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Calculation of Primary and Secondary Carbon Footprint in the Environment of the Sahid University Jakarta

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ABSTRACT

This study aims to identify and measure the primary and secondary carbon footprints within the environment of the Sahid University Jakarta. As an educational institution, a university plays a strategic role in climate change mitigation; however, most campuses in Indonesia have not yet optimally implemented environmentally friendly practices. Sahid University Jakarta is among the institutions that have not been classified as a green campus in the UI GreenMetric rankings. This study was conducted in the Faculty of Engineering, employing a descriptive-analytical quantitative approach that combined primary data (surveys and observations) with secondary data (campus reports). Carbon footprint calculations were based on emission standards from the IPCC and EPA. The results show that the total annual carbon emissions from campus activities reached 542.14 tons of CO_2-eq, with the most significant contributions coming from the use of air conditioning (49.29 percent) and desktop computers (24.16 percent). Primary carbon emissions account for the majority of the total footprint, compared to secondary emissions, such as those from the use of LPG and paper. These findings underscore the importance of implementing mitigation strategies that focus on managing electricity consumption, particularly for cooling systems and electronic devices.

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1. INTRODUCTION

Campuses, as educational institutions, play a significant role in knowledge transformation and also contribute substantially to global carbon emissions. According to the Intergovernmental Panel on Climate Change (IPCC), the education sector, including campuses, accounts for 2–3% of global greenhouse gas (GHG) emissions through operational activities such as energy use, transportation, and waste management (IPCC, 2022). Energy-intensive campus activities, including the use of electronic devices, air conditioning, and fossil fuel-based transportation, are the primary contributors to the high carbon footprint within academic environments (Li et al., 2021). However, the strategic role of campuses as agents of change in promoting sustainable lifestyles is often underutilized (Febrina et al., 2021).

In Indonesia, out of 4,004 higher education institutions, only 20 are classified as "green campuses" based on the UI GreenMetric 2022 rankings (UI GreenMetric, 2022). Sahid University Jakarta, as one of the private universities, is not yet included in that list, indicating a gap in the implementation of sustainability practices. However, efforts to reduce carbon emissions not only benefit the environment but also improve operational cost efficiency. A study by Wright & Lewis (2022) shows that transitioning to renewable energy on campus can reduce electricity costs by up to 25 percent. Moreover, education on sustainability through curriculum integration and supportive facilities (such as bike parking and electric vehicle charging stations) can encourage environmentally friendly behavior among students (Febrina et al., 2021).

Primary carbon footprint refers to direct emissions from sources controlled by producers or consumers, such as fuel combustion for production or energy use in electronic devices. In contrast, secondary carbon footprint refers to indirect emissions from processes or energy use that producers or consumers do not directly control. For example, the primary carbon footprint of electronics refers to the direct CO_2 emissions from the production and use of devices such as computers, phones, and other electronic devices. Meanwhile, the secondary carbon footprint includes indirect emissions from the use of LPG and paper. LPG (Liquefied Petroleum Gas) produces CO_2 when burned, and paper production and usage also contribute to emissions.

Research on carbon footprints in campus environments has grown rapidly over the past decade, especially in developed countries. A study by Li et al. (2021) found that energy-related activities, including air conditioning and campus transportation, are significant contributors to primary carbon emissions. Meanwhile, research by Huang et al. (2021) noted that campus carbon footprint analyses often focus on direct (primary) emissions—such as fossil fuel combustion—while neglecting indirect (secondary) emissions from electricity consumption and waste management. In fact, in developing countries, secondary emissions are reported to contribute 60–70 percent of the total campus carbon footprint (Huynh et al., 2018). In Indonesia, carbon footprint assessments are still limited to institutions already designated as "green campuses," such as UI (UI GreenMetric, 2022), while private institutions like Sahid University Jakarta remain under-researched. Furthermore, previous studies tend to adopt a partial approach, such as analyzing emissions from transportation (Wright & Lewis, 2022) or building energy use (Hu et al., 2017), without integrating both emission categories holistically (Prihatmaji et al., 2016; Suharyanto et al., 2022).

This study offers novelty in three aspects. First, it integrates the analysis of both primary (direct) and secondary (indirect) carbon emissions simultaneously, a rare approach in the context of Indonesian campuses. Most previous studies focus on only one category, resulting in an incomplete picture of total carbon contributions. Second, this study focuses on a specific case at Sahid University Jakarta, a private institution not listed in the UI GreenMetric rankings, offering new insights into the challenges and opportunities for emission reduction at non-green campuses. Third, the methodology combines a quantitative approach using IPCC (2022) emission factors with a comparative analysis of the relative contribution of each emission source, enabling data-driven identification of mitigation priorities. This combination has not been applied previously in the context of Jakarta campuses, thus providing a valuable reference for similar institutions to design more measurable and impactful emission reduction strategies.

Based on this background, the research questions are formulated to determine the magnitude of primary and secondary carbon emissions generated in the campus environment of Sahid University Jakarta. First, how much is the contribution of primary carbon emissions, such as those from transportation and fossil fuel consumption, and secondary emissions from electricity use and waste. Second, which emission source—primary or secondary—contributes the most to the total campus carbon footprint. These questions serve as the foundation for determining priority strategies for effective emission reduction. The purpose of this research is to comprehensively assess the carbon footprint in the environment of Sahid University Jakarta. First, the study aims to identify and quantitatively measure both primary emissions (such as fossil fuel-based transportation) and secondary emissions (such as electricity use and waste production). Second, it aims to analyze the relative contribution of each emission source to the campus's total carbon footprint, determining whether primary or secondary activities have a more significant environmental impact. These objectives align with the research questions and are intended to support evidence-based recommendations for climate change mitigation at the institutional level.

2. RESEARCH METHOD

2.1. Research Period and Design

This research was conducted at the Faculty of Engineering, the Sahid University, Jakarta. Data collection took place from October 2024 to January 2025, encompassing observations of campus activities, surveys, and document analysis related to electricity consumption, LPG usage, and paper usage. The study employed a quantitative approach with a descriptive-analytical design to calculate primary and secondary carbon footprints within the campus environment. This method was chosen as it allows for the numerical measurement of carbon emissions based on actual data and standardized emission factors (IPCC, 2021). Data collection involved a combination of primary data (observations and surveys) and secondary data (internal campus reports), which were then analyzed using carbon footprint calculations based on international standards (EPA, 2021). The research sample comprised the population of the Sahid University, which consisted of 5 faculties with a total population of 3,000 individuals. The number of research respondents was determined using the Slovin formula, with a 10 percent margin of error, resulting in a sample size of 100 respondents.

2.2. Data Collection Methods

Primary data were collected through direct observations and surveys conducted on campus. Observed activities included the use of electricity, gas, and paper in campus facilities (laboratories, lecture halls, offices), as well as commuting patterns of staff and students, and the use of campus transportation. Survey data were obtained using structured questionnaires to measure energy and transportation habits among students and staff. Data collection instruments included questionnaires, interviews, and energy monitoring records from the campus energy management system. Secondary data were sourced from internal campus documents and reports, including annual reports on electricity, gas, and paper consumption. These sources were used to validate and complement the primary data.

2.3. Emission Calculation Method

The carbon footprint calculator was the primary tool used to convert energy and waste consumption data into estimated carbon emissions. This tool applies standard emission factors from the IPCC and EPA to the collected activity data (IPCC, 2021; EPA, 2021).

a. The primary carbon footprint is calculated from direct emissions generated by the use of electrical equipment on campus. The formula is as follows (IPCC, 2021):

$$Primary\ carbon\ footprint\ (Emission) = \sum\nolimits_i (E_i\ x\ EF_i)$$

Where:
E_i = Energy consumption from source i (kWh)
EF_i = Emission factor for source i (kg CO2/kWh)
$EF_{Electricity}$ =0.7744 kg CO2/kWh

b. The secondary carbon footprint includes indirect emissions from activities such as the use of LPG. The formula is as follows (EPA, 2021):

$$Secondary\ carbon\ footprint\ (Emission) = \sum\nolimits_j (S_j\ x\ EF_j\ x\ CV)$$

Where:
S_j = Amount of LPG or other emission-contributing sources (kg)
EF_j = Emission factor for LPG or source j (kg CO2-eq/Kg)
EF_{LPG} = 0,0631 kg.CO2-eq/Kg.
CV = Calorific Value (44,7 MJ/l)

c. The secondary carbon footprint also includes emissions from paper usage. The formula is as follows (EPA, 2021):

$$Secondary\ carbon\ footprint\ (Emission) = \sum\nolimits_j (S_j\ x\ EF_j)$$

Where:
S_j = Amount of paper or emission-contributing source (kg)
EF_j = Emission factor for paper or source j (Kg CO2-eq/Kg)
EF_{Paper} = 1,22 Kg.CO2-eq/Kg.

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2.4. Data Analysis

Data were analyzed through four main stages to answer the research questions. First, emission quantification was carried out by calculating the total primary and secondary carbon footprints using the formulas provided. Primary emissions were calculated based on energy and fossil fuel consumption (e.g., electricity, diesel, and gas), multiplied by the standard IPCC emission factors (2021). Secondary emissions were measured from waste management and other indirect activities using EPA emission factors (2021). Second, a contribution comparison was conducted to assess the proportion of primary and secondary emissions to the campus's total carbon footprint. This step aimed to identify the dominant emission sources (primary or secondary) that have the most significant environmental impact. Third, emission hotspots were identified by analyzing specific activities generating the highest emissions, such as air conditioning, private vehicle use, or plastic waste generation. These findings served as the basis for prioritizing mitigation programs, such as transitioning to renewable energy sources or optimizing waste management practices. Fourth, data validation was performed by cross-checking the results of the carbon footprint calculator against secondary data from internal campus reports. This validation ensured the accuracy of the analysis results and reduced methodological errors (IPCC, 2021; EPA, 2021). Through these stages, the research produced evidence-based strategic recommendations for reducing the campus environment's carbon footprint.

3. RESULTS AND DISCUSSIONS

3.1. Carbon Emissions from Electricity Use

To calculate the amount of carbon emissions generated from electricity usage, the total electricity consumption is multiplied by the emission factor of the power plant, as shown in Equation 1. In this study, it is assumed that the electricity is generated using diesel-powered generators. The electricity system in South Jakarta, where the Sahid University Jakarta is located, is supplied by a power plant.

In measuring the primary carbon footprint within the Usahid environment, the electronic devices considered include outdoor and indoor lighting, air conditioners, and computing machines. Lighting devices account for over 1,200 units with power consumption ranging from 10 to 36 watts. There are 213 air conditioning units, each consuming 750 watts, and 239 computing machines (desktops and laptops) with a power usage of 450 watts each. The average daily usage ranges from 4 to 12 hours. The data on the number of air conditioning units and lamps used at the Sahid University Jakarta is shown in Table 1.

Table 1. Electronic Equipment Using Electricity at the Sahid University

No	Electrical Equipment	Type	Amount	Power (Watt)	Average Usage /Day (Hours)
1	Lamp	Neon Box	1240	36	12
		Room Neon	95	20	4
		LED Bulb	71	10	12
2	AC	AC Split	213	750	9
3	Computer	Desktop	174	450	9
		Laptop	55	450	9

Example Calculation of Electricity Consumption from Lighting Use:

Electricity Consumption (kWh) of Neon Box

= Power × Number of Lamps × Time = 36 W × 1,240 × 12 hours = 535,608 Wh = 535.68 kWh/day

Emissions from Electricity Use

= Consumption × Emission Factor = 128,563.20 × 0.7744 = 99,557.91 tons CO_2/year

Table 2 presents data on daily, monthly, and annual electricity consumption from various types of electronic equipment used at the Sahid University Jakarta, as well as the estimated carbon emissions (CO_2) resulting from these activities. The data reflects the primary carbon footprint—direct emissions produced by electricity use in campus operations. For a year, the total electricity consumption at the campus was recorded at 700,080

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kWh, resulting in total carbon emissions of 542,134.18 tons CO_2-eq. Among the electronic devices, air conditioners contributed the most to these emissions, with an annual electricity consumption of 345,060 kWh, resulting in emissions of 267,210.63 tons CO_2-eq, or approximately 49.29 percent of the total campus emissions. Next in line, desktop computers contributed 130,970.85 tons of CO_2-eq, equivalent to 24.16 percent of total emissions, while neon box lights produced 99,557.91 tons of CO_2-eq, or 18.36 percent. Conversely, laptop computers, room neon lights, and LED lamps contributed significantly less to the campus's total carbon emissions, indicating that low-power devices have a relatively minimal environmental impact.

Table 2. Measurement Results of Electronic Equipment Using Electricity at the Sahid University

Equipment Electricity	***kWh/ Day***	***kWh/ Month***	***kWh/ 6 Month***	***Emisi CO_2/ 6 Month***	***kWh/ Year***	***Emisi CO_2/ Year***
Neon Box	535,68	10.713,60	64.281,60	49.778,96	128.563,20	99.557,91
Room Neon	7,60	152,00	912,00	706,24	1.824,00	1.412,49
LED Bulb	8,52	170,40	1.022,40	791,74	2.044,80	1.583,47
AC	1.437,75	28.755,00	172.530,00	133.605,32	345.060,00	267.210,63
Desktop	704,70	14.094,00	84.564,00	65.485,42	169.128,00	130.970,85
Laptop	22,75	4.455,00	26.730,00	20.699,42	53.460,00	41.398,83
Total	2.917,00	58.340,00	350.040,00	271.067,09	700.080,00	542.134,18

The study by Kasman et al. (2020) also found that the highest emissions originated from the use of air conditioners and laboratory computers, accounting for a combined contribution of over 70 percent to the campus's total electricity-related emissions. These findings align with those from the Sahid University, confirming that air conditioners are the primary contributors to the carbon footprint in Indonesian campus environments. In international studies conducted in developing countries, Naderipour et al. (2016) and Huynh (2018) found that air conditioners and lighting systems accounted for over 50 percent of total campus energy consumption. However, they also highlighted that improving the efficiency of electronic devices and building architecture can reduce consumption by up to 30 percent. An internal study by Sagal et al. (2023) demonstrated that utilizing automatic timers and motion sensors for air conditioning and lighting systems resulted in a 25 percent reduction in electricity consumption over one year. The application of such simple technologies has proven effective for energy efficiency in the education sector. As part of improvement efforts, research by Hu et al. (2017) and Li et al. (2025) emphasized that digital transformation, the use of cloud computing, and energy-efficient equipment (such as inverter AC units and all-in-one computers) can significantly reduce campus carbon emissions. The implementation of these technologies can cut the annual carbon footprint by up to 20 percent.

3.2. Carbon Emissions from Gas Usage

LPG usage in campus activities at the Sahid University primarily originates from canteen operations, which utilize one blue cylinder (12 kg) and eight green cylinders (3 kg) per month (Table 3). Canteens tend to prefer the 3 kg LPG cylinder (commonly referred to as the "melon cylinder") for several reasons, primarily due to its affordability and ease of use. The smaller 3 kg cylinders are lighter, more portable, cheaper, and take up less space. Similar findings were reported by Kasman et al. (2020), who also found that the 3 kg cylinder was the preferred choice for most campus canteen operators.

Table 3. LPG Fuel Used on the Sahid University

LPG	**Type**	**Amount**	**Volume (Kg)**
LPG Cylinder	Green Cylinder	8	3
	Blue Cylinder	1	12

Example Calculation: Energy Consumption from LPG Cylinder Use
Gas energy consumption = Volume × Quantity = 3 × 8 = 24 = 0.024 kg/day
Emissions from LPG usage = Consumption × EFLPG × CV = 0.288 × 0.0631 × 44.7 = 0.812 tons CO_2/year

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Table 4 presents the carbon emission measurements from LPG usage on the Sahid University campus over a one-year period, representing part of the secondary carbon footprint. Two types of gas cylinders are used: the Green Cylinder (3 kg) and the Blue Cylinder (12 kg), both of which are commonly used for canteen operations. Over six months, Green Cylinders produced 0.406 tons CO_2-eq, while Blue Cylinders produced 0.203 tons CO_2-eq. The total six-month carbon footprint from both cylinder types was 0.609 tons CO_2-eq. Annually, LPG consumption amounted to 0.432 kg, with total emissions reaching 1.218 tons of CO_2-eq per year. Green Cylinders remained the highest contributors due to their more frequent use, despite having a smaller gas capacity. This reflects a denser consumption pattern for smaller, more practical, and economical cylinders in daily campus canteen operations.

Table 4. Carbon Emission Measurements from Gas Use at the Sahid University

LPG Type	*Kg /Month*	*Emission CO_2/Month*	*Kg /6 Month*	*Emission CO_2/6 Month*	*Kg /Year*	*Emission CO_2/Year*
Green Cylinder	0,024	0,068	0,144	0,406	0,288	0,812
Blue Cylinder	0,012	0,034	0,072	0,203	0,144	0,406
Total		0,102		0,609		1,218

3.3. Carbon Emissions from Paper Usage

Paper usage on campus originates from academic and administrative activities within the Sahid University, which uses 55 packs of F4 paper (each weighing 2.84 kg) and 55 packs of A4 paper (each weighing 2.50 kg) per month (Table 5). Indonesian universities often prefer F4 (folio) paper over A4 primarily due to its longer format, which provides more writing space, handy for academic documents such as papers, reports, and assignments. The larger area allows more text to fit on each page, reducing the number of pages needed and the frequency of printing.

Table 5. Paper Usage at the Sahid University

Paper	Type	Amount (RIM)	Volume (Kg)
Plain Paper 1	F4	55	2,84
Plain Paper 2	A4	12	2,50

Example Calculation: Energy Consumption from Paper Use
Paper consumption = Volume × Quantity = 55 × 2.84 = 15.6 = 0.156 kg/day
Emissions from paper use = Consumption × EFPaper = 0.312 × 1.22 = 0.381 tons CO_2/year

Table 6 presents the measurement results of paper consumption and the estimated carbon emissions resulting from its use over one month, six months, and one year at Sahid University. Two paper types are used: F4 and A4, with different consumption levels and emission amounts. F4 paper is used more extensively, with annual usage of 0.312 kg producing 0.381 tons CO_2-eq. A4 contributes 0.073 tons CO_2-eq/year from 0.060 kg. Combined, annual emissions from paper use total 0.454 tons CO_2-eq, representing only about 0.08 percent of the campus's total annual footprint of 542.14 tons CO_2-eq.

Table 6. Paper Usage and Emissions at the Sahid University

	Kg /Month	*Emission CO_2/6 Month*	*Kg /6 Month*	*Emission CO_2/6 Month*	*Kg /Year*	*Emission CO_2/Year*
Paper						
F4	0,026	0,032	0,156	0,190	0,312	0,381
A4	0,005	0,006	0,030	0,037	0,060	0,073
Total		0,038		0,227		0,454

Paper-related emissions contribute about 0.5–1 percent of a typical campus's carbon footprint, primarily for academic and administrative purposes. This aligns with the Sahid University's data, where paper emissions are also a minor category (Kasman et al., 2020). The university has implemented partial digitization and paperless systems to reduce emissions, improve administrative efficiency, and support environmental sustainability. These measures have reduced paper-related emissions by up to 30 percent over the past five years. The “Digital Campus” program significantly contributed to a decrease in per-student paper usage (Sagala et al., 2023). Li et al. (2025) also noted that in developing countries, paper consumption remains high due to limited digital infrastructure. However, its emissions contribution is relatively low, ranging from 0.1 percent to 0.5 percent of the total campus emissions, supporting Sahid University’s findings. Studies by Kasman et al. (2020) and Sagala et al. (2023), which measured carbon emissions from LPG usage in campus canteens, found that their contribution to total campus emissions was minimal, ranging from 0.2 percent to 0.5 percent. This is consistent with Sahid University’s findings, where LPG accounts for approximately 0.22 percent of total annual emissions (1.218 tons of CO_2-eq out of 542.14 tons). Studies by Naderipour et al. (2016), Hu et al. (2017), Huynh (2018), and Li et al. (2025) report that in developing countries, LPG consumption in educational institutions is relatively low but contributes to indirect emissions, particularly from canteen and laboratory activities. A transition to renewable energy-based electric stoves is recommended to reduce carbon footprints significantly. Other suggestions emphasize the importance of conducting energy audits in canteens and student service facilities, as annual accumulated emissions—while small—can still be significantly reduced through equipment efficiency and operator education.

Table 7 presents a comprehensive overview of annual energy consumption and carbon emissions generated by various activities on the Sahid University campus. The data include both primary (direct) and secondary (indirect) carbon footprints, with a total annual emission of 542.14 tons CO_2-eq. The analysis reveals that the majority of emissions come from primary sources. The largest emission source is from AC split units, accounting for 49.29 percent of the total (267.210,63 tons CO_2-eq), driven by high electricity usage of 345,060 kWh/year, indicating a heavy reliance on air conditioning. Desktop computers also significantly contribute, with 24.16 percent or approximately 130.970,85 tons CO_2-eq, followed by neon box lighting at 18.36 percent. This pattern aligns with findings from Kasman et al. (2020), which indicate that electricity-based equipment—especially cooling and lighting—was the dominant source of emissions. Similarly, Sagala et al. (2023), Febrina et al. (2021), and Lazuardi et al. (2021) focused on technical buildings and laboratories, identifying lab equipment and AC as the most significant contributors. They emphasized that replacing equipment with inverter technology and automation could reduce emissions by up to 30 percent. Meanwhile, secondary emissions from LPG and paper usage are very minimal, each contributing less than 1 percent to total emissions. This suggests that indirect activities have a relatively minor impact on campus operations, reinforcing the need to focus emission reduction strategies on electricity use. Related studies by Hu et al. (2017) and Hoang et al. (2021) have concluded that in developing countries, secondary emissions can account for 60–70 percent of total emissions, primarily due to poor material use and waste management practices.

Table 7. Compilation of Primary and Secondary Carbon Footprints on the Sahid University

	kWh/Kg /6 *Month*	***Emission* CO_2/6 *Month***	**kWh/Kg /Year**	***Emission* CO_2/ Year**	**Proportion (%)**
Lamp Type					
Neon Box	64.281,60	49.778,96	128.563,20	99.557,91	18,36
Room Neon	912,00	706,24	1.824,00	1.412,49	0,26
LED Bulb	1.022,40	791,74	2.044,80	1.583,47	0,29
AC					
AC Split	172.530,00	133.605,32	345.060,00	267.210,63	49,29
Computer					
Desktop	84.564,00	65.485,42	169.128,00	130.970,85	24,16
Laptop	26.730,00	20.699,42	53.460,00	41.398,83	7,64
LPG					
Green Cylinder	0,14	0,07	0,29	0,81	0,00
Blue Cylinder	0,07	0,03	0,14	0,41	0,00
Plain Paper					
F4	0,16	0,19	0,31	0,38	0,00
A4	0,03	0,04	0,06	0,07	0,00
				542.135,85	**100**

4. CONCLUSION

Based on the analysis, the total annual carbon footprint of the Sahid University Jakarta is 542.14 tons CO_2-eq, with the majority arising from primary emissions, i.e., emissions directly produced by internal campus activities. The highest contributors are air conditioning units (49.29 percent), desktop computers (24.16 percent), and neon box lighting (18.36 percent). Meanwhile, secondary emissions from LPG and paper use make up a much smaller portion, each contributing less than 1 percent of total emissions. These results highlight that the most effective mitigation efforts should focus on improving electricity efficiency. Effective strategies include enhancing energy efficiency, replacing outdated equipment with energy-saving alternatives, and raising awareness among the campus community about sustainable energy use. Additionally, integrating energy planning with institutional sustainability policies is crucial to help Sahid University become a more environmentally friendly and energy-efficient campus.

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