FROM EMISSION TO OFFSET: REINVENTING GREEN STRATEGIES FOR A SUSTAINABLE EDUCATION

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Abstract - This study seeks to estimate carbon emissions generated from electricity consumption and waste disposal activities in student dormitories, assess the carbon sequestration required through reforestation efforts, and examine the role of asset management in supporting the implementation of an eco-office framework. Data were collected through institutional documentation concerning electricity-consuming assets and field observations related to waste management practices. A descriptive quantitative approach was employed to analyze the emission data. The findings indicate that total annual carbon emissions amounted to 394.124 tons of CO_2, with electricity consumption accounting for 98.85% of this total. To offset these emissions, an estimated 40 to 77 trees would need to be planted annually, contingent on the species selected. Asset management was identified as a key component in enhancing energy efficiency, promoting circular waste management systems, and informing reforestation initiatives. These results highlight the urgency for integrated, evidence-based sustainability strategies in higher education institutions, particularly those that incorporate energy monitoring, carbon offset mechanisms, and environmentally responsible asset governance.

Keywords: Carbon; Emission; Offset; Green Strategy; Sustainability.

1. INTRODUCTION

1.1 Introduction

Global warming is one of the main issues facing the world today, characterized by an increase in the average temperature on the earth's surface due to the accumulation of greenhouse gases in the atmosphere (Nirmala et al., 2023; Zien & Kirschstein, 2023). The accumulation of these gases, such as carbon dioxide (CO_2), methane (CH_4), and nitrogen oxides (NO_x), contributes to climate change by increasing extreme temperatures, melting ice at the poles, and increasing the frequency of natural disasters (Adjei Kwakwa, 2023; Kwakwa et al., 2023; Sun & Chen, 2023). Human activities, such as motor vehicle emissions (Guo et al., 2024; Lei et al., 2024), fossil-based power plants (Barbera et al., 2022), and forest fires (Abdul-Kadir et al., 2022), are the main causes of the increase in greenhouse gas levels in the atmosphere. This phenomenon not only has an impact on the global environment but also has direct consequences for local ecosystems, including increased air pollution in various cities

(Bainy et al., 2021; Y. Zhang et al., 2022), such as South Tangerang, where the research object, one of the most prestigious vocational schools in Indonesia, is located.

As an educational institution with a large number of students, activities at the research object, the State Public Finance College, also contribute to carbon emissions through daily mobility, electricity consumption, and waste production. With the existence of a student dormitory since 2021, activities on campus have increased, which contributes to high electricity usage and increased solid waste production. This factor triggers negative externalities in the form of an increased carbon footprint which can impact the health of the surrounding environment (Hacopian Dolatabadi et al., 2023; Paniagua & Rayamajhee, 2024; Somerville & Wetzel, 2022). The use of fossil-based energy in campus operations and student consumption patterns in dormitories are challenges for environmental sustainability, which, if not properly managed, can further exacerbate the impact of climate change at the local level (Edo et al., 2024; Huang et al., 2022; Singh & Singh, 2022).

Previous research shows that most research on carbon emissions in academia focuses on lecture activities, such as the use of electronic devices in the classroom and the mobilization of student vehicles (Aji et al., 2024; Ismail, 2020; M. Rahayuningsih et al., 2021). However, there has been no research specifically examining the impact of carbon emissions produced by dormitory life, especially at the State Public Finance College, which combines academic activities and student life in one environment. In addition, previous research has focused more on the resulting carbon emissions, without considering the aspect of carbon sequestration as a factor in mitigating environmental impacts (Khalil et al., 2022; Kjerstadius et al., 2017; Ma et al., 2022). Thus, there are still gaps in the literature that need to be filled through research that integrates the calculation of emissions and carbon sequestration needs in a more comprehensive study.

This study offers novelty in three main aspects. From a theoretical perspective, this study develops an understanding of the relationship between carbon emissions and carbon sequestration in the higher education environment, which has so far focused more on the industrial and urban sectors (X. Li et al., 2015; Silaydin-Aydin & Çukur, 2012; X. Zhang & Zhang, 2023). In terms of method, this study adopts a quantitative approach by calculating the carbon emission estimates from dormitory activities and comparing them with the carbon absorption capacity of green spaces available on campus (Baldocchi & Penuelas, 2019; He et al., 2022; Mallick et al., 2024) Empirically, this study is the first in the context of the State Public Finance College to examine how carbon emissions from student activities can be offset by green space management strategies and eco-green campuses. (Ali et al., 2022; Murphy, 2024; Natarajan et al., 2022)

Using the constructivism paradigm, in reference to Qadri and Jauhari (2020), this study aims to construct and explain the extent to which dormitory activities at the State Public Finance College contribute to carbon emissions and the need for carbon sequestration to offset their impact. This study uses a non-inferential quantitative method with a carbon estimation approach that includes the use of electricity and solid waste disposal in the college dormitory (Amaral et al., 2023; Gherheș et al., 2024; Washington-Ottombre, 2024). In practical terms, the results of this study are expected to provide input for the management of campus assets in implementing the eco-office and green building concepts, as well as to serve as a basis for policy-making in reducing the environmental impact of academic activities and student life in dormitories (Paredes-Canencio et al., 2024; Xue et al., 2024).

1.2 Literature Review

The Resource-Based View (RBV) theory is one of the main approaches in strategic management, emphasizing the importance of internal resources in creating sustainable competitive advantage. Penrose (2009) first introduced this concept, which was later reinforced by Barney (1991) through a model that explains that valuable, rare, difficult to imitate, and non-replaceable (VRIN) resources are the main factors in creating competitive advantage. Mahoney and Pandian (1992) developed this theory by dividing RBV analysis into three main perspectives, namely strategic management, economic organization, and industry. In the context of environmental sustainability, the concept of carbon offsetting can be seen as a strategic resource that improves the company's image in the eyes of stakeholders and supports compliance with environmental regulations (Peteraf & Barney, 2003)

The asset management theory is an important aspect in organizational management, especially in educational institutions such as the State Public Finance College. Assets can be movable or immovable goods that must be managed optimally to provide maximum benefits for the organization (Pambudi et al., 2017). Asset management involves various stages, such as inventory, legal audit, assessment, optimization, and asset supervision and control (Aryani-Soemitro & Suprayitno, 2018). The concept of life cycle asset management is a relevant approach in maintaining the value of assets throughout their life cycle, so that the efficiency and effectiveness of assets can continue to increase (Siregar, 2004). In this context, the college can implement a sustainability-based asset management strategy by utilizing green spaces as part of the carbon emission reduction initiative.

The *Evidence-Based Policy* approach is increasingly being applied in policy formulation, including in the aspects of the environment and energy efficiency (Handoyo, 2009). Evidence-based policy utilizes empirical data obtained from academic research and studies to ensure that decisions are more objective and effective (Budi & Fauzela, 2020). In its application, this approach involves various sources of evidence, such as scientific research results, actual data, and input from experts and stakeholders (Hernawan et al., 2022). With increasing attention to environmental issues, policies oriented towards carbon emission reduction and energy efficiency are a priority for many institutions, including higher education institutions such as the State Public Finance College, which has begun to implement the concepts of *green building* and *eco-office* in accordance with applicable regulations (Hafez et al., 2023). Carbon emissions are one of the main factors contributing to global warming, with the main sources coming from transportation activities, electricity consumption, and waste management (Naderipour et al., 2021). In the context of a campus, sources of carbon emissions include the use of electronic devices, lighting, air conditioning, and student and staff vehicles (Y. Li et al., 2024). Waste management is also a challenge in reducing carbon emissions, especially those from the disposal and incineration of domestic waste (Yang et al., 2018). Therefore, an approach that combines emission reduction strategies with increasing carbon sequestration through green spaces is becoming an increasingly applied solution, in line with stricter environmental policies in various sectors (United Nations, 2022).

In an effort to support environmental sustainability, the concept of *Benefit Transfer* is one approach that can be used to assess the impact of environmental policies based on previous research results (Boutwell & Westra, 2013). This method allows policymakers to apply research results from other locations with similar characteristics to estimate the benefits of an environmental policy or initiative (Latham, 2001). By using this approach, carbon management and energy efficiency strategies can be more measurable in their implementation. In addition, the theory of environmental sustainability, which includes the anthropocentric, biocentric, and ecocentric perspectives, provides a basis for understanding the relationship between humans and the environment, as well as how ecological balance can be maintained through evidence-based policies.

This study is structured based on the background, theory, and results of previous research by developing a relevant research framework and scheme. Since the implementation of the dormitory system at the State Public Finance College in 2021, the activities of dormitory residents have increased, which has contributed to the increase in carbon emissions. Dormitory residents follow a set academic and non-academic schedule, with regulations on the number and type of devices that are allowed to be brought for study purposes or personal use. Electricity consumption in the dormitory, both for educational needs and daily activities, generates additional carbon emissions outside of teaching and learning hours. In addition, the production of waste from food and plastic waste is another factor that contributes to the carbon footprint of the dormitory environment. In this study, we estimates the carbon emissions resulting from the use of electricity and dormitory waste by utilizing an online carbon emissions calculator. In addition, this study also analyzes the potential for carbon sequestration on campus through green open spaces, especially tree vegetation, to identify the balance between the resulting emissions and the available carbon sequestration capacity. The results of this study are expected to provide strategic recommendations in the management of dormitory assets and sustainability policies that support the mitigation of carbon emissions at the college.

2. RESEARCH METHODOLOGY

Research conducted by Scvotland (2012) explains that research is described as an in-depth approach to understanding various phenomena, influenced by the paradigm chosen by the researcher. Research is considered good if it produces strong evidence, offers credible and accountable explanations, and allows the results to be used in different situations (external validity). The research paradigm consists of four main components: ontology, epistemology, methodology, and method (Qadri, 2019b, 2019a, 2020). Ontology relates to an understanding of reality, while epistemology discusses how knowledge is obtained (Hidayat & Qadri, 2020; Qadri, 2024; Qadri & Murwaningsari, 2023). Methodology is the strategy or plan underlying the selection of a particular method, while method refers to the techniques used to collect and analyze data (Ananta & Qadri, 2024; Daulay & Qadri, 2024; Pratiwi & Qadri, 2024).

The constructivism research paradigm emphasizes that knowledge is not found as an absolute truth, but is constructed through social interaction and individuals' subjective perceptions of the world (Maharani & Qadri, 2024; Qadri & Jawak, 2024; Rahmithasari & Qadri, 2024). In the context of our research, the constructivism paradigm allows researchers to understand more deeply the environmental impacts resulting from the activities of dormitory users, especially in the context of electricity consumption and dormitory waste disposal (Anjani, Fitrijanti, et al., 2024; Anjani, Qadri, et al., 2024; Wardhani et al., 2022). Through the constructivist paradigm, this study can explore how experts interpret and respond to the concept of *carbon offset*, both individually and collectively, which can then influence how to conduct carbon assessments from the perspective of energy consumption and waste disposal. In addition, the constructivist approach allows for flexibility in data analysis, which is important in understanding the complexity of dormitory residents' behavior regarding electricity and waste use. In this study, the constructivism paradigm provides room for researchers to interpret data not only from a quantitative point of view, but also from the personal narratives of experts regarding environmental impacts. In-depth interviews are used to obtain subjective and contextual data, which will then help researchers identify the perspectives and values that underlie the thinking of experts regarding the practice of carbon assessment in terms of electricity consumption and waste disposal. Thus, the constructivism paradigm will help researchers to explore further how the actions of dormitory residents can contribute to reducing their carbon footprint in terms of electricity consumption and waste disposal, while opening up new horizons regarding the challenges of implementing *carbon offset* strategies that are in line with their needs.

We conducted this research using the case study method. Research with a case study approach has the main objective of producing a comprehensive and in-depth analysis of a specific case. The case studied can be a program, event, activity, process, or individual that has clear time and place limitations. In the process, this research involves detailed data collection with structured procedures, carried out within a specific predetermined time frame. Focusing on a single case with a specific setting allows researchers to gain a more in-depth understanding of the unique aspects of that context.In addition, the case study approach allows researchers to uncover the complexity of phenomena that cannot be explained by other methods. Through a combination of various data collection methods, such as in-depth interviews, direct observation, and document analysis, case study research provides a broader and more holistic insight. This integrated approach helps researchers identify relationships and dynamics that may be hidden, so that the understanding of the phenomenon under study becomes richer and more comprehensive.

The type of data used in this study is primary data, which consists of data collected directly from the field (calculations and inventories). Then the secondary data method, which consists of literature research and data from relevant and used agencies. This study also uses descriptive quantitative methods, which is a type of quantitative research designed to formulate research problems in order to explore or describe the social situation under study in a comprehensive, broad, and in-depth manner. Quantitative research methods such as descriptive ones aim to systematically outline the facts or characteristics of a particular population or field in a factual and accurate manner. This study uses primary data that will be taken directly in the field, such as the number and documentation of assets that use electricity and the quantity of waste disposal at the college dormitory. This study also uses secondary data from the college management, including: (1) list of assets that use electricity in each flat/dormitory building (air conditioning, lights, and washing machines); (2) electricity usage data in each flat/dormitory building; and (3) data on the number of active students in the dormitory.

In its implementation, we conducted research with several limitations. The calculation of the carbon emissions of the dormitory will be limited to the available data provided and also the estimated use of devices by each student in the dormitory according to the limitations of luggage entering the dormitory. Then, for waste management, it will be taken from the collection of waste disposal in the dormitory within a certain period of time. The amount will be adjusted or weighed, depending on the waste management carried out in the dormitory building. Carbon emissions are calculated using the emissions calculator provided by the Ministry of Environment and Forestry (KLHK) via https://jejakkarbon.id/ and WRI Indonesia via https://nol-emisi.id/. In this study, we will not test the tools used, because the testing domain is under the authority of the ministry itself. The use of these two *online* emission calculators is based on the completeness of the carbon emission variables to be calculated. The calculation results from the two calculators will be combined and adjusted to the author's limitations and assumptions.

The researchers' decision to utilize online carbon emission calculators, specifically those provided by the Ministry of Environment and Forestry (KLHK) and WRI Indonesia, was grounded in both practical and methodological considerations. These tools offer government-endorsed credibility and are widely recognized for their standardized approaches to estimating emissions based on electricity consumption and waste generation. Their accessibility and comprehensive input parameters made them particularly suitable for quantifying emissions in a dormitory setting, where data on electrical appliances and waste production could be readily matched to the calculator's requirements. Furthermore, by using established tools, the researchers ensured consistency and replicability of results while avoiding the need for independent validation, as the calculators themselves are considered authoritative by the institutions that developed them.

However, the use of these calculators is not without limitations. The tools operate on fixed assumptions and general emission factors, which may not reflect specific regional energy profiles or the unique conditions of the research site. For example, they do not account for variations in appliance brand, capacity, or efficiency, nor do they adjust for fluctuations in usage patterns such as holidays or reduced occupancy. Input options are limited to predefined categories, offering little room for customization or the inclusion of nuanced variables such as behavioral practices or energy-saving measures already in place. Additionally, the calculators assume uniform and continuous use of devices, which may oversimplify real-world dormitory operations. As such, while these tools provide a credible baseline for estimating carbon emissions, their inherent constraints must be acknowledged in interpreting the study's findings and formulating policy recommendations.

The Directorate General of Climate Change Control (DJPPI) is a work unit of the Ministry of Environment and Forestry that deals with climate change, especially in the implementation of mitigation, adaptation, reduction of greenhouse gas emissions, reduction and elimination of ozone-depleting substances, resource mobilization, greenhouse gas inventory, monitoring, reporting and verification of climate change mitigation actions as well as control of forest and land fires. The establishment of the DJPPI brings new hope for the implementation of well-managed climate change control activities in support of development goals in the environment and forestry sectors. The development of the Carbon Footprint Calculator 2.0 is the result of cooperation between the Government of Indonesia and the Federal Government of Germany. The following *online* emission calculator requires data in the form of the quantity of equipment used (for calculating emissions generated by electricity) in units of pieces and time and data in the form of quantity in units of kilograms for the calculation of waste disposal.

Established in 2014 under the name of the World Resources Institute Foundation, WRI Indonesia is an independent organization that focuses on research to achieve a balance between environmental protection, economic development, and improving the quality of human life. By promoting transparent and data-based research results, WRI Indonesia is committed to supporting policies that are scientific and relevant. In addition, the organization forges strategic partnerships with the government, business sector, and community to promote sustainable solutions that can provide widespread benefits. As part of the World Resources Institute (WRI) global network, WRI Indonesia targets various environmental and development challenges in Indonesia, such as climate change, land management, renewable energy, and sustainable urban development. With an evidence-based, technological, and data-driven approach, WRI Indonesia strives to protect the environment while meeting the needs of present and future generations. Its main mission is to create prosperity in harmony with environmental preservation and its carrying capacity for future generations. As a form of service to realize its vision and mission, WRI Indonesia has developed an application that is available for free on the *website* and can be downloaded on mobile devices to calculate daily carbon emissions in a practical way. The calculation on this page requires data in the form of a research period, the number of users, the number of devices that use electricity in units of pieces, and also the estimated usage of devices in units of time per hour. The calculation results will be adjusted to the author's limitations and assumptions.

This research has several limitations and assumptions in the process of its implementation, so that the calculation results are close to and in accordance with the actual situation. Some of the limitations and assumptions in this study include: (1) data collection based on data provided by the college (according to the attached official memorandum) and data directly in the field with the help of active dormitory students on behalf of Rick Purba and Debora Sihotang as senior dormitory assistant; (2) data on the number of state property using electricity is calculated directly from the documentation that has been taken, adjusted to the actual circumstances (counted for attached goods/equipment); (3) data on the amount of waste disposal is collected by sampling for a week, looking at the different waste trends per day. The amount/mass of waste is multiplied according to the number of trash bags per day for all flats/dormitory buildings; (4) the use of electronic devices by college dormitory students is assumed to be one laptop and one *mobile phone* in accordance with the dormitory's luggage regulations, with the ability to recharge once a day. The calculations in this study assume the number of active days and holidays based on the academic calendar. We separates two types of academic holidays, which are divided into short and long holidays. For short holidays, the amount of electricity usage is adjusted to the number of students who remain based on information obtained from the dormitory management. Long holidays are considered as time when the dormitory building is not in use; (5) the calculation for carbon emissions based on appliances that use electricity and waste disposal is done with the features available in the *online* carbon emissions calculator, with the unit of calculation without considering the label/brand, capacity, and age of the goods; and (6) the result of the carbon emission calculation will be multiplied by the level of availability (vacancy) based on the schedule on the academic calendar and other assumptions.

In this study, we used a descriptive quantitative method. Descriptive quantitative research is a method used to understand a phenomenon by describing characteristics, patterns, or trends based on numerical data. This approach does not involve variable manipulation, but rather focuses on the systematic collection of information through surveys, observations, or secondary data analysis. The research results are then analyzed using descriptive statistics such as average, median, mode, and frequency distribution to identify trends that appear in the data. This method is often used in various fields, such as economics, health, and social sciences, to provide an empirical description that can be the basis for further research. Due to its exploratory nature, this approach helps in understanding situations or phenomena without drawing causal conclusions between the variables under study. More than just describing data, descriptive quantitative research plays an important role in designing evidence-based policies, business strategies, or social interventions. For example, in the health sector, this method can be used to map disease patterns in a population, thus providing a basis for planning prevention programs. In the economic field, this research can reveal trends in community consumption based on certain demographic categories. By providing an accurate overview, this approach enables researchers and policymakers to formulate more targeted measures based on measurable findings. Although it does not test causal relationships, descriptive quantitative research remains an essential tool in understanding phenomena broadly and systematically.

Data analysis starts from preparing a list of the use of electronic devices available and used by the dormitory building. We made a request for data on state-owned goods that use electricity and also data on waste disposal. In addition to making requests for data, We also conducted direct observations to obtain primary data documentation in the field. After obtaining the primary data, We curated and reduced the data for presentation in writing. The data on state property and the amount of waste disposal were selected and recalculated based on the limitations and assumptions set in conducting this research. The calculation of estimated carbon emissions in this study was based on the data on the number of state property that had been calculated and collected, then input into the carbon emission calculator that we had selected according to the calculation needs. The calculation was divided based on the type of device with time provisions according to the regulations in the dormitory. The process of charging student electronic devices was calculated based on the number of students in the dormitory, with the number of charges being once per day. Carbon sequestration needs are calculated based on the data on sequestration capacity obtained in previous studies. The amount of carbon sequestration capacity is adjusted per type of plant/tree. The estimated amount of carbon emissions is then divided by the carbon sequestration capacity per type of tree, to obtain the estimated number of trees needed in the college environment.

3. RESULT AND DISCUSSION

Based on the results of direct observation and documentation obtained, this study records a recapitulation of the number of State Property (short) that uses electricity in six dormitory buildings. The components observed are limited to the main equipment commonly used by dormitory residents, namely air conditioners (AC), 5–10 watt and 10–15 watt light bulbs, washing machines, and water dispensers. The data was obtained from a combination of field observations and the assistance of active students residing in each flat. This approach provides a fairly detailed picture of the profile of electricity consumption in student residential environments. In Dormitory Flat 1, there were 27 air conditioners, 264 10-15 watt light bulbs, 12 washing machines, and 1 water machine. Flat 2 also has a considerable electricity consumption with 45 air conditioners, 124 5–10 watt light bulbs, 7 washing machines, and 1 water machine. Flat 3 is equipped with 49 air conditioners, 105 5–10 watt light bulbs, 10 washing machines, and 1 water machine. These three flats show the trend of using air conditioners as devices with high power consumption that are widely used, as well as main lighting supplied by energy-saving lamps.

Furthermore, Flat 4 is recorded as the flat with the most air conditioners, namely 56 units, accompanied by 202 5–10 watt lamps, 14 washing machines, and 1 water machine. Flat 5 has different characteristics, with 30 air conditioners and lighting supported by 305 10–15 watt lamps—the most for the lamp category—as well as 9 washing machines and 1 water machine. Meanwhile, Flat 6 recorded the use of 33 air conditioners, 310 10–15 watt lamps, 8 washing machines, and 1 water machine. The existence of these facilities shows that all flats have considerable energy needs to support the daily operations of their residents. Overall, the total accumulation of electrical devices in the six flats consists of 240 air conditioners, 1,324 light units (combined 5–10 watts and 10–15 watts), 60 washing machines, and 6 water machines. The data in **Table 1** reflects the high intensity of electrical energy use in supporting the comfort, cleanliness, and daily activities of students in the college dormitory. This finding also serves as the basis for calculating the estimated carbon emissions resulting from the operation of these buildings.

Table 1. Total Number of State-Owned Properties Using Electricity

No.	Type	Quantity
1.	Air Conditioner in Men Flats	240
2.	Air Conditioner in Women Flats	431
3.	Lamps (5-10 watt)	879
4.	Lamps (10-15 watt)	60
5.	Washing Machines	6

6.	Water Machines	240

Source: Research Analysis 2024

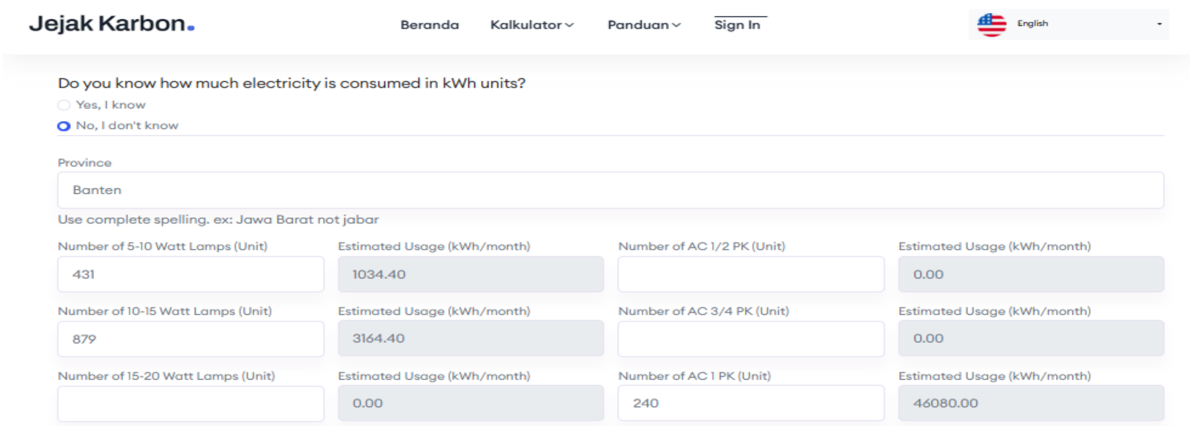
Table 2. Average Quantity of Waste Disposal for Male and Female Dormitories

No.	Days	Quantity (kg)	
		Male	Female
1.	Monday	3,6	4,7
2.	Tuesday	4,6	6,5
3.	Wednesday	5	6,1
4.	Thursday	5	6,1
5.	Friday	6,2	8
6.	Saturday	5	4
7.	Saturday	5	4
	Average	**4,9**	**5,6**

Source: Research Analysis 2024

The data on the number of active students in the dormitory in the 2024/2025 academic year shows that there are 860 students divided into six dormitory buildings in the college environment. In this study, we assumes that students use personal electricity based on the number of gadgets they bring and use during lectures. One of the basic assumptions about the number of gadgets brought by dormitory students refers to one of the rules of dormitory life. In 2023, the college dormitory manager issued Announcement Number Peng-107/Pkn/2023 concerning the Provisions for Entering the Dormitory for State Public Finance College Students of the 2023/2024 Academic Year which contains a list of luggage that students are allowed to bring into the dormitory. Based on the information obtained through active dormitory students who were informants in this research, the regulations for luggage were only distributed in the form of a regular *file* and not as regulations, but with the same contents and list of luggage.

The regulation states that college dormitory students are required to bring *mobile phones* and laptops as a means of supporting the teaching and learning process while at the college. Based on this regulation, we assumes that each of the 860 dormitory students bring one *mobile phone* and one laptop with them while living in the dormitory, and charge them at least once a day for each device. Based on this assumption, the calculation of the personal electricity usage of dormitory students is calculated at two devices per person, with a charging frequency of once a day, for a number of active days of teaching and learning at the college.



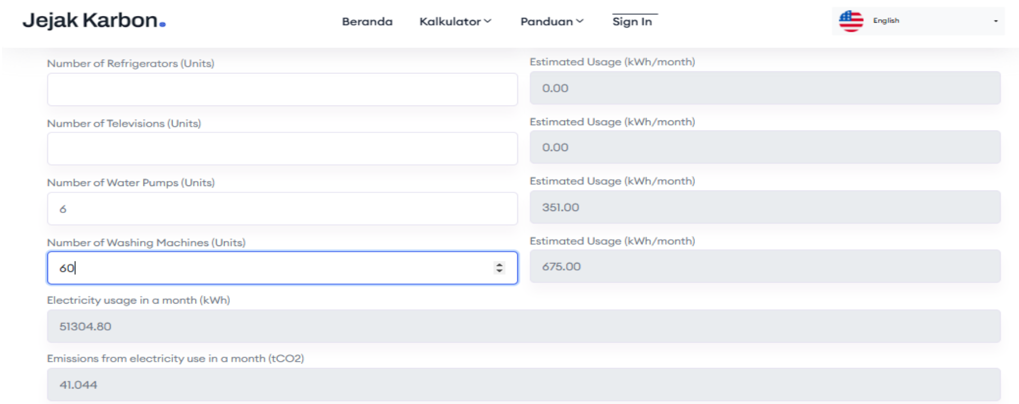


Figure 1. Calculation of Estimated Carbon Emissions of BMN During Activity
Source: https://jejakkarbon.id/

In this study, we calculated the estimated carbon emissions from waste in the dormitory buildings. In practice, college's waste has no organized recording, separation, or processing. We used a sampling method by recording the mass of waste disposal in the men's and women's dormitories, in different time spans and days, in order to see the trend of waste mass in the dormitories, which was then used as the basis for calculating carbon emissions later. We conducted observations based on documentation carried out by active dormitory students to obtain the quantity. Based on the results of the average of the following sample data, we used it as the basis for calculating the estimated carbon emissions from waste disposal per apartment building. It was found that for each female apartment, the average waste disposal was 5.6 kg per week, and for male apartments, it was 4.9 kg per week (see **Table 2**). The estimated carbon emissions in this study are calculated based on the number of state-owned properties that use electricity and the duration of their use during the teaching and learning activities period.

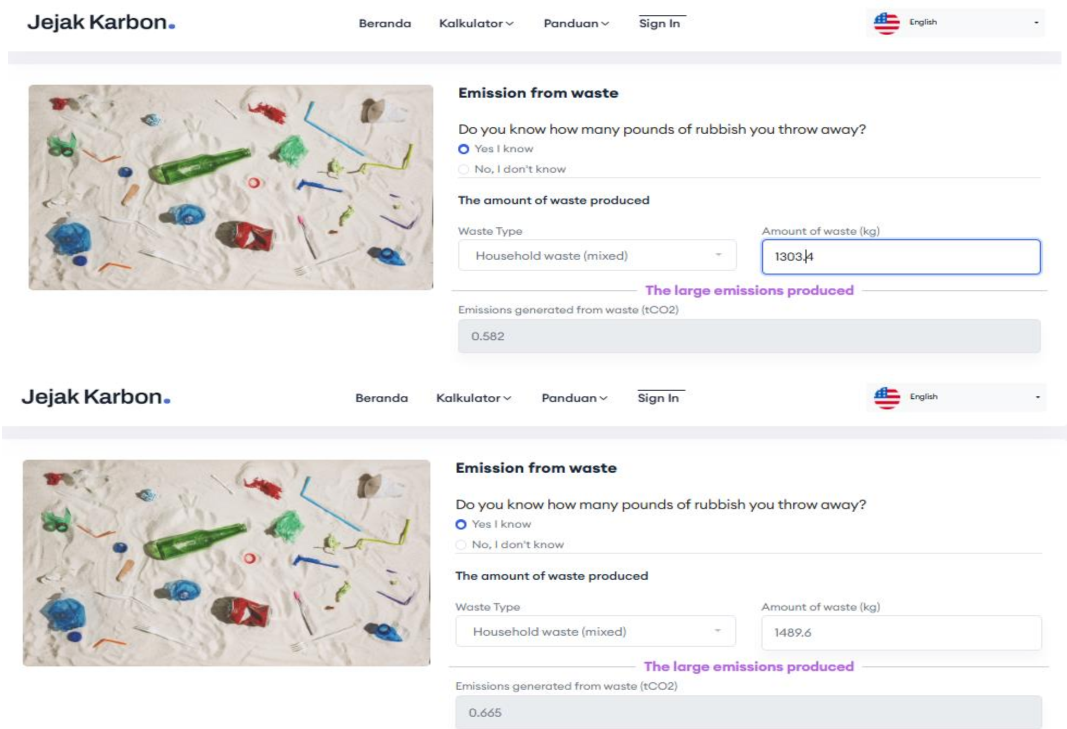


Figure 2. Calculation of Estimated Carbon Emissions from Dormitory Waste

Referring to the Announcement of the Director of the State Public Finance College Number PENG-89/PKN/2024 regarding the academic calendar for 2024/2025, the active teaching and learning process lasts for 38 weeks in an academic year. The calculation data begins with recording the number of BMN components that use electricity, such as air conditioners, lights, washing machines, and water machines, which are then entered into an online emissions calculator: https://jejakkarbon.id/, as you can see in **Figure 1,** and **Figure 2**. Because the calculator's results are based on a monthly basis, the total value of carbon emissions per month is 41.004 tons of CO_2 multiplied by the duration of 9.5 months of lecture period or *"Kegiatan Belajar Mengajar"* (KBM), resulting in an estimated annual carbon emission of 389.538 tons of CO_2. In addition to electricity consumption, waste disposal from the dormitories is also taken into account in the carbon emission estimate. With an average waste production of 4.9 kg/day for the men's dormitory and 5.6 kg/day for the women's dormitory, the total accumulated waste during the KBM period reached 1,303.4 kg and 1,489.6 kg respectively. The results of the calculation using the emission calculator show that waste from the men's dormitory contributed 0.582 tons of CO_2, while the women's dormitory produced 0.665 tons of CO_2 during the KBM period.

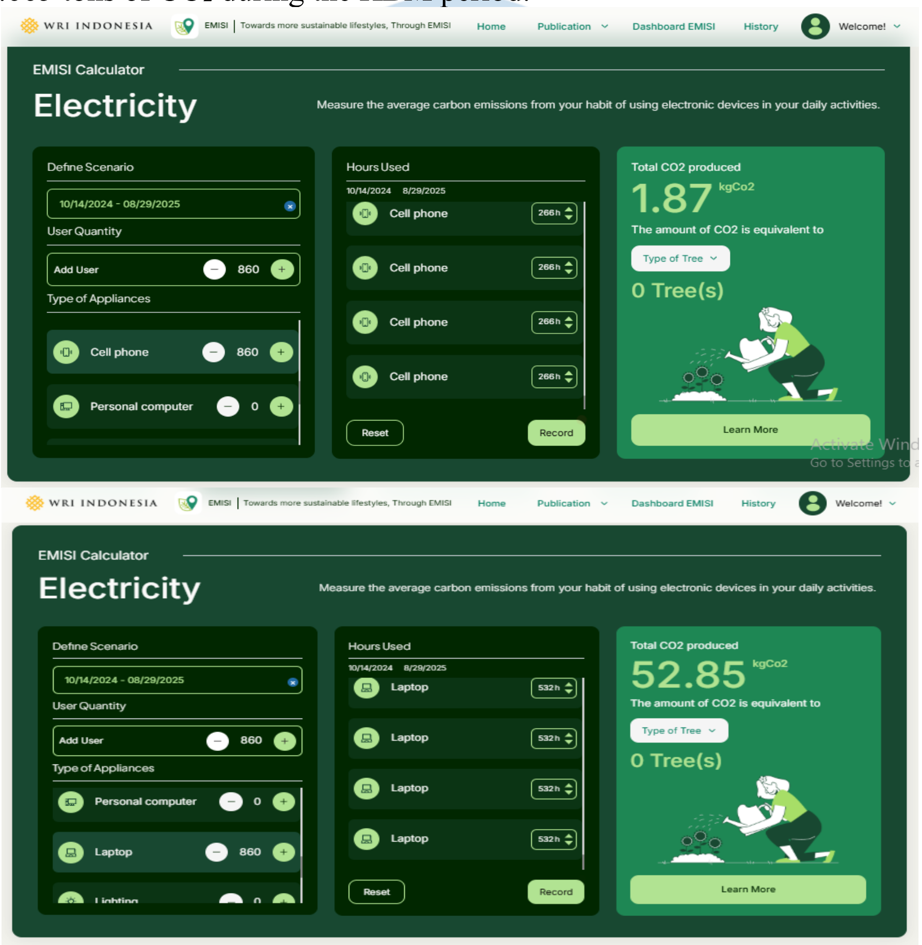


Figure 3. Estimated Calculation of Carbon Emissions from Active Personal Electricity Use

Source: https://nol-emisi.id/

In addition to electricity consumption from BMN, this study also takes into account the carbon emissions resulting from the personal use of electricity by dormitory students, especially the charging of electronic devices such as cell phones and laptops. Based on the dormitory's baggage regulations, each student is assumed to have one cell phone and one laptop with a charging frequency of once a day each. The time for charging cell phones is assumed to be 1 hour per day, while laptops are charged for 2 hours per day. With reference to the duration of teaching and learning activities for 38 weeks, the total charging time in one academic year reaches 266 hours for cell phones and 532 hours for laptops. The results of the calculation using the emission calculator show that cell phone charging produces emissions of 1.87 kg of CO_2, while laptop charging produces 52.85 kg of CO_2 in one academic year (see **Figure 3**). Overall, electricity consumption from BMN, waste, and personal use by students contribute significantly to the total carbon emissions generated in the college dormitory environment during the active period of teaching and learning.

In addition to the active period of KBM, this study also takes into account the carbon emissions generated during the student vacation period, as highlighted in **Table 3**. Based on the same academic calendar, there are several vacation periods that are categorized into two types, namely short and long vacations. Short vacations last for 4 weeks during some major holidays, such as Christmas and Eid, during which some students stay in the dormitories. To calculate the estimated carbon emissions during this holiday period, the study used the same approach as in the calculation when classes were in session, adjusting for the number of residents remaining in the dormitories and lower electricity consumption compared to the active period. The results show that during the holidays, BMNs that use electricity in the dormitories generate an estimated carbon emission of 3,286 tons of CO_2 (see **Figure 4**).

In addition to electricity consumption from BMN, the study also calculated the carbon emissions from the personal electricity use of students who stayed in dormitories during the holidays. Based on the data on the number of students living there, the calculation shows that the use of electricity to charge cell phones and laptops by 88 students results in an estimated carbon emission of 5.76 kg of CO_2 during a short vacation period (see **Figure 6**). In addition, the waste disposal of the residents who stay in the dormitory also contributes to carbon emissions. Taking into account the average daily waste production and the number of students who stay in the dormitory, the calculations show that the dormitory's waste during the holiday period results in an estimated carbon emission of 66 kg of CO_2 (see **Figure 5**). Thus, even though energy consumption and waste production are reduced during the holiday period compared to the active teaching and learning period, there is still a contribution to carbon emissions that needs to be managed to support environmental sustainability at PKN STAN.

Table 3. Number of BMNs in Dormitories During Holidays

No.	Type	Quantity
1.	Air Conditioner in Men Flats	10
2.	Air Conditioner in Women Flats	8
3.	Lamp (5-10 watt)	24
4.	Lamp (10-15 watt)	120
5.	Washing Machines	4
6.	Water Machines	2

Source: Research Analysis 2024

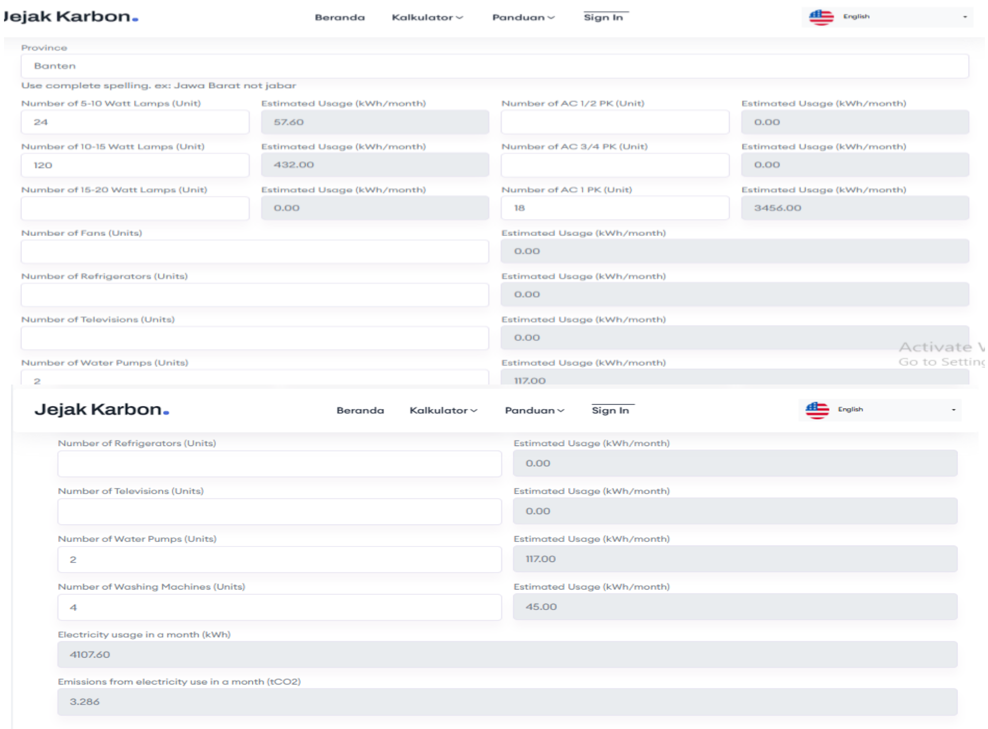


Figure 4. Calculation of BMN Carbon Emission Estimates During Holidays
Source: https://jejakkarbon.id/

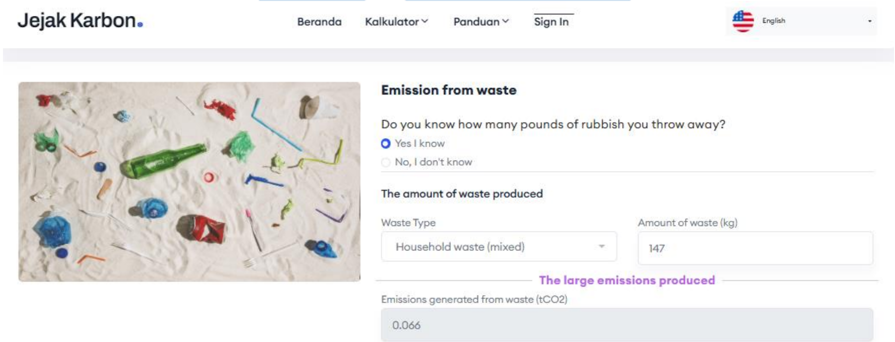


Figure 5. Calculation of Estimated Carbon Emissions from Waste During Holidays
Source: https://jejakkarbon.id/

x

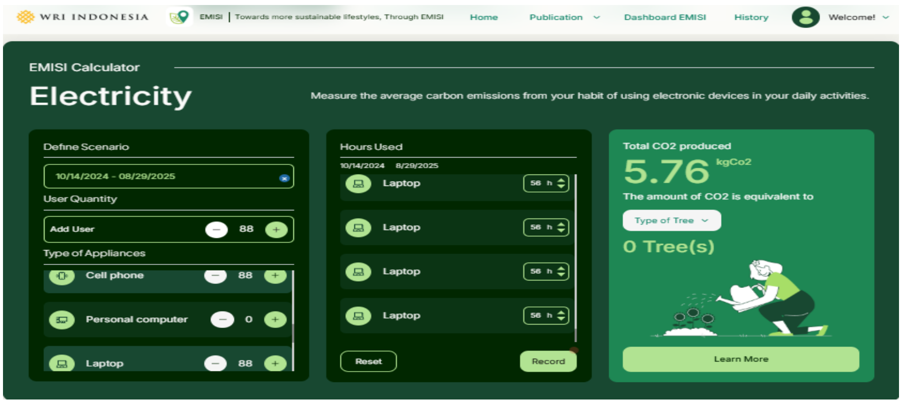


Figure 6. Calculation of Estimated Carbon Emissions from Waste During Holidays
Source: https://nol-emisi.id/

Table 4. Total Estimated Dormitories Carbon Emissions

No.	Type of Carbon Emission Estimate	Quantity (tonCO2)
1.	Electricity Use During Active Period	389,592
2.	Waste Disposal During Active Period	1,247
3.	Electricity Use During Holidays	3,291
4.	Waste Disposal During Holidays	0,066
	Total	394,124

Source: Research Analysis 2024

The results of carbon emission estimates show that the main source of emissions comes from electricity consumption during the active operational period, with a contribution of 389.592 tons of CO_2 or around 98.85% of the total emissions produced. This shows that the use of electrical energy is a dominant factor in the production of carbon emissions in the dormitory environment. In addition, waste disposal during the active period also contributes to carbon emissions, although the amount is relatively small, at 1,247 tons of CO_2. During the non-operational or holiday period, there was a significant decrease in electricity consumption, with total emissions of 3,291 tons of CO_2. Meanwhile, waste disposal during the holiday period was recorded as the lowest source of emissions, at 0.066 tons of CO_2. Overall, the total carbon emissions generated from all activities in the dormitory reached 394.124 tons of CO_2 per year as listed in **Table 4**.

After obtaining the estimated carbon emissions from electricity consumption and waste production, the calculation of carbon sequestration needs was carried out by referring to the absorption capacity of trees based on previous research. The number of trees needed to offset the total carbon emissions of the dormitory is calculated by dividing the total emissions produced by the carbon absorption capacity per tree per year. Based on research by Darlina et al. (2023), several tree species in Indonesia have different levels of carbon absorption. For example, Ornamental Walnut 1 (*Canarium sp*) has the ability to absorb 5.107 tons of CO_2 per year, so it takes around 77 trees to offset the carbon emissions of the dormitory. Other species such as Angsana (*Pterocarpus indicus*) are capable of absorbing 7.117 tons of CO_2 per year, so the number of trees needed to absorb carbon emissions is 55 trees. Meanwhile, the Sea Cedar (*Casuarina equisetifolia*) has the highest carbon absorption rate, which is 9,859 tons of CO_2 per year, so only 40 trees are needed to offset the carbon emissions produced by the dormitory. Based on these calculations, the Sea Cedar is the most effective tree species in absorbing carbon, because fewer trees are needed compared to other species. However, in the implementation of a greening program for carbon emission mitigation, in addition to considering carbon absorption capacity, other factors such as adaptability to the environment, available land area, and tree growth rate must also be taken into account. A combination of species with high carbon absorption rates and species with good environmental resilience can be an optimal strategy to support long-term environmental sustainability. Therefore, the selection of vegetation types must be done strategically so that the effectiveness of carbon mitigation can be maximized according to the conditions of the ecosystem on campus.

The calculation of carbon sequestration needs in this study was carried out by considering the criteria of trees that had been studied previously. According to research conducted by Susila and Apriliani (2021), carbon reserves in vegetation are strongly influenced by the volume and specific gravity of trees. Tree biomass is a major factor in carbon storage, where the higher the specific gravity of the wood, the greater its capacity to absorb and store carbon. Conversely, even if an area has a large amount of vegetation, the total biomass produced will not be significant if the dominant species have a low specific gravity. Thus, the effectiveness of carbon storage depends not only on the number of trees planted, but also on the characteristics of the biomass and the species used in the reforestation program. Over time, the carbon absorption capacity of each tree will increase as the vegetation itself grows. Changes in tree dimensions, such as trunk diameter, tree height, and biomass, will contribute to an increase in annual carbon sequestration capacity. This means that the number of trees needed to offset carbon emissions can decrease as the planted trees grow. With the dynamics of vegetation growth, the carbon mitigation strategy implemented needs to consider the life cycle of trees and environmental factors that can affect the effectiveness of carbon sequestration in the long term.

Energy use at the college dormitory, especially electricity consumption and waste production, is a major contributor to carbon emissions. To mitigate the environmental impact, it is necessary to implement a strategy based on the concepts of *green building* and energy efficiency as explained in the research by Hafez et al. (2023). The implementation of this approach not only aims to reduce energy consumption, but also supports environmental sustainability and optimization of dormitory building asset management. With more efficient energy management and a structured reduction of carbon emissions, it is hoped that the dormitory environment can become more environmentally friendly and support the sustainability policies implemented at PKN STAN.

Optimizing electricity consumption in the dormitory can be done through the application of *smart energy management* technology, which enables more efficient energy management. One method that can be applied is the installation of automatic sensors in the lighting and air conditioning systems, so that electrical devices only operate when needed and do not turn on continuously. In addition, the use of smart meters can help monitor electricity consumption in real-time, so that power management can be done more accurately. Another approach is the implementation of a *demand response* system, which allows electricity consumption to be adjusted based on actual needs, thus preventing excessive power usage. In addition to power management technology, energy efficiency can also be improved through the use of energy-saving devices, such as replacing conventional lamps with low-power LEDs, utilizing inverter-technology air conditioners, and collectively scheduling the use of washing machines to reduce electricity consumption without compromising the comfort of residents. In addition, the use of renewable energy can be a solution in reducing dependence on fossil-based energy sources. One of the steps that can be taken is the installation of solar panels on the roof of the building and the implementation of a hybrid energy system (*hybrid renewable energy system*), which combines various environmentally friendly energy sources to increase the efficiency and sustainability of electricity use in the dormitory environment.

In addition to electricity consumption, waste production is also a significant source of carbon emissions. To overcome this, waste management in dormitories can be optimized through the application of the *circular economy* concept, which focuses on waste reduction, reuse, and recycling. One strategy that can be applied is a waste sorting system into organic and inorganic categories to increase efficiency in the waste treatment process. The plastic and paper waste produced can be recycled by collaborating with waste banks or waste processing industries, while organic waste can be composted to support greening around the dormitory. In addition to recycling efforts, a plastic waste reduction strategy can also be implemented through policies on the use of *reusable* drinking bottles and food containers, supported by the provision of drinking water dispensers on each floor to reduce dependence on single-use plastic bottled water. To improve the efficiency of waste management, *waste-to-energy* systems such as biodigesters can be applied to convert organic waste into biogas, which can be used as an alternative energy source. In addition, the use of environmentally friendly *incinerators* can also be a solution in processing waste that is difficult to decompose without causing a significant increase in carbon emissions. With the implementation of this strategy, waste management in the dormitory environment can be carried out more sustainably, thereby reducing pollution and supporting carbon emission mitigation efforts more effectively.

Tree planting is one of the main strategies in offsetting carbon emissions resulting from electricity consumption and waste production in dormitories. As explained by Yang et al. (2018), urban carbon emissions generally come from waste disposal methods such as *landfilling* and *incineration*, as well as electricity consumption in waste management. To reduce this impact, carbon sequestration efforts through reforestation are an essential step. Based on the results of carbon sequestration needs calculations, the number of trees needed to offset carbon emissions of 394,124 tons of CO_2 per year has been calculated based on the carbon sequestration capacity of various tree species. Based on research by Darlina et al. (2023), the tree species with the highest carbon sequestration rate is the Sea Cypress (*Casuarina equisetifolia*), with a sequestration capacity of 9,859 tons of CO_2 per tree per year, so that around 40 trees are needed to balance the carbon emissions of the dormitory. Meanwhile, Angsana (*Pterocarpus indicus*) has a carbon absorption rate of 7,117 tons of CO_2 per tree per year, with a requirement of 55 trees. Ornamental Canarium (*Canarium sp*), which has a lower carbon absorption rate of 5,107 tons of CO_2 per tree per year, requires a greater number of trees, namely 77 trees.

In implementing a tree planting strategy, in addition to considering carbon absorption capacity, the aspects of cost and sustainability are also important factors. Based on planting cost calculations, some tree species have higher seedling prices than other species. For example, Sea Fir seedlings cost IDR 15,000 per tree, while Angsana only costs IDR 9,000 per tree, making it a more economical alternative with a consistently high level of carbon sequestration. On the other hand, Ornamental Walnut has the most expensive seedling price, which is IDR 50,000 per tree, so the total cost required is greater than other species. Therefore, the optimal tree planting strategy is to choose species that have a high carbon absorption capacity at a more efficient cost. In addition to economic aspects, the selection of tree species must also consider environmental conditions and adaptation to the local climate. Sea Fir is more suitable for areas with sandy soil, while Angsana and Ornamental Walnut are more optimal in soil with higher humidity levels. If the available land area is limited, choosing species with high carbon absorption capacity such as the Sea Fir can be a more effective solution because fewer trees are needed. Combining several tree species with high carbon absorption capacity can be a more effective approach than using only one type of tree with high costs.

In addition, research by Susila and Apriliani (2021) shows that the carbon absorption capacity of trees will increase along with the growth and development of vegetation biomass. Factors such as trunk diameter, tree height, and wood density play a role in increasing the effectiveness of carbon storage. Therefore, a sustainable carbon mitigation strategy must consider the dynamics of long-term vegetation growth. By choosing species that have an optimal balance between carbon sequestration capacity, planting costs, and environmental adaptation, the greening program at the college can run more effectively and support significant efforts to reduce carbon emissions. After determining the type of tree and the amount needed to absorb carbon based on previous calculations, the next step is to determine the optimal tree planting scheme. To achieve efficiency in carbon emission offsets, this study uses the Markowitz Model approach which is commonly applied in investment portfolio management. This model introduces the concept of diversification to reduce total risk without compromising the expected rate of return. In the context of tree planting, this model is applied to determine the optimal combination of different types of trees based on their carbon absorption capacity. With this approach, it is hoped that tree planting can be carried out more efficiently to offset the carbon emissions generated by activities at the college dormitory.

The optimal calculation is done by *linear programming* method using the *Solver* tool in Microsoft Excel. In the Markowitz model, *Expected Return*, which usually refers to the rate of return on investment, is equated with the carbon absorption capacity of each type of tree, because both have the same function in providing long-term benefits. Meanwhile, the risk in this model is interpreted as the total estimated carbon emissions which are considered as negative externalities. This calculation is made in the form of a table that includes the type of tree, total carbon uptake, total carbon emissions, and net carbon uptake. In the *Solver* application, the *Net Emissions Uptake* column is targeted to be zero to ensure that the number of trees planted can fully offset the resulting carbon emissions. The variable that can be changed is the number of trees without additional constraints, using the GRG Non-Linear method in the *Solver*.

Based on the optimization results, the optimal number of trees that can be planted in the college environment consists of 20 Angsana trees, 15 Ornamental Walnut trees, and 19 Sea Cypress trees. With this number, tree planting can be done efficiently according to the preferences of the relevant parties and environmental conditions. This calculation also allows for adjustments to the number of trees based on budget and necessary carbon sequestration needs. With this optimal scheme, the calculation of planting costs can be calculated based on the cheapest seedling prices available on the market. The total cost required to plant trees according to the optimal amount is IDR 1,215,000, which consists of IDR 750,000 for Ornamental Walnut, IDR 180,000 for Angsana, and IDR 285,000 for Sea Cypress. This figure may change depending on the actual price of the seedlings at the time of implementation and additional costs that may arise during the planting process.

In addition to the initial cost of purchasing seedlings, the tree planting strategy also considers maintenance costs throughout the tree's life cycle. These costs include watering, fertilizing, pruning, pest control, labor, and replacing trees that are not growing well. The estimated total annual cost for the maintenance of 54 planted trees is IDR 5,670,000, with a seed capital cost of IDR 1,215,000. To obtain a more comprehensive picture of long-term costs, a *present value* analysis was conducted on all costs incurred over a 15-year tree growth period. This calculation uses a *Social Discount Rate* (SDR) of 5%, as used by the Global Green Growth Institute in the Extended Cost-Benefit Analysis (eCBA) (Roesad et al., 2016). The results of the *present value* calculation show that the total cost of planting and maintaining trees for 15 years is IDR 75,579,291. This amount includes all cost components from seedling purchase to long-term tree maintenance, which will be a long-term investment in supporting environmental sustainability at PKN STAN. This calculation is a simulation that can be adjusted to the actual costs during the implementation of the greening program, so that it can be used as a basis for designing a more efficient and sustainable carbon offset strategy.

4. CONCLUSION, SUGGESTION, LIMITATION

This study aims to identify the main factors that contribute to carbon emissions in the college dormitory environment and propose mitigation strategies that focus on greening and energy efficiency. The results show that electricity consumption and waste are the main sources of carbon emissions. During the active period, electricity use generated emissions of 389.592 tons of CO_2, while during the holidays this figure decreased to 3.291 tons of CO_2. On the other hand, waste contributed 1.247 tons of CO_2 during the active period and 0.066 tons of CO_2 during the holidays. Overall, total annual carbon emissions reach 394,124 tons of CO_2, so an effective mitigation strategy is needed to balance the environmental impact caused. Based on the analysis of the carbon absorption capacity of various tree species, the number of trees needed to absorb annual carbon emissions depends on the type of tree chosen. If using Sea Cypress (Casuarina equisetifolia), about 40 trees are needed, while Angsana (Pterocarpus indicus) requires 55 trees, and Ornamental Canarium (Canarium sp) requires 77 trees. To achieve higher efficiency, the Markowitz Model approach is used to determine the optimal number of trees to be planted, namely 20 Angsana trees, 15 Ornamental Walnut trees, and 19 Sea Cypress trees. This combination was chosen based on high carbon absorption capacity and more economical seedling cost considerations, so that this greening strategy can run sustainably with more efficient costs.

In addition to reforestation, carbon emission mitigation strategies can also be implemented through more systematic energy efficiency and waste management. Optimization of electricity consumption can be achieved by implementing smart energy management, such as installing automatic sensors, smart meters, and using energy-saving devices to reduce power waste. Meanwhile, the concept of a circular economy in waste management can be applied through waste sorting, composting, and the use of biodigesters to convert organic waste into biogas as an alternative energy. The tree planting program remains a strategic step in balancing carbon emissions, with the selection of species that have high carbon absorption and are suitable for the surrounding environment. With the implementation of this strategy, it is hoped that the college dormitory can reduce the environmental impact caused and support the achievement of sustainability in energy and waste management.

Based on the results of the research and conclusions, the researchers made the following suggestions: (1) energy savings and efficiency, as well as waste management in the context of reducing emissions from college dormitory activities, can begin with routine evaluation and data collection of assets in each building and sorting of waste based on processing categories to facilitate the implementation of strategies and; (2) optimization of energy use in the college dormitories. Considering that electricity consumption is the main source of carbon emissions, further research can focus on strategies to optimize energy use in the dormitory environment. Studies can include the application of *smart energy management* technology, analysis of the effectiveness of using energy-saving devices such as LED lights and *inverter* air conditioners, as well as electricity consumption management policies based on student activity patterns; (3) application of the *Eco-Office* Concept in the college dormitory. Asset management has an important role in supporting the *eco-office* concept on campus. Future research can focus on the implementation of a broader *eco-office* strategy, including energy efficiency, sustainable waste management, and green policies in campus operations; and (4) campus greening through the mechanism of planting trees on campus and dormitory areas as a tangible form of emission reduction by increasing carbon absorption through plants.

The calculation of the estimated carbon emissions of the college dormitory was carried out by observing the use of state property that uses electricity and also waste disposal, due to the limitations of the data held. The estimation calculation is limited to electricity and waste as variables with several assumptions because these data are the most possible to be quantified. The strategy in energy efficiency and also tree planting is limited to the number of trees needed without data on plant distribution due to the unavailability of land data that is ready for reforestation, and it is possible to do so in further research.

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