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Article

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Energy Management Strategy in Campus Towards a Green Campus Through Promoting Carbon Footprint and Energy Efficiency Index Improving

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ABSTRACT

The energy management strategy is the key to increasing the energy efficiency index (EEI) and controlling buildings' carbon emissions. This article discusses the energy policy strategy at Siliwangi University based on four main components of green campus: the profile of the electricity load, energy consumption, the rate of the number of vehicles, and vehicle activity in the campus environment. We propose four scenarios to meet the EEI and carbon emissions standards in 2025. The analysis of carbon emission production uses the UI Green Metric approach by referring to the carbon emission strategy from the Climate Action Tracker (CAT) and the profile of the world bank. Simultaneously, the EEI analysis uses the ASEAN-USAID standard, which is also used in the Indonesian National Standard (SNI). The conclusion is that even with the highest scenario to meet the target EEI level in 2025, Siliwangi University can only reach the EEI level in the "Extremely Efficient" category for the area with AC facilities and Extremely-Inefficient class for the area with AC facilities. The analysis results show that the most considerable contribution of carbon emissions is from motorbikes, 66%, cars and buses 33% and electricity use only 1.4%. Although the use of electricity does not have a significant emission impact, the EEI analysis results show a tendency towards electricity waste. Siliwangi University must immediately implement electric vehicles on campus to reduce carbon emissions from the mobility of motorbikes, cars, and buses.

Keywords: Energy, Strategy, Carbon Footprint, Energy Efficiency Index, Emission
JEL Classifications: C33, E210, E310, O470

1. INTRODUCTION

The Carbon Footprint (CF) on campus is an essential component of many green campus assessment standards, such as assessment standards based on the UI GreenMetric Assessment standard (Universitas Indonesia, 2016), United Nations Environment Program (UNEP) Assessment standard (Sisriany and Fatimah, 2017), GreenShip Assessment standard (Indonesia, 2016). Therefore, many campuses are trying to suppress carbon production to get an ideal carbon footprint (CF) (Wu et al., 2017; Liu et al., 2017), or a sustainable university design (Dagiliūtė et al., 2018) to get the criteria for a green campus (Sonetti et al., 2016). The big question is about the right strategy so that universities can control the electricity load to meet the Energy Efficiency Index (EEI) standard and control carbon emissions to fulfill the Climate Action Tracker (CAT) standard and the world bank. Meanwhile, the conditions that cannot be avoided are the high competitiveness among colleges forces the addition of facilities, which is high consumption of electrical energy and increased production of carbon pollution (Ambariyanto and Utama, 2018).

The rate of electric usage per year on campus represents the performance of electric energy use in universities. The growth rate of electricity load on campus is directly proportional to the availability of operational funds. The higher the costs of energy procurement, the higher the interest in purchasing equipment, which ultimately increases electrical energy and carbon emissions. Therefore, this article focuses on how to profile the Energy Efficiency Index (EEI) and how the production of per capita carbon emissions on the Siliwangi university campus in 2025 with survey data from 2015 to 2019. This study can contribute to policy decision-making about energy management to achieve a green campus.

There are two limitations as a reference for this article. They include the Energy Efficiency Index (EEI), which refers to the Indonesian National Standard (SNI), for commercial buildings the EEI value is not more than 240kWh/m^2/year (Nasional, 2000) and per capita carbon emissions, which refer to programs issued by the world organization G20 (Donat et al., 2018). Meanwhile, based on linear regression from data from the world bank, the production of carbon emissions per capita per Year in Indonesia in 2025 is 3.1 MTCO$_2$e/capita (World Bank, 2016). This value is much lower than that specified in the CAT-based standard. The carbon emission in Indonesia 1990-2019 can be seen in Figure 1.

The approach we adopted in this article is to control electricity consumption using a strategic load growth approach (Kostková et al., 2013) by limiting the growth of electricity loads per year. This limitation will have an impact on improving EEI (Benetti et al., 2016; Kurkute and Patil, 2019; Maritz, 2019), while the analysis of carbon emissions on campus uses the approach of the UI Green Matrik (Universitas-Indonesia, 2016) with variables of vehicle population and vehicle activity in the campus environment.

The study object's location is Siliwangi University, which has been operating since 1980 and is ready to apply the green campus concept, so it is necessary to have a variety of scenarios for the growth of electrical energy consumption in the campus environment. The data analysis is based on the electricity consumption profile data for 2015-2019.

1.1. Studies of Carbon Footprint (CF) in University

Carbon emissions in universities are caused by various factors, including the high consumption of energy used, high mobilization in the campus environment, the number of active transformations on campus, procurement of materials and equipment, infrastructure, food, waste, and water used. The carbon emission factor from energy use (Kg.CO$_2$/kWh) results from multiplying electricity consumption (kWh) with the carbon factor. Several standards are applied to determine the carbon emission caused by electricity consumption, as in Table 1.

Table 1: Greenhouse Gas (GHG) standards caused by electricity consumption

GHG emission (kgCO$_2$ e/kWh)	References
0.3972	DEFRA (Department for Environment, Food, and RuralAffairs Gov. UK) Minenergia, 2017 (Yañez et al., 2020)
0.5610	TC Common data (Aroonsrimorakot et al., 2013)
0.220	Red Eléctrica Española/Spanish Electrical Grid (REE) (Loyarte-López et al., 2020)
0.84	http://carbonfootprint.org (Universitas-Indonesia, 2016)

Many researchers agree that the energy strategy on campus to control carbon emissions is an important issue. Therefore, the energy management strategy is supposed to break the dissipation, not to create it. For that reasons, some researchers have proposed approaches that can be used to reduce CF on campus, including through improvements in electrical energy management, (Yañez et al., 2020; Ravindran and Selvaram, 2016), the application of new renewable energy on campus (Chowdhury et al., 2018; Hasapis et al., 2017; Shukla et al., 2019) or the integration of EBT on campus (Maritz, 2019), water and waste use management (Yañez et al., 2020)., transportation (Wu et al., 2017; Liu et al., 2017; Yañez et al., 2020), building materials (Wu et al., 2017).

Ravindran and Selvaram (2016), promoting greening for carbon absorption on campus (Ravindran and Selvaram, 2016), Pablo Yañez et al. (2020) believe that student transportation activities on campus are a significant stressor in the problem of carbon emissions (Yañez et al., 2020). Li et al. (2015) found that, on average, students produce 3.84 tons of CO2, which consists of 65% daily activities, 20% transportation, 15% academic activities (Li et al., 2015). It means that reducing electricity consumption and controlling transportation activity can significantly reduce carbon emissions on campus. So then it points to improve the performance of energy use on campus (Shen et al., 2020).

Based on the results of previous studies on the leading causes of carbon emission factors on campus (Table 2), the leading cause of carbon emissions is energy use, although some researchers have shown that transportation is the most significant contributor to carbon emissions (Li et al., 2015; Shen et al., 2020; Güereca et al., 2013; Vásquez et al., 2015).

1.2. Energy Efficiency Index (EEI)

Performance Indicator (KPI) regarding energy use in a building. Therefore, EEI can be called the Building Energy Index (BEI) (Tahir et al., 2017), or it can also be called the Energy Performance Index (EPI) (De Ruggiero et al., 2017). The basic definition of EEI as in (1) is the energy input ratio to the factor related to the energy-using component (Abidin et al., 2017). Factor related to the energy performance consists of eight components, (1) the weight of product produced, (2) The number of items produced, (3) weight of raw material used, (4) period of production, (5) period of plant usage, (6) number of in-patient bed per night (hospital building), (7) number of occupied rooms per night (hotel building), (8) floor area of building (Abidin et al., 2017; Malaysia, 2012). Buildings are affected by electrical loads such as heating, ventilation, and air-conditioning systems (HVAC) (Bakar et al., 2015), lighting (Tahir et al., 2017).

$$\text{EEI}=\frac{\text{Energy Input (Kwh)}}{\text{Factor related to the energy using component}} \tag{1}$$

The Energy Efficiency Index (EEI) is an index used as a Key If the EEI is determined based on the land area ratio, equation (1) can be adjusted to (2) where EC is the annual energy consumption of the building (kWh / y), A is the floor area of the building (m^2).

Table 2: Variations in the central carbon emission factors in universities

Author	Country	Method	Occupation CE production (tCO_2e)	Main cause of CE
(Lambrechts and Van Liedekerke, 2014)	Spain	ISO 14064	0.31 tCO_2e per student 2.69tCO_2e per employee	1. Direct energy use 2. Mobility
(Güereca et al., 2013)	Mexico	Greenhouse Gas (GHG) Protocol	1.46 tCO_2e per student	Transportasi and Car
(Vásquez et al., 2015)	Countries: Spain, México, USA, Norway	Greenhouse Gas (GHG) Protocol	1.0 tCO_2e per student	1. Student commuting (excluding institution bus) 2. Electricity consumption 3. Student commuting including institution bus 4. staft commuting
(Li et al., 2015)	China	Novel methodology based on survey	3.84 tCO_2e per person	1. 65% form Daily life activities 2. 20% from transportation 3. 15% from academic activities
(Letete et al., 2011)	South Africa	Adapted GHG protocol	4.0 tCO_2e per student	1. 56.59% Electric used 2. 13.94% Staff and student commuting
(Larsen et al., 2013)	USA	GHG protocol	9.6 tCO_2e per student for the Faculty of Medicine 4.2 tCO_2e per student for the Faculty of Science 1.7 tCO_2e per student for the Faculty of Architecture and 0.7 tCO_2e per student for the faculty of Economy	1. 19% from Energy 2. 19% from building 3. 19% from equipment 4. 16% from transportation

$$EEI=\frac{EC}{A} \tag{2}$$

In Indonesia, the standard for assessing the performance of energy use in buildings uses EEI, which has also been used as the ASEAN-USAID standard, the Green Building Council Indonesia (GBCI) Standard, and the ESDM Standard through the Indonesian National Standard (SNI) with code SNI 03-6196-2000 (Nasional, 2000). Based on SNI 03-6196-2000 standards, the commercial buildings' provisions are 240 kWh/m^2/year, and the residential building is 300 kWh/m^2/year, shopping centers 330 kWh/m^2/year. Therefore, for simplification, the EEI level is divided into six categories for rooms that use HVAC, while for rooms without HVAC, the category levels are divided into four efficient levels as in Table 3.

1.3. Load Management in Campus

A good load management strategy requires commitment and the right approach from policymakers, policy implementers to the energy audit team. Outcomes from load management impact maintaining a rational ratio of energy consumption to population, low carbon pollution, and ecosystems around campus.

Load management plays an essential role in increasing the efficiency of sustainable energy use. In practical terms, load management is divided based on two primary focus studies: load management based on energy diversification and load management based on energy conservation. Demand-side government (lighting load reducing, improving HVAC, replacing the motor, smart home automation system), Supply-side management such as waste to energy generation, superconductivity, wind energy, solar energy, pumped hydro, compressed air energy storage, thermal storage (Bellarmine, 2000).

Table 3: Category of EEI Standard rating for building

Category	Area with air conditioner system (kWh/m²/month) (Fitriani et al., 2017)	Area without air conditioner system (kWh/m²/month) (Kolokotsa et al., 2012)
Extremely efficient	4.17–7.92	0.84–1.67
Slightly efficient	7.92–12.08	1.67–2.5
Inefficient extremely	12.08–14.58	-
Extremely efficient	14.58–19.17	-
Slightly efficient	19.17–23.73	2.5–3.34
Inefficient extremely	23.75–37.75	3.34–4.17

The load management strategies on campus have been proposed by many researchers: direct load management and indirect load management approaches (Kostková et al., 2013). the direct load management strategiy includes load control, interruptible tariffs, and load curtailment programs. while indirect includes pricing programs, rebates, and subsidies, education programs. Implementing the building energy management system (BMS) on campus provides a 14% increase in electricity consumption efficiency (Jomoah et al., 2013). Controlling peak load with a real-time energy monitoring system (Benetti et al., 2016) has been shown to improve the efficiency of electrical energy consumption, such as optimization of HVAC on campus (Kaur et al., 2018) or a decentralized system architecture approach for load management in demand-side (Weinert and Mose, 2016).

2. MATERIALS AND METHODS

2.1. Conditions at the Campus of Siliwangi University

Siliwangi University (UNSIL) is located in West Java, the air conditioner is good, and the temperature is 28-32 C0, humidity is 68%. UNSIL has many trees and forests on campus. UNSIL has eight faculties, 14 buildings with a total building area are 32,929 m^2, and a total area of UNSIL is 316,000 m^2. The population average per year is 12,671 people per year. The average number of vehicles per year is 157,684 units per year, the number of motor vehicles is 2 million units per year with parking facilities on an area of 4000 m^2. Based on data on electricity consumption at UNSIL from 2015 to 2019, it tends to increase or 2MwH per year or 11% per year. The map of Siliwangi university can be seen in Figure 2.

Table 4, shows that Siliwangi University has 14 buildings with each building area, installed electricity load, and an annual electricity consumption profile. The electrical consumption (%) 2015-2019 based on the type of building can be seen in Figure 3.

Table 4: Profile of energy consumption in Siliwangi University

Building	Area (m^2)	Total rate consumption (kWH)/Year	Rated consumption (kWH)/year	
			Lighting	Load (excl. lighting)
Rectorate	2.754	11.860	1.261	11.859
Faculty of economic	2.594	4.744	2.235	4.741
Faculty of technique	3.565	8.697	922	8.696
Research and society service department	950	5.534	1.722	5.533
Library	1.146	4.744	438	4.743
Faculty of public health	510	5.534	369	5.534
Postgraduate programme	10.483	5.534	403	5.534
Faculty of social and political sciences	6.133	7.116	219	7.116
Faculty of Islamic sciences	950	3.953	46	3.953
Training and certificate service department	224	3.953	207	3.953
Faculty of agriculture	392	5.534	461	5.534
Faculty of teacher training and education	522	5.534	1.832	5.533
Ballroom	1.206	3.162	1.308	3.161
Mosque	15	3.162	121	3.162
Total	3.1444	79.070	11.543	79.058

2.2. Scenario

This article proposes approvement which consists of four groups main of scenario. Scenario-1 is where the growth in electricity consumption follows the character of the existing development; Scenario-2 is a policy where electricity consumption is reduced by 10% per year, Scenario-3 is a policy to limit the increase in electricity consumption 20% per year, and scenario 4 is a policy to limit the rise in electricity consumption to 30% per year. Each scenario we proposed will contain three levels, namely optimistic value, moderate value, pessimistic value.

The population growth of students and teaching and administration staff is planned for 2025 to be a maximum of 13,500 people. From these four scenarios, it will be known that the optimistic value, moderate value, pessimistic value of the EEI achievement that can be fulfilled until 2025 EEI at Siliwangi University can be categorized as Extremely Inefficient, Slightly efficient, or Extremely efficient as in Table 3.

The total carbon emissions produced on campus is the sum of carbon emissions each year in metric tons caused by electricity ($EC_{(EL)}$), transformation ($EC_{(bus)}$), and motorbikes ($EC_{(mtr)}$). A simple expression to reflect in the arithmetic term of total CF calculation in the campus is the following.

$$EC = \sum EC_{(EL)} + \sum EC_{(bus)} + \sum EC_{(car)} + \sum EC_{(mtr)} \tag{3}$$

Carbon emission in matric ton, produced from electricity usage defined from following:

$$EC_{(EL)} = \frac{\sum \text{Electricity usage (KwH)}}{1000} \times 0.84 \tag{4}$$

$EC_{(EL)}$ is Carbon emission produced from electricity usage (metric ton), "CE" is electricity usage (kWh), 0.84 is the coefficient to convert kWh to Metric ton. Therefore, the total carbon emissions produced from bus activities on campus can be calculated using the following equation:

Figure 1: Carbon emissions in Indonesia 1990-2019 and predictions based on several scenarios (Donat et al., 2018)

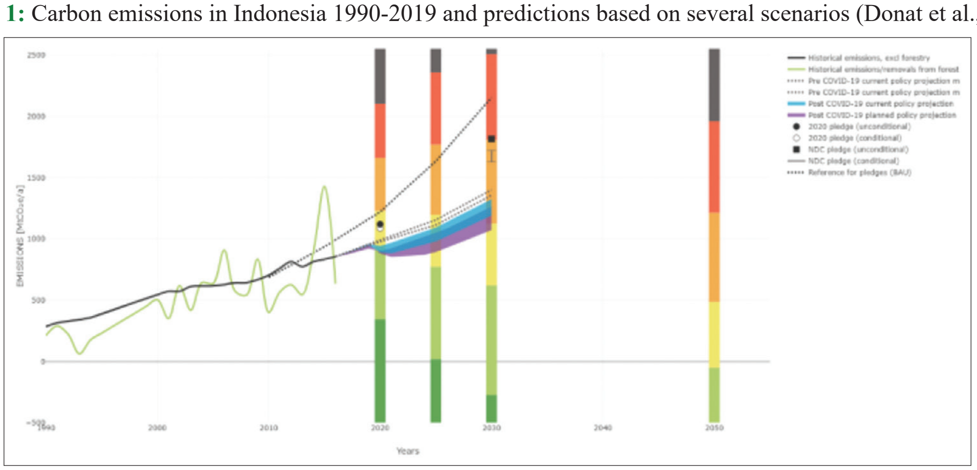


Figure 2: Maps of Siliwangi University

Figure 3: The electrical consumption (%) 2015-2019 based on the type of building

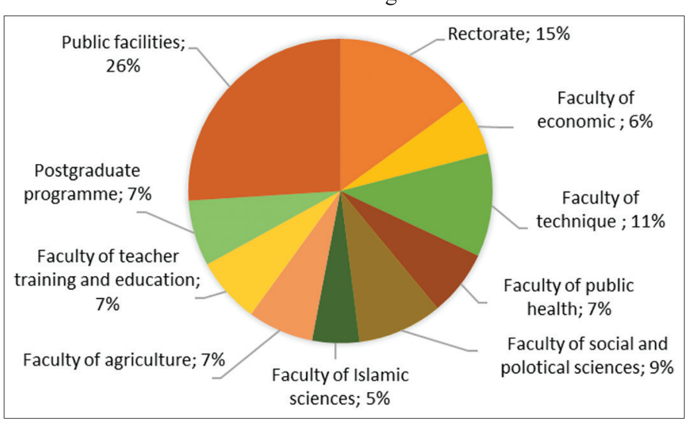
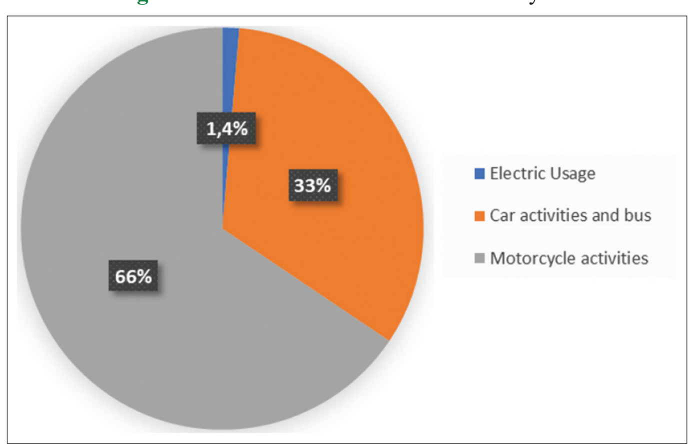


Figure 4: Carbon emissions from electricity use



$$EC_{(bus)} = \frac{(\sum \text{Bus shuttle}) \times \text{Trip} \times L \times D}{100} \times 0.01 \quad (5)$$

The total shuttle bus is the number of buses operating on campus. The trip is total trips for shuttle bus service each day, “L” is the approximate travel distance of a bus for each day inside campus only (km), "D" is the number of working days per year, 0.01 is the coefficient to calculate the emission in metric ton per 100 km.

The total carbon emissions produced from vehicle (bus) activities on campus are determined using the following equation:

$$EC_{(car)} = \frac{(\sum \text{Total car}) \times 2 \times L \times D}{100} \times 0.02 \quad (6)$$

The total car is the number of cars operating on campus, "L" is the length of the car track within the campus (km), D is the number of working days per year, 0.02 is the coefficient to calculate the emission in metric ton per 100 km.

The total carbon emissions produced from vehicle (bus) activities on campus are determined using the following equation:

$$EC_{(Motorcycle)} = \frac{(\sum \text{motorcycle}) \times 2 \times L \times D}{100} \times 0.01 \quad (7)$$

The total motorcycle is the number of motorcycles operating on campus, "L" is the length of the motorbike track on campus (km), "D" is the number of working days per year, 0.01 is the coefficient to calculate the emission in metric ton per 100 km.

3. RESULTS AND DISCUSSION

3.1. Energy Consumption Forecasting

Based on the data in Table 4, with electricity consumption data from 2015 to 2019, a linear forecasting equation is obtained as in equation (8). The results of forecasting electricity consumption show that in 2020-2025 the average growth in energy consumption is 8% per year so that in 2025, electricity consumption will reach 1,737,503 kWh. This growth rate can be relatively high, due to the trend of academic services requiring equipment with large capacities and large quantities, for example, the provision of air conditioning unit in each class, the addition of photocopying machines, the addition of significant capacity laboratory equipment. Numerically, the growth of energy consumption profile can be represented as (8).

$$Y=103741(x)+ 596352 \quad (8)$$

3.2. Carbon Footprint Forecasting Analysis

Carbon emissions in the Siliwangi University campus environment are caused by electricity, motor vehicle activities, and car activities. Carbon emissions from electricity use are calculated using equation (4) with data from Figure 4, so the annual carbon emission growth rate is 8.8%, or in 2025 it will reach a maximum of 1,460 $MTCO_2e$/year.

Figure 4 shows the trend of growth in carbon emissions caused by bus, car, motorcycle, and electricity use on campus based on using equation (5) for emissions from bus activities, equation (6) for emissions from car activities, equation (7) for emissions from motorcycle activity. Furthermore, the production of carbon emissions from cars using equation (6), while motorbikes use equation (7) using the data in Figure 5, so carbon emissions in 2025 are 37,781 $MTCO_2e$ (Figure 4). These emissions consist of

Figure 5: Energy consumption forecasting with increasing rate (kWh/y)

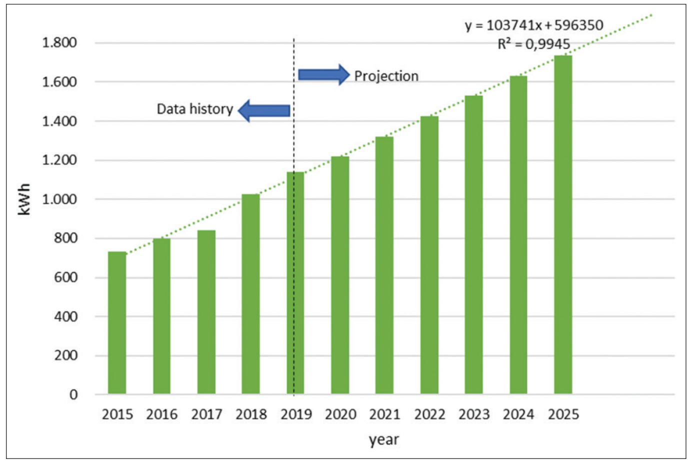


Figure 6: Projected population, number of motorbikes, cars, and buses in 2015-2025 at Silwiangi University

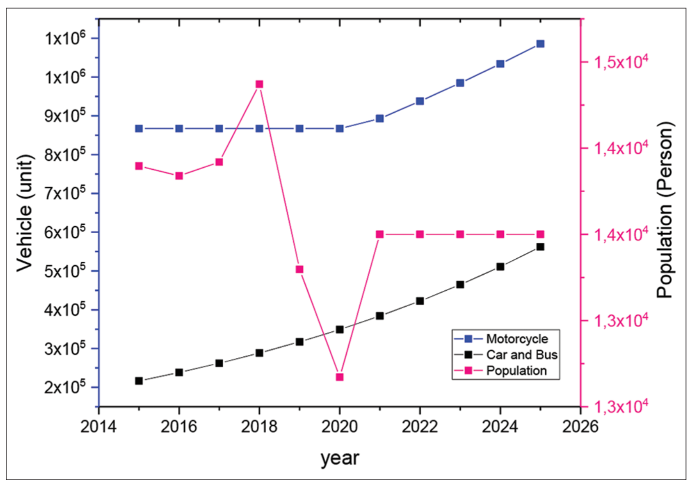
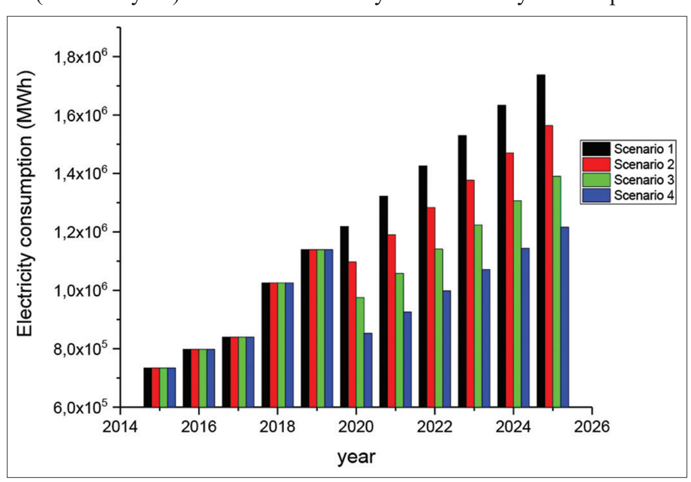


Figure 7: The ratio of production of carbon emissions per year (MTCO2/year) from vehicle activity and electricity consumption



37,780 $MTCO_2e$ from car activities and 0.926 $MTCO_2e$ from bus activities. The growth in emissions from bus activities on campus is 14.7% per year, while the growth in emissions from car activities on campus is 9.4% per year. The calculation results in Figure 4 show a significant trend of increasing carbon emissions due to car and bus activities on campus. However, the most significant contribution to carbon emissions is due to a large number of motorbike activities. Total carbon emissions are predicted in 2025 to reach 1460 $MTCO_2e$ (Figure 4), while the population is fixed at 13,500 persons (Figure 6). The ratio of carbon emissions to the population in 2025 is 0.108 $MTCO_2e$/capita. This value is still far from the maximum per capita emission requirement from CAT standards or even the world bank in the same year. Figure 4 shows the carbon emissions from motor vehicles in the campus environment obtained by equation (7). Using the data from Figure 4, the carbon emissions from motor activities in 2025 will be 57,320 $MTCO_2e$ with an annual growth of 2.2%.

From three sources of carbon emissions, electricity, car activity, bus, and motorbike activities in the campus environment, it can be concluded some condition. Figure 7 shows that the average carbon emission produced each year from 2015 to 2025 is that the most significant contribution of carbon emissions is from motor activities that are 66%, cars and buses contributed 33%, and electricity usage was only 1.4%. From these results, it is concluded that a distance of 1.1 km and a growth of 2.2% per year has a very significant environmental impact.

3.3. Energy Efficiency Index (EEI) Analysis

Siliwangi University has space with quite a lot of HVAC. Because it is in a tropical country, the HVAC system is very much needed for staff and students' comfort. Electricity consumption by HVAC is 37%, as in Figure 8 since 2017 continues to increase. After we recap (Figure 6) and predict using a linear approach (Figure 9) with four planned scenarios, then using equations (1) and (2), then we classify it based on (Table 3) with scenario boundaries (Figure 9). We found the fact that for area with HVAC systems, the performance range of electricity usage is 1626 kWh/m^2/month, which can be classified into three categories based on Table 3, namely "in extremely efficient," "slightly efficient," and "extremely efficient" (Figure 10).

In Figure 10, it can be seen that of the four scenarios we propose, if using Scenario-1, the category obtained is "inefficient extremely," this is certainly not expected. Choosing Scenario-2 is a rational scenario to achieve the "slighty efficient" category because reducing electricity load growth is only 10% per year. Nevertheless, Scenario-3 is a scenario that does not need to be carried out, because besides the results are the same when using Scenario-2; the effort required is heavier, namely reducing the growth in electricity load by 20% per year. The category "extremely efficient" can be achieved using Scenario-4. However, it takes considerable effort and resources to achieve the "extremely efficient" category.

Figure 8: Profile rate of electric consumption base on load type in Siliwangi University

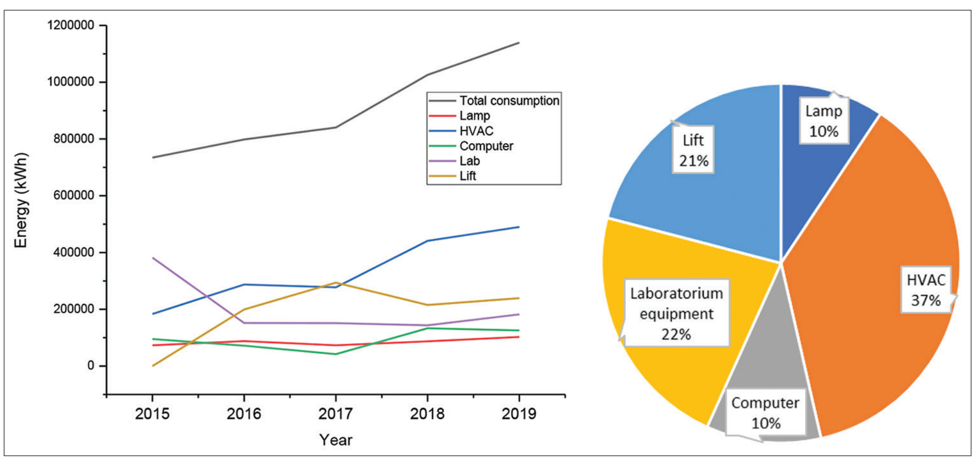


Figure 9: Energy consumption forecasting with load optimization scenario (kWh/y)

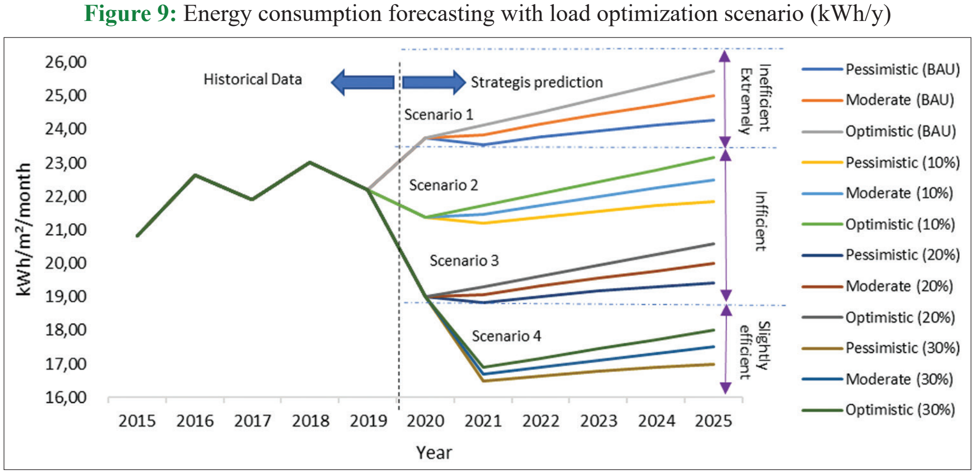


Figure 10: Scenario classification based on EEI standard for area with HVAC system

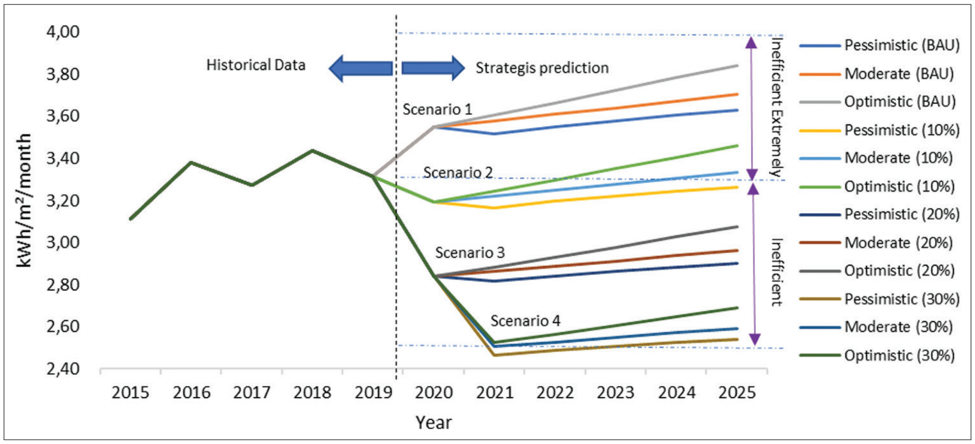
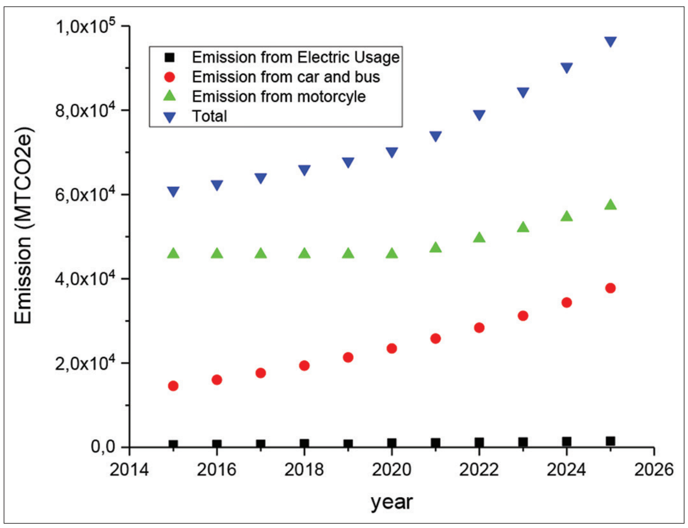


Figure 11: Scenario classification based on EEI standard for without HVAC system



The electricity load management scenario also applies to areas without an HVAC system, and we found that for a room without an HVAC system, the electricity usage performance range is 2.4–4.0 kWh/m^2/month. This range of values can be classified into two categories based on Table 3, namely "extremely inefficient" and "inefficient." It can be seen in Figure 11 that of the four scenarios we proposed for areas without an HVAC system, none of the four scenarios were able to meet the expected categories (efficient or Extremely efficient). This result is because there are many electrical loads in the laboratory room. So it can be concluded that areas without HVAC require a higher scenario. The minimum must be with a program to reduce the electric load rate by 40% per year.

4. CONCLUSION

Green campus requires a high commitment in achieving it, and therefore from the collected data, we have successfully tested four different scenarios and identified the need for Siliwangi University to reach a green campus by 2025. EEI standards for measuring electricity use and CAT standards and the World Bank for controlling carbon emission production we have successfully implemented in this article. The conclusion from field observations is that it is found that Siliwangi University has a trend to 2025 with 8% per year for electric consumption rate and 8.8% per year for carbon emission annual growth rate. The most significant carbon emission contribution is 66% from motorcycles, 33% from car activities, and 1.4% from electricity use. The production of carbon emissions in 2025 is predicted to reach 0.108 $MTCO_2e$/capita. This value is smaller than the prediction by CAT, namely 3.4 $MTCO_2e$/capita and the world bank 0.108 $MTCO_2e$/capita. The performance of electricity usage for are with the HVAC system meets three categories based on EEI standards. Scenario-2, with a reduced rate of electricity load growth reaching 10% per year, is the most rational scenario to implement. In the performance of electricity usage for the area without an HVAC system, the result fulfills only two categories, and of the four scenarios offered, none of which can be applied, therefore it requires a higher target scenario.

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