Green Campus Establishment Through Carbon Emission and Energy Efficiency Control

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Abstract— Campus greening has become an obsession for every University; even though being a green campus is not easy, it takes a long-term strategy to be implemented. This article discusses strategies to reduce carbon production and increase efficiency in the use of electrical energy. The campus control policy uses the standards used in the Climate Action Tracker (CAT) and the World Bank standard. While increasing the efficiency of electricity use by observing the annual electricity use of the building and then dividing it by the building area so that the actual energy efficiency index (EEI) identification value is obtained. The object of research is the University of Siliwangi (UNSIL). Data analysis uses field observation data with a range from 2015 to 2021. We use a regression approach to determine conditions in 2030. The results of the investigation on carbon and electricity emissions are divided into four scenarios. The analysis of the efficiency of the use of electrical energy focuses on two types of areas, namely areas with an HVAC system and areas without an HVAC system. The calculation results are recapitulated into six categories. The conclusion from our analysis, it appears that UNSIL needs a breakthrough and a solid commitment to reduce carbon production on campus, misconvert the use of electric vehicles in the campus environment, reduce car and motorcycle activities. The efficiency of electricity use can apply scenario two or scenario 3, which is to keep the electricity consumption rate per year at a minimum of 10%.

Keywords— Green campus, carbon emission, energy, strategy

I. Introduction

The greening concept has become an essential issue in many universities, including high energy efficiency, low carbon emission, sustainable environmental awareness. Along with that issue, there is some assessment tool for assessment, such as UI Green Metric indicator standard from University of Indonesia [1], Greenship indicator standard from Green Building Council Indonesia (GBCI), UNEP indicator standard from the United Nations [2], and the GreenShip Assessment standard"[3]. For these purposes, many schools are working to minimize carbon production (CF [4], [5], or a sustainable university design [6], [7] for a green campus. Universities are having a hard time controlling their energy consumption to meet Energy Efficiency Index (EEI) and Climate Action Tracker (CAT) standards. The additional facilities required to compete in college-level athletics increase energy consumption and carbon pollution [8].

Two of the article's sources are limited—programs offered by the G20, which look at per-capita carbon emissions. According to the Indonesian National Standard (SNI), which refers to commercial buildings, Indonesia's carbon emissions will reach 3.1 MTCO2e per capita by 2030 [11]. The specified value is much higher than this value.

Siliwangi University, which has been in operation since 1980, is eager to implement the green campus concept in its academic location. The campus electrical energy consumption must be addressed with many scenarios. The electricity consumption profile data is used to conduct the data analysis. This article aims to manage power consumption using a load growth strategy in which each year's electricity consumption is limited. The reduction of EEI [13]–[15] will be affected by this restriction. Simultaneously, the carbon emissions on campus are examined using the UI Green Metric [1] method, which incorporates variables such as the total number of vehicles and the level of vehicle activities.

A. *Research about carbon footprint (CF) at colleges*

Various causes of carbon emissions in universities include excessive energy use, operational transformations in the campus environment, procurement of building materials, infrastructure and other equipment, water usage, waste, and food. The carbon emission unit (kg.CO_2 / kWh) results from calculating electricity usage (kWh) and the carbon factor. The carbon emissions caused by electricity consumption are determined as some references have the Green House Gas (GHG) emissions as shown in Table I.

Table I. Electricity-related GHG standards

GHG Emission ($kgCO_2e/kWh$)	References
0.3972	DEFRA (Department for Environment, Food, and RuralAffairs Gov. UK) Minenergia, 2017 [1].
0.5610	TC Common data [2].
0.220	Red Eléctrica Española/Spanish Electrical Grid (REE) [3].
0.84	http://carbonfootprint.org [4]

A significant portion of scientists concurs that the emissions-reduction strategy on campus is essential. That is why the energy management strategy is supposed to overcome entropy rather than create it. Some researchers have suggested a number of methods to reduce the CF on campus, including the use of renewable energy [20], [21],

[22], building materials [4], [16], [5], [10] a combination of renewable energy, water, and waste management [16], [15], transportation [4], [16], and water and waste management [16]. Ravindran et al. have reported that student transportation on campus is a significant contributor to carbon emissions [19]. The other article by Li et al. reported that the average student produces 3.84 TCO2 with daily activities accounting for 65%, transportation accounting for 20%, and academic activities contributing 15% [23]. We could also significantly reduce the carbon emissions here on campus by limiting electricity consumption and controlling transportation activity. This effort means improving energy use performance on campus [24]. According to prior studies, many researchers believe that electricity consumption is the leading cause of carbon emissions on campus (Table II). Still, some researchers have found convincingly that the activities from the vehicle were the most effective in carbon emissions on campus, even though others have shown that other sectors are to blame [25].

TABLE II. DISCREPANCIES IN UNIVERSITY-WIDE OF THE FACTOR FOR CARBON EMISSION.

Author (Country)	Method	Occupation CE production ($tCO2e$)/person	Main cause of CE
[5] (Spain)	ISO 14064	0.31 tCO2e 2.69tCO2e	1. Direct energy use 2. mobility
[6] (Mexico)	GHG	1.46 tCO2e	Transportasi and Car
[7] (Spain, México, USA, Norway)	GHG	1.0 tCO2e	1. Student commuting (excluding institution bus) 2. Electricity consumption 3. Student commuting including institution bus 4. staft commuting
[8] (China)	Novel methodology based on survey	3.84 tCO2e	1. 65% form Daily life activities 2. 20% from transportation 3. 15% from academic activities
[9] (South Africa)	GHG	4.0 tCO2e	1. 56.59% Electric used 2. 13.94% Staff and student commuting
[10] (USA)	GHG	9.6 tCO2e (Faculty of Medicine), 4.2 tCO2e (Faculty of Science), 1.7 tCO2e (Faculty of Architecture), 0.7 tCO2e (faculty of Economy)	1. 19% from Energy 2. 19% from building 3. 19% from equipment 4. 16% from transportation

B. Energy Efficiency Index (EEI)

Energy use-related performance indicator (KPI) Consequently, EEI may be referred to as the Building Energy Index (BEI) [30] or the Energy Performance Index (EPI) [31]. According to [32], EEI, or energy input ratio, is the proportion of the energy-using component's energy input to the total energy input. One of the factors related to energy performance is the number of parts, including: (1) the amount of product made, (2) the number of items produced, (3) the weight of raw materials used, (4) the amount of time it takes to produce the item, (5) the amount of time the manufacturing facility is used, (6) the number of patients who stay in a hospital overnight, (7) the number of occupied rooms in a hotel at night, and (8) the building's floor space [33], [32]. The electrical load of buildings, including heating, ventilation, and air-conditioning systems (HVAC) [34], lighting [30], can cause a structure to sway. If the EEI is determined based on the land area ratio, the EEI is an essential factor. Adjusting Equation (1) to (2) yields annual energy consumption (kWh/y) EC and building floor area A. (m^2).

$$EEI = \frac{Energy\ Input\ (kWh)}{Factor\ related\ to\ the\ energy\ using\ component} \quad (1)$$

$$EEI = \frac{EC}{A} \quad (2)$$

The EEI standard is also used as the ASEAN-USAID standard, the GBCI standard, and SNI, ESDM Standard, with code SNI 03-6197-2000 [9] and others. SNI 03-6196-2000 standards recommends a 240 kWh/m^2/year commercial building power consumption, while the residential power consumption is 300 kWh/m^2/year. Shopping centers are required to consume 330 kWh/m^2/year. For ease of understanding, the EEI level is broken down into six categories for spaces with HVACs. Regarding rooms without HVAC, Table III shows that four efficiency levels exist according to building utility, such areas with HVAC [35] and building areas without HVAC [36].

TABLE III. CATEGORY OF EEI

Category	Area building with HVAC ($kWh/m^2/y$) [35]	Area building without HVAC ($kWh/m^2/y$)[36]
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

C. Load management on campus

A strong strategy for managing load needs commitment from policymakers, an appropriate approach from policy implementers, and the right resources from the energy audit team. A balance of energy consumption, low carbon emission, the population in campus, and campus ecosystems can be maintained by having a management plan for the load. The key to boosting the efficiency of sustainable energy use is practical to load management. Energy diversification and energy conservation are the two primary focus studies of load management. Governmental policies (such as making houses more energy-efficient, reducing lighting loads, improving HVAC systems, replacing motors, and using intelligent home automation systems) can reduce demand. At the same time, management strategies while waste-to-energy generation, high electrical conductivity, wind energy, solar energy, pumped hydro, energy storage systems, and thermal storage are management practices [37] can increase supply. Various researchers have proposed two types of load management strategies, direct and indirect, [12]. Interruptible tariffs, load curtailment programs, and load control are direct load management strategies. The indirect approach to business includes things like pricing programs, rebates, subsidies, and education courses. Implementing the BMS in the buildings provides a 14% increase in campus electricity consumption efficiency [38]. A real-time energy monitoring system [13] can help to optimize electrical energy consumption by allowing for campus HVAC optimization [39] or optimization electrical load management [40], [41]. Some researchers propose solutions such as energy diversification [42], [43] with a technological approach to monitoring electrical energy consumption [44].

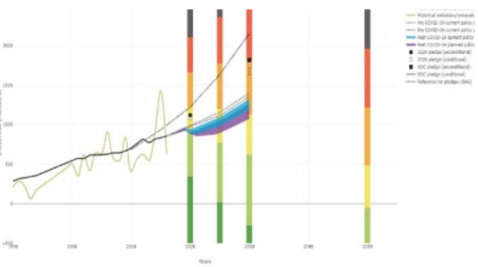

Fig. 1. The carbon emissions scenarios in Indonesia between 1990 and 2019 [8].

II. Materials and Methods

A. Conditions at the Campus of Siliwangi University

Located in West Java, Siliwangi University (UNSIL) is one of the largest universities in Indonesia. The air conditioner is functioning correctly, and the room's temperature is in the range of 28-32 Celcius, and the humidity is 68%. On-campus, UNSIL is still green. It can be seen causes as the remnants of many forests, grass, and plant. The following UNSIL Building area consists of 14 buildings totaling 32,929 square meters in building area, a total area of 316,000 square meters, and eight faculties (Fig. 2). Around 12,671 students migrate annually. Every year, 157,684 vehicles are registered, and 2 million units total is available with parking on a surface area of 4,000 m^2. According to UNSIL data from 2015-2019, electricity consumption seems to be rising by either 2 MWh or 11 percent per year. There are three types of loads that consume the most electricity: HVAC, laboratory facilities, and elevators. Fig.3 shows the percentage of electricity consumption by type of load in the range of 2015 to 2019. It appears that there are three buildings with a percentage of electricity consumption above 50%, namely public facilities 26%, rectorate building 15%, and engineering faculty 11%.

B. Scenario

This article advocates approval, which comprises four elements: setting, objective, dramatis personae, and premise. Policy-1 features a 10% annual decline in energy use, Policy-2 decreases consumption by 20%, Policy-3 limits annual increase in energy use to 30% and Policy-4 reduces electricity consumption by 30% per year. There will be three value levels for each scenario we outlined: optimistic, moderate, and pessimistic.

The Total carbon emission from electricity usage (MT) was defined by Equation (3). Emission from electrical usage by Equation (4). Emission from bus activities by Equation (5). Emission from car activities by Equation (6). Emission from motorcycle activities by Equation (7). On-campus, the total number of shuttle buses is the total number of buses running. To estimate total carbon emissions produced by bus activities yearly. The following variables must be calculated: the total number of daily bus trips (km), the number of working days per year, and the emission coefficient of 0.01. There are three parameters used to calculate the carbon emission in MT per 100 km. The Total cars on campus, "L" (car track length within the campus), and working days per year, and the emission coefficient is 0.02.

$$\sum EC_{(Total)} = \sum EC_{(EL)} + \sum EC_{(bus)} + \sum EC_{(car)} + \sum EC_{(mtr)} \quad (3)$$

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

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

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

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

Fig. 2. Maps of Siliwangi University Building [11]

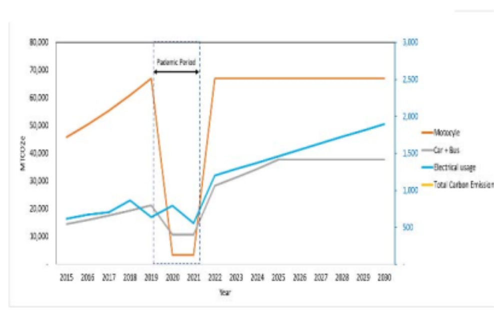

Fig.4. The population estimates for students, vehicles, and motorbikes at Siliwangi University in 2015-2030 [11].

III. Results and Discussions

A. Predicting energy usage

Fig.4 shows the prediction of electricity consumption from 2022 to 2030. It appears that based on the characteristics of electricity consumption from 2015 to 2021, there is a significant decline starting in 2019 to 2021. This decline is due to the COVID-19 pandemic, which began in early 2019. So that activity on campus is terminated temporarily. In addition, visits by employees, staff, and lecturers in the office are reduced by up to 50%. The COVID-19 pandemic has resulted in 30%-50% of electricity usage.

Despite the decline from 2019 to 2021, we assume that the decline is temporary, and we are optimistic that in 2022 lecture activities will return to normal. Therefore, in 2022, electricity consumption is predicted to return to its pre-COVID-19 characteristics in 2017 and 2018. The energy consumption forecasting in Siliwangi University has been calculated by 1 Equation (8). Electricity consumption predictions show that average energy consumption will increase by 5% annually between 2022 to 2030, with Fig.4 rising to 1,573,717 kWh in 2030. Equipment like HVAC installed in each class, along with things like photocopying machines and a lab's ability to handle larger tasks, is partly why this growth rate can be high. The energy consumption profile can be represented numerically as Equation (8).

$$Y = 5846.5566\,(x) - 10948923.5392 \qquad (8)$$

B. Analysis of carbon emission forecasting

Emissions of carbon are caused by Siliwangi University campus electricity, motor vehicle use, and vehicle travel. The carbon emission growth rate was predicted to increase by 8.8% annually, and this increase means that in 2030, the carbon emission will reach a maximum point of 106,708 MTCO^{2}e/year. It is determined by Equation (4).

Fig.5 demonstrates the progression of emissions caused by the vehicle activities on the campus, such as buses, cars, motorcycles, and the consumption of electricity. The motor vehicle carbon emissions on the campus were calculated by equation (7), and another hand, the carbon emissions from the motor in 2030 will reach 67,032 MTCO2e, increasing by 3.25% per year. The carbon emission from the bus was calculated by Equation (5), the carbon emissions from the car were calculated by Equation (6), the carbon emission from the motorcycle was calculated by Equation (7). The accumulation of carbon emissions from cars, motorcycles, buses, and electricity use is shown in Fig 7. Motorbikes have predicted will produce 37,781 MTCO^{2}e of carbon emissions in 2030. (Fig 7). A total of 38,820 MTCO2e from automobiles and 0.926MTCO2e from buses are emitted. While bus activities on campus had a 14.7% increase in emissions each year, car activity increased only 9.4% annually. The data in Fig 7 shows a growing trend of car and bus emissions due to their increased activity on campus. However, the primary source of carbon emissions is due to numerous motorbike trips. According to Fig 7, the total carbon emissions are projected to be 1,460MTCO2e in 2030, and the population will remain at 13,500 people (Fig 5). Per capita, the emissions of carbon in 2030 are 0.108MTCO2e. The annual average emission rate for the year in question still has a long way to go before it even gets close to the upper limit set by World Bank or CAT standards in the same year.

Based on the emissions from three sources, including electricity, car use, bus, and motorbike activity, certain conclusions can be drawn about the campus environment. A whopping 67% of carbon emissions come from motor activities each year from 2015 to 2030. The activities of cars and buses each contribute 32%, and electricity usage is only 1.4%. According to these findings, a 1.1-kilometer expansion and 2.2 percent growth, each year has a significant environmental impact.

C. Energy Efficiency Index (EEI)

For student and worker comfort purposes, Siliwangi University has been consistently using of HVACs. Because it is in a tropical country, air conditioning is required to benefit students and staff. HVAC's electricity consumption is up 37% from Fig 3 in 2017, with the rate continuing to increase. We outline four scenarios (Fig.6) before we predict using a linear approach (Fig.4). Then we used Equations (1) and (2) for EEI analysis. We have categorized the result based on Table 3, with the boundaries of the four scenarios in Fig 9. We found that in the area where HVAC systems are in use, the electricity consumption per square meter per month is between 16 kWh and 26 kWh. This electric consumption can be divided into three categories, including "extremely efficient," "slightly efficient," and "extremely efficient," as seen in Table III such as in Fig 10.

Fig.7 and Fig 11 show the IEE index predictions based on four scenarios, namely (1) BAU (business as usual) scenario, (2) 10% scenario (10% reduction per year), (3) 20% scenario (20% reduction per year), years), (4) 30% scenario (30% reduction per year). Each scenario consists of three predictions, namely pessimistic, moderate. Several predictions of the IEE index in a space with HVAC are shown in Fig 10. Based on the performance characteristics of energy use from 2015 to 2021, the IEE category only fulfills four categories: the inefficient category, the slightly inefficient category, the slightly efficient category, and the efficient one category.

In the BAU strategy, it appears that the IEE index in 2022 – 2030 has increased significantly so that the optimal value is 19.78 kWh/m^2/y and the optimistic value is 21.7 kWh/m^2/y or is included in the inefficient category. The strategy of reducing electricity consumption by 10% to 20% every year can only produce up to the slightly inefficient category. Reducing electrical energy consumption by 30% per year is necessary to get these results in the slightly efficient category. Based on Fig 10, the IEE index from 2022 to 2030 has increased 0.8% per year because some electrical equipment such as HVAC has decreased performance. This increase in the IEE index causes the performance of electricity usage to be categorized as inefficient or even highly inefficient. The solution to overcome this decrease in the performance of the use of electrical energy can be avoided with a routine replacement and maintenance program for the HVAC unit.

Fig 11 shows the characteristics of the IEE index in the area without HVAC. The BAU scenario and a decrease of 10% per year will lead the IEE index to the inefficient category. Therefore, we recommend that energy management be carried out so that there is a decrease of 20% per year.

The solution to this goal is to create energy conservation programs in areas without HVAC, such as adding windows so that natural light sources can illuminate areas inside the building optimally throughout the day.

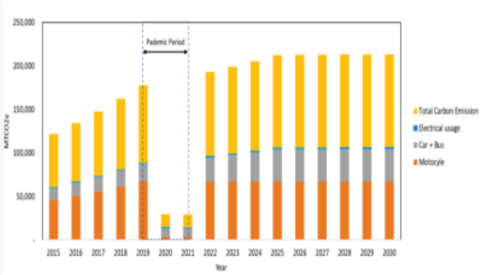

Fig.5. Carbon emissions from electricity use

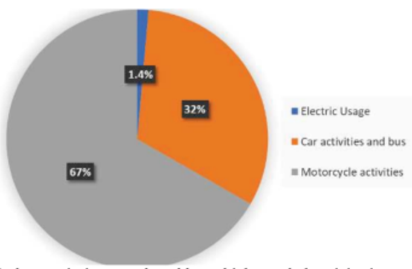

Fig.6. Carbon emissions produced by vehicles and electricity in a year (MTCO2/year)

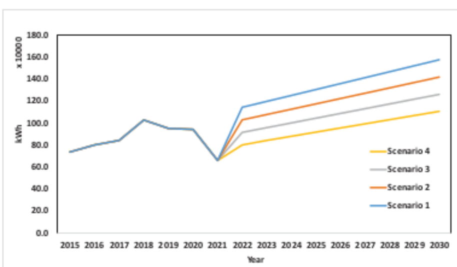

Fig.7. Electrical consumption forecasting with different scenarios (kWh/y)

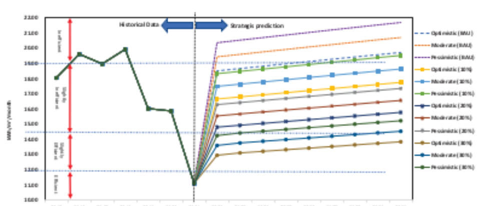

Fig.8. The HVAC area's EEI-based scenario classification

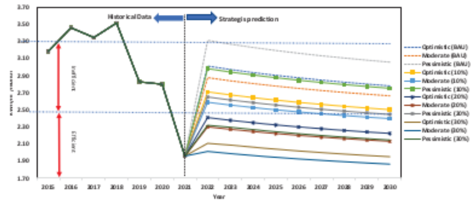

Fig.9. EEI standard scenario classification for those without HVAC systems

IV. Conclusions

It is essential to set a high priority on a green campus. This result gives us confidence in saying that Siliwangi University must achieve a green campus by 2030. The World Bank has also had a hand in controlling carbon emission production, with our successful implementation of EEI category for energy performance index based on CAT standards. The data we've gathered from our field studies indicates that Siliwangi University is trending toward a 2030 scenario with 8% per year in annual electric consumption and 8.8% per year in annual carbon emission growth. Motorcycles contribute 66 percent of the total carbon emissions, while automobiles are responsible for 33 percent and electricity 1.4 percent. The amount of carbon emissions that will be produced in 2030 is estimated to be 0.108MTCO2e/capita. The predicted value was 3.4 MTCO2e/capita, while the value predicted by the World Bank was 0.108 MTCO2e/capita. The electricity usage of the HVAC system adheres to EEI standards and meets three categories. The most reasonable scenario to implement, with a 10 percent % annual increase in electricity load, is Scenario-2. The final result provides a remedy only for two of the categories of electricity use when there is no HVAC system. None of the four options available are applicable, so a higher target scenario is needed.

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