Jurnal Serambi Engineering
Volume X, No.4, Oktober 2025 Hal 15942 - 15950
p-ISSN : 2528-3561
e-ISSN : 2541-1934

An Analysis of the Carbon Footprint of on Campus Activities at President University (Main Campus)

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Received: September 16, 2025 Approved: September 23, 2025

Abstract
Climate change has become a crucial environmental issue in various sectors, including educational institutions. This study aims to analyze total carbon emissions from campus activities based on Scope 1 data, which includes generator set data and campus bus operations (2023). Scope 2 consists of electricity bill data (January-December 2023) obtained from the institution. The study uses a quantitative approach with emission calculations based on secondary energy consumption data and transportation activities, as well as carbon absorption estimates based on vegetation tree species and age identification. The results show that the total carbon emissions from campus activities in 2023 can reach 969,217.03 KgCO_2/year. Meanwhile, the emission absorption capacity of existing vegetation only reaches 774,546.11 KgCO_2 per year. Thus, there are residual emissions of 194,670.92 KgCO_2 per year that are not absorbed. This finding indicates that campus vegetation has not fully offset the resulting carbon footprint and serves as an important basis for developing emission mitigation strategies towards a more sustainable campus.
Keywords: *carbon footprint, co_2 emission, existing vegetation*

Abstrak
Perubahan iklim telah menjadi isu lingkungan yang krusial di berbagai sektor, termasuk institusi pendidikan. Penelitian ini bertujuan untuk menganalisis total emisi karbon dari aktivitas kampus berdasarkan data Cakupan 1, yang meliputi data generator set dan operasional bus kampus (2023). Cakupan 2 terdiri dari data tagihan listrik (Januari-Desember 2023) yang diperoleh dari institusi. Penelitian ini menggunakan pendekatan kuantitatif dengan perhitungan emisi berdasarkan data konsumsi energi sekunder dan aktivitas transportasi, serta estimasi penyerapan karbon berdasarkan jenis pohon vegetasi dan identifikasi umur. Hasil penelitian menunjukkan bahwa total emisi karbon dari aktivitas kampus pada tahun 2023 dapat mencapai 969.217,03 KgCO_2/tahun. Sementara itu, kapasitas penyerapan emisi vegetasi yang ada hanya mencapai 774.546,11 KgCO_2 per tahun. Dengan demikian, terdapat emisi residual sebesar 194.670,92 KgCO_2 per tahun yang tidak terserap. Temuan ini menunjukkan bahwa vegetasi kampus belum sepenuhnya mengimbangi jejak karbon yang dihasilkan dan menjadi dasar penting untuk mengembangkan strategi mitigasi emisi menuju kampus yang lebih berkelanjutan.
Kata Kunci: *jejak karbon, emisi karbondioksida, vegetasi eksisting*

1. Introduction

The climate crisis is a pressing global challenge facing many people today. The massive increase in human activities, such as the fossil fuel energy used, the rise in the number of private vehicle users, and the lack of seriousness in carrying out commitments to reduce global carbon emissions, have resulted in slow but deadly damage to our planet [1]. According to a report from the Intergovernmental Panel on Climate Change (IPCC AR6, 2022), to limit global temperature rise to no more than 1.5 degrees, global carbon emissions must be reduced by around 43% by 2030, and net zero carbon emissions must be achieved by 2050 at the latest [2]. On the other hand, the trend of rising global temperatures continues, with 2024 recorded as the hottest year since global records began in 1850. The global average temperature that year reached 1.46 degrees Celsius above pre-industrial levels (1850-1900) [3]. In Indonesia itself, it shows that the manufacturing industry sector ranks first in contributing national emissions at 38%, followed by electricity procurement at 33% and AFOLU at 9.8% in third place in 2024 [4].

Higher education institutions – such as universities and campuses – have a dual responsibility, both as centers of education and as pioneers in the implementation of sustainable practice [5]. Learning activities that rely on modern infrastructure, such as electricity usage from the electronic devices, and fuel usage for internal transportation (campus buses), are major contributors to carbon emissions in the campus environment [6][7]. Unfortunately, behind the increasing awareness of sustainable campuses, the active participation of universities in Indonesia, such as UI Green-Metric, is still relatively low. In 2023, the number of universities registered nationally was recorded at 4.416 active universities, and only around 150 universities in Indonesia were members, meaning only around 3-4% of the total active universities have committed to environmental sustainability [8][9].

2. Material and Methods

The emissions studied were based on measurements in accordance with the Catalan Office for Climate Change (OCCC) Guidelines for the "Practical Guide for Calculating Greenhouse Gas (GHG) Emissions." In particular, at least two scopes can be defined based on the stated emissions [10]:

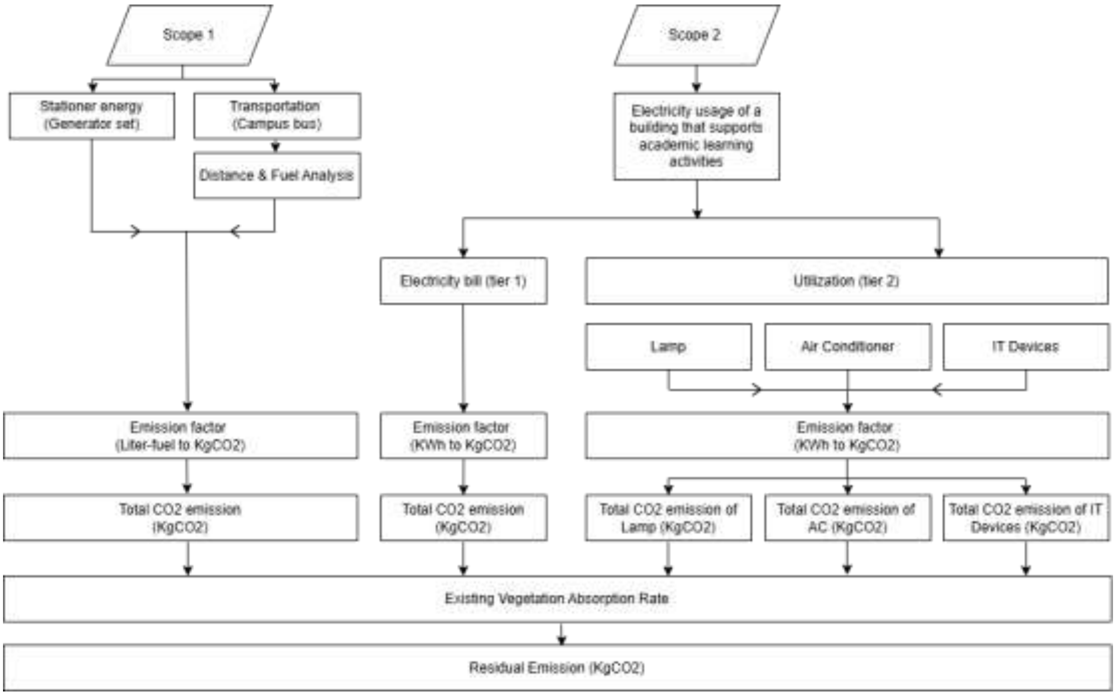

Figure 1. Design Calculation Method

a. Scope 1: Direct Emissions

Direct Emissions from sources owned or under the control of the party responsible for the activity. This category contains emissions from combustion in the entity-owned generator set [11] and operational vehicle [12].

- Generator Set (Genset)

CO_2 Emission = $P \; x \; t \; x \; SFC \; x \; EFCO_2$ ……………………………………………………..(i)

Where:
CO_2 Emission = Carbon Emission of Activity ($KgCO_2$)
P = Power (kW)
t = Duration (hour)
SFC = Specific Fuel Consumption (L/kWh)
$EFCO_2$ = Emission Factor ($KgCO_2$/liter)

- Operational Vehicle (Bus Campus)

CO_2 Emission = $D(n) \; x \; FC \; x \; EFCO_2$ ……………………………………………………..(ii)

Where:
CO_2 Emission = Carbon Emission of Activity ($KgCO_2$)
D = Distance of PU-NBH round trip (km)
FC = Fuel Consumption (L/km)
$EFCO_2$ = Emission Factor ($KgCO_2$/liter)

b. Scope 2: Indirect Emissions

Indirect Emissions from the power sector, such as heat, steam, or cooling, are physically produced when energy is acquired in the form of heat, steam, and cooling [13][14]. These production facilities are distinct from the company that estimates the emissions.

CO_2 Emission = $EF\ CO_2$ x $F_{cy}Electricity$ ……………………………………………………..(iii)

Where:

CO_2 Emission = Emission Carbon of Activity ($KgCO_2$)

$F_{cy}Electricity$ = Electricity Consumption (kWh)

$EF\ CO_2$ = Emission Factor ($KgCO_2$/kWh)

Research was also conducted on existing vegetation (trees) in the campus area as a medium for absorbing emissions, based on the productive age of the trees and the type of trees (woody) who planted in the campus area and have an absorption level between medium and high [15]. Calculation of CO_2 emissions that can be absorbed by the vegetation existing at President University can be calculated by the equation below:

Ar of CO_2 = $\sum_i^n Vegetation_i\ D$ x $CO_{2_i}\ Absorption\ capacity$ ……………………………………...(iv)

Where:

Ar of CO_2 = Absorption rate of CO_2

Calculation of residual emission of CO_2 can be calculated by using the equation below:

$Residual\ Emission\ (kg/year) = MCO_2 - Absorption\ rate\ CO_2$ …………………………………...(v)

Where:

MCO_2 = Total CO_2 Emissions (KgCO2)

3. Results and Discussion

3.1 Emission Inventory

The inventory of greenhouse gas emissions within the campus environment is conducted using Scope 1 and Scope 2 categories, in accordance with the Greenhouse Gas Protocol guidelines. Scope 1 emissions include direct sources from operational activities, such as fuel consumption in campus operational vehicles and the use of generators as backup energy sources. Meanwhile, Scope 2 emissions come from indirect energy consumption, specifically electricity from external energy providers.

Table 1. Fuel Consumption from Generator Set

Type	Power (kWh)	Time (hour)	Usage (l/year)	CO2e- (KgCO2/y)
HT-275D	220	0.25	696,9	1.867,8
WT-P880	640	0.25	1.927,7	5.166,2
Total			2.624,6	7.034

Based on **Table 1**, it can be seen that the total of emissions from genset reached 7.034 KgCO2, the graph of the variation by type can be seen in **Figure 2** below.

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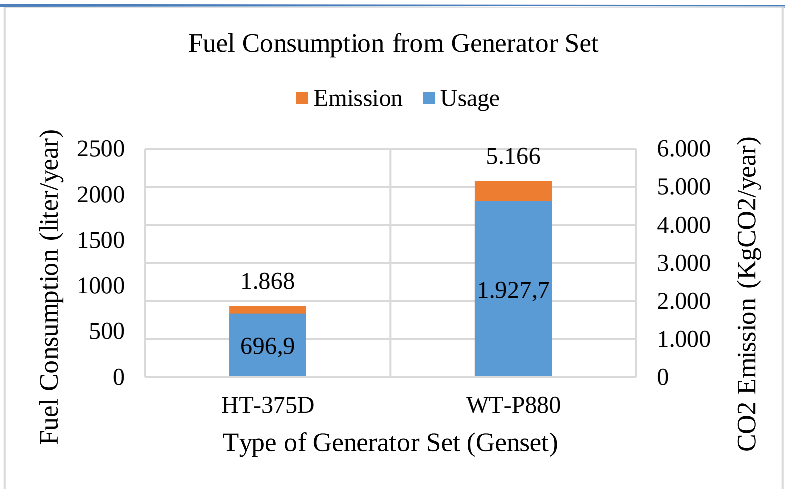

Figure 2. Fuel Consumed (Genset) Graph

The use of diesel fuel in campus bus operations contributes greatly to carbon emissions. **Figure 3**, shows the campus bus route that operates on every active lecture day, taking students from the dormitory area (New Beverly Hills) to the main campus area of president university and vice versa.

Figure 3. Route of Operational Vehicle (Campus Bus)

Average fuel consumption efficiency (L/km) > 3.500 cc = 0.29 L/km. The emission factor for diesel fuel (IPCC, 2006) is 2.68 kg CO2/liter. The distance for one trip is approximately 4.3 km (round trip). Fuel use in 2023 can be seen in Table 2, below:

Table 2. Fuel Consumption (Campus Bus, 2023)

Month	Day	Usage	Unit	CO2e- (KgCO2)
Jan	17	21,19		56,81
Feb	20	24,94		66,83
Mar	22	27,43		73,52
Apr	9	11,22		30,07
May	17	21,19		56,81
Jun	20	24,94	Liters	66,83
July	20	24,94		66,83
Aug	0	0		0
Sep	19	23,69		63,49
Oct	22	27,43		73,53
Nov	22	27,43		73,53
Dec	14	17,45		45,68
Total		251,85	Liters	675,03

Based on **Table 2**, it can be seen that the total fuel consumption of campus buses throughout 2023 reached 251.85 liters, with the amount of carbon emissions produced being 675.03 $KgCO_2$, The graph of the variation in usage per month can be seen in **Figure 4**, below.

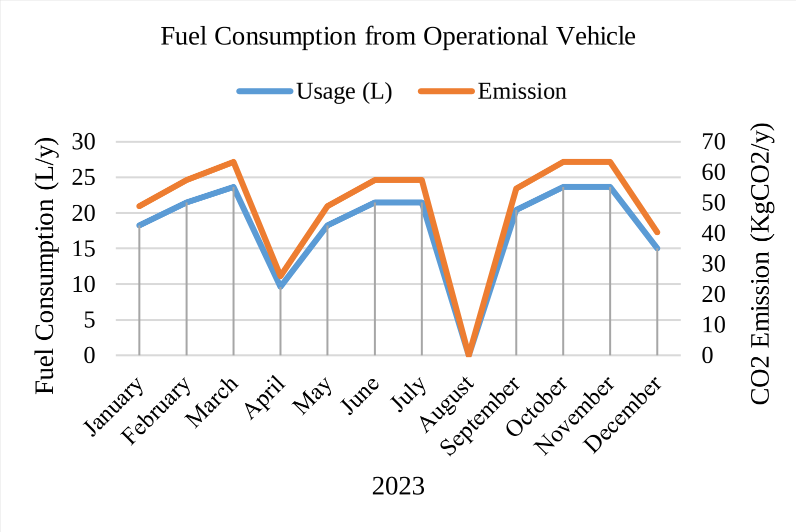

Figure 4. Fuel Consumption Graph (Jan-Dec, 2023)

To calculate scope two, the data included can define as indirect emissions such as electricity or material usage that is not directly emitting carbon emission. For the scope two, the emission categories is consist of the institution's energy consumption. The data on purchased electricity comes from the electricity bill on 2023. This is real data because it represents the actual electricity consumption by President University for the past year. Electricity consumed can be seen in **Table 3**, as follows;

Table 3. Purchased Electricity 2023

Months	Usage	Unit	CO2e- (KgCO2)
Jan	75.570		63.479
Feb	93.840		78.826
Mar	88.530		74.365
Aor	94.800		79.632
May	60.220		50.585
Jun	103.970	kWh	87.335
Jul	93.390		78.448
Aug	97.190		81.640
Sep	84.880		71.299
Oct	111.520		93.677
Nov	123.450		103.698
Dec	117.290		98.524
Total	1.144.650	kWh	961.508

Based on **Table 3**, it is known that the total consumption of electrical energy throughout 2023 reached 1,144,650 kWh, with the amount of carbon emissions produced being 961.508 $kgCO_2$, the graph of the variation in usage per month can be seen in **Figure 5**, below;

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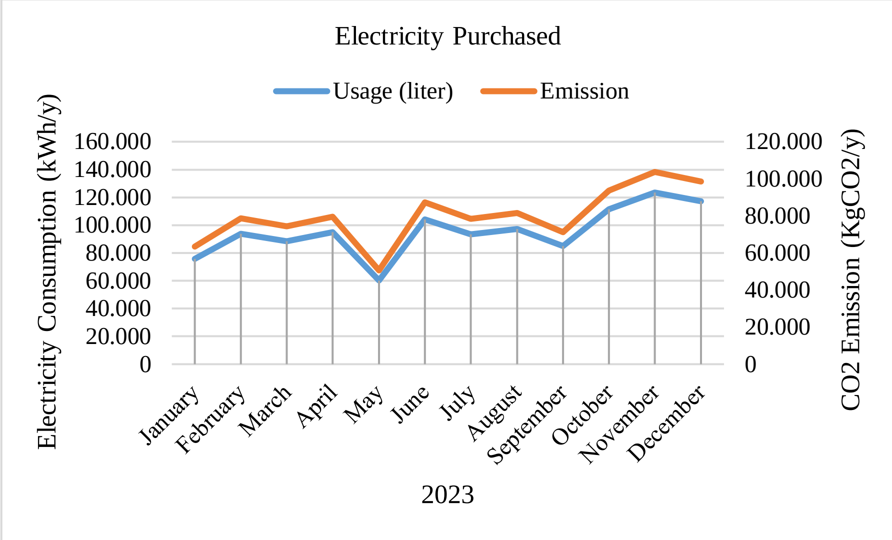

Figure 5. Purchased Electricity Graph (Jan-Dec, 2023)

The results of the inventory of greenhouse gas emissions from campus activities show the total emissions originating from direct (Scope 1) and indirect (Scope 2) sources summarized in **Table 4**, as follows;

Table 4. Total Emission Exists

Scope	Activity	CO2e- (KgCO2/y)
Scope 1	Generator Set	7.034
Scope 1	Operational Vehicle (Campus buses)	675.03
Scope 2	Electricity Purchased	961.508
Total		**969.217,03**

References: Analysis result, 2025

3.2 Existing Vegetation

In this study, the division of the area at President University is divided into four zones, namely area A, area B, area C, and Area D, as shown in **Figure 6,** is used as a basis for grouping vegetation locations, making it easier to calculate the number of trees in each area and to analyze the potential for absorption of CO_2 emissions by existing vegetation in a more systematic and structured manner.

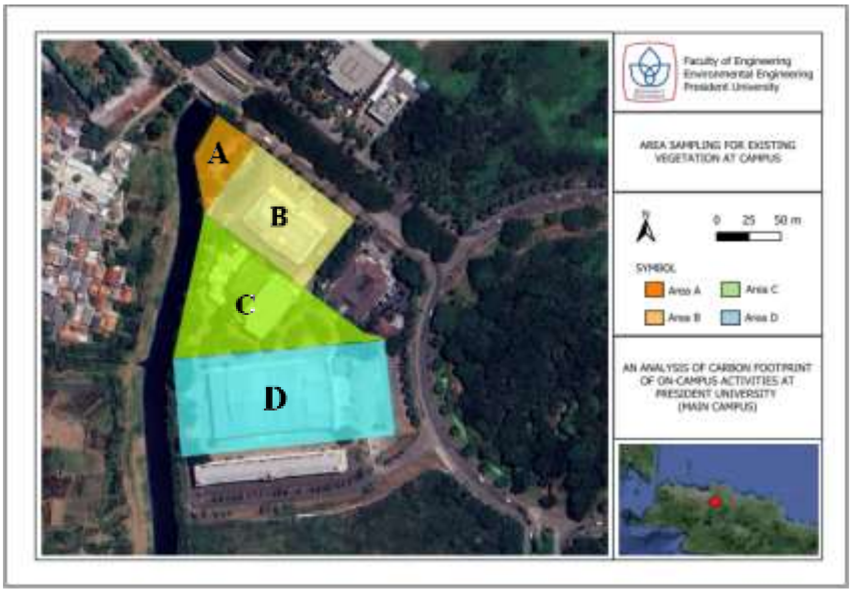

Figure 6. Area of Existing Vegetation

Based on the results of observations in the four designated areas (A, B, C, D), the total number of trees identified was 64 trees, which were then used as a basis for calculating the total CO2 emission absorption capacity by existing vegetation at the research location, as shown in **Figure 7**.

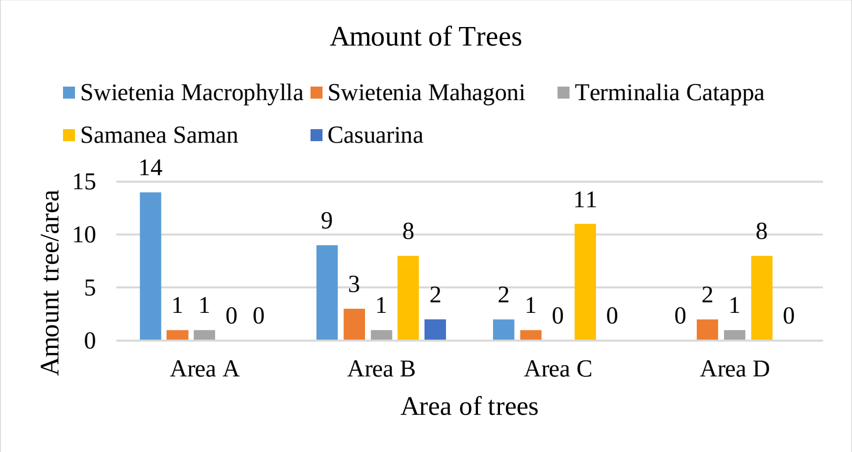

Figure 7. Number of trees by area

The results of vegetation analysis show that there are five types of trees with a total of 64 individuals. *Samanea Saman* is the most widely planted type. The following types of trees (percentage) in the President University area are shown in **Figure 8**.

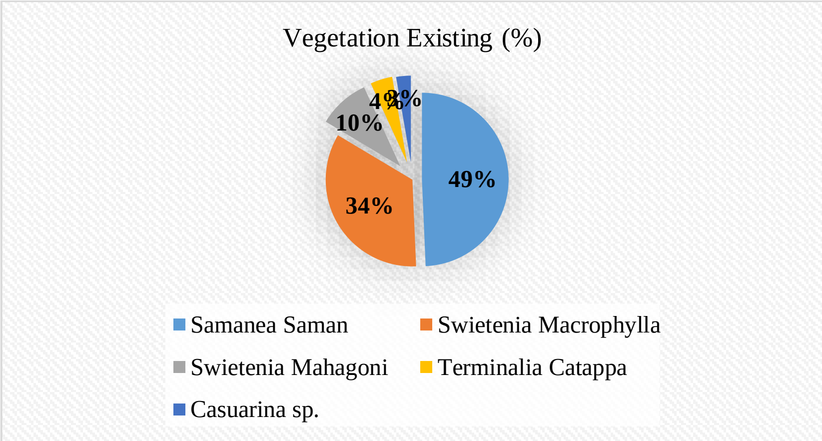

Figure 8. Percentage of Existing Vegetation

The absorption capability of each type of tree can be shown in **Table 5**, below;

Table 5. Carbon absorption by vegetation exists

Type of trees	Absorption capability (KgCO2/trees/year)	Quantity	Emission absorption (KgCO2/year)
Samanea Saman	28.488,39	27	769.186,53
Swietenia Mahagoni	295,73	7	2.070,11
Swietenia Macrophylla	114,03	25	2.850,75
Casuarina	126,51	2	253,02
Terminalia Catappa	61,9	3	185,7
Total		**64**	**774.546,11**

The calculations are made on the total emissions absorbed by existing vegetation, obtained from the following equation:

$$Residual\ Emission\ (kg/year) = 969.217{,}03 - 774.546{,}11$$
$$= \mathbf{194.670,92\ are\ residue}$$

4. Conclusion

Emissions generated in the campus environment, which include Scope 1 (direct emissions from owned or controlled sources, such as the use of operational vehicle fuel) and Scope 2 (indirect emissions from electricity consumption), were recorded at 969.217,03 $KgCO_2$ per year. Vegetation spread across the campus area plays an important role in supporting climate change mitigation efforts through its ability to absorb carbon emissions. Based on the calculation results, the total absorption of emissions by existing vegetation reached 774,546.11 $KgCO_2$ per year, which includes various types of trees such as Samanea saman, Swietenia macrophylla, Terminalia cattapa, and other species. This figure illustrates the significant contribution of green open spaces in mitigating emissions generated from campus activities, particularly from the energy and transportation sectors.

5. Abbreviations

CO_2	Carbon Dioxide
$KgCO_2/y$	Kilograms of Carbon Dioxide per year
IPCC	Intergovernmental Panel on Climate Change
AR6	Sixth Assessment Report
%	Percentage

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