment required. Institutions that have not adopted distance learning or remote work practices, which could reduce commuting and on-campus resource consumption, also tend to exhibit higher carbon footprints.

As for infrastructure, universities with older or poorly insulated buildings tend to exhibit higher energy consumption, particularly for heating and cooling, which increases their carbon footprint. In contrast, high academic institutions that have invested in more efficient infrastructure, such as buildings with environmental certifications or renewable energy systems, can significantly reduce their environmental impact. Additionally, efficient technologies, such as LED lighting systems and low-energy computing equipment, contribute to lowering emissions.

Finally, institutional sustainability policies are fundamental in determining the magnitude of a university's carbon footprint. Institutions that implement robust policies on energy efficiency, waste reduction, renewable energy use, and sustainable transportation tend to report lower carbon footprints. However, the absence of a comprehensive sustainability approach-one that not only aims to reduce energy consumption but also to offset emissions-may result in higher carbon footprints.

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

5. Conclusion

This study has provided a clear overview of UNAJ's carbon footprint, underscoring the urgent need to adopt sustainability policies in its operations. The total carbon footprint for the year 2023 was 1,461.03 tCO_2e, with a per capita footprint of 0.47 tCO_2e per person. The primary source of emissions was transportation, accounting for 75.88% of total emissions, with home-to-university commuting alone representing 73.45%. This highlights the critical importance of implementing measures that promote sustainable mobility within the university. Emissions associated with energy consumption and the use of institutional products also play a significant role, contributing 5.12% and 14.29%, respectively.

These findings indicate that, beyond addressing mobility, it is crucial to optimize energy use and reassess procurement practices to reduce indirect emissions. Compared with other universities, the per capita carbon footprint is moderate; however, sustained efforts are necessary to reduce emissions and achieve carbon neutrality. Despite limitations in data collection, this research provides a robust foundation for informed decision-making, enabling the implementation of more effective GHG reduction policies.

This study provides a valuable dataset for implementing the necessary sustainable policies within the university, highlighting critical areas such as transportation, energy efficiency, and responsible procurement. It is recommended that higher education institutions take measures that consider sustainable transportation, improve energy efficiency, and promote green purchasing practices to reduce GHG emissions and achieve carbon neutrality. Despite some limitations in data collection, the findings offer a solid foundation for future research and mitigation strategies at UNAJ and other Peruvian institutions.

Author Contributions

Conceptualization, G.H., M.M.Q., and D.C.; methodology, G.H. and M.M.Q.; software, M.Q. and D.C.; validation, G.H., M.M.Q., and D.C.; formal analysis, G.H., R.O.S., and W.F.R.; investigation, G.H., M.Q., and D.C.; resources, G.H.; data curation, R.O.S., and W.F.R.; writing-original draft preparation, G.H. and M.M.Q.; writing-review and editing, G.H. and M.M.Q.; visualization, R.O.S. and W.F.R; supervision, M.Q.; project administration, G.H.; funding acquisition, G.H. All authors have read and agreed to the published version of the manuscript.

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Not applicable.

Data Availability Statement

The data supporting the findings of this study are available upon reasonable request from the corresponding author.

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Conflicts of Interest

The authors declare no conflict of interest.

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