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Carbon Footprint Analysis in UNNES Sekaran Campus Environment as Energy Conservation Data

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ABSTRACT

The UNNES Sekaran Campus is the center of UNNES academic and non-academic activities, with the number of academicians increasing yearly. That will impact increasing activities and carbon footprints from academic and non-academic activities that use electricity, LPG, or fuel. Only now are two faculties at the UNNES Sekaran Campus whose carbon footprints have been studied using the IPCC and tier 1 methods. This study will analyze the carbon footprint of energy use in each faculty using the IPCC method with tiers 1 and 2. This study will also develop strategies to conserve energy at the UNNES Sekaran Campus. In this study, GHG emissions using the IPCC tier 1 and 2 methods were 1853,742 tons of CO_2 equivalent and 1697.86 tons of CO_2 equivalent, respectively. Energy conservation strategies that can be implemented at the UNNES Sekaran Campus include collaborating with relevant stakeholders, optimizing clean energy production, improving the technical capabilities of the academic community in green technology, conducting energy audits on each activity unit and building, and developing an independent electricity system.

Keywords: *carbon footprint, IPCC, UNNES, energy conservation strategy.*

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1. INTRODUCTION

Greenhouse gases (GHG) have increased significantly in the atmosphere in the last 150 years (Khambali, 2019). Conventional energy is still used for various human activities, which is the leading cause of this (Ellabban et al., 2014). Countries worldwide continue to make various efforts to reduce GHG emissions in every sector of their activities. The carbon footprint is substantial because it can determine the amount of carbon used and serve as a basis for formulating efforts to reduce GHG emissions (Pandey et al., 2010).

Indonesia continues to encourage activities in every sector to have low GHG emissions, including education (Lee et al., 2018; Parker, 2018). Many educational institutions in Indonesia still need to carry out a comprehensive carbon footprint calculation to determine the contribution of academic and non-academic activities to the amount of GHG emissions released due to these activities. Universitas Negeri Semarang

(UNNES) is one of the educational institutions that still needs to carry out a comprehensive carbon footprint calculation in academic and non-academic activities.

UNNES has several campuses spread across various regions, one of which is in Sekaran Village. The Sekaran Campus is the centre of UNNES academic and non-academic activities, so the number of academicians and activities is more significant than campuses in other regions (Sub Direktorat Konservasi UNNES, 2023). That will impact the level of consumption, and GHG emissions from energy consumption on this campus will be more significant. Only now have two faculties calculated their carbon footprints: the Faculty of Engineering by Sagala et al. (2017) and the Faculty of Mathematics and Natural Sciences by Rahayuningsih et al. (2021). Both studies used the IPCC method with accuracy (tier) 1 to calculate GHG emissions from electricity, LPG, and fuel consumption. In calculating emissions from electricity consumption, both researchers compared the total building area. That allows for a significant difference in GHG emission values compared to actual conditions. The study also involved paper use and waste disposal to calculate the carbon footprint. However, these activities contribute less than 1% to the equivalent CO2 produced.

The carbon footprint in the university environment has been carried out using various methods, activity limits, and energy. The IPCC method is a method commonly used to calculate the carbon footprint in the university environment because the calculation can be adjusted to the available data (Robinson et al., 2018; Yanez et al., 2020). If we refer to the results of the carbon footprint with the IPCC method in the research of Negoro et al. (2021), Kasman et al. (2020), Sagala et al. (2017), and Azizah et al. (2017), it can be seen that activities with significant contributions to GHG emissions are only activities that use electricity, LPG, and fuel. Previous researchers only used tier 1 in studying carbon footprints in the university environment, even though a higher tier will produce GHG emissions with more accurate values. In addition, the data needed to calculate the carbon footprint using the IPCC tier 2 method can be accessed from relevant national institutions or agencies. Based on the explanation above, this study will study the carbon footprint of electricity, LPG, and fuel consumption in each faculty at the UNNES Sekaran Campus and formulate strategies to conserve energy.

2. METHODS

Sampling

The sample in this study will be given a questionnaire to determine the level of understanding and application of the academic community regarding energy conservation at the UNNES Sekaran Campus. In addition, the questionnaire will obtain information related to the use of fuel in motorized vehicles from the academic community's domicile to the UNNES Sekaran Campus.

The researcher determined the sample using the proportionate stratified sampling technique with the number of samples using the Slovin method.

$$n = N/(1+(N*e))$$

Explanation :

n = Sample size

N= Population size

e = Error rate (5%)

The number of samples determined using the Slovin method is shown in Table 1.

Table 1. Population Unit and Sample

No	Population Unit	Sample
1	Faculty of Education and Psychology	44
2	Faculty of Languages and Arts	53
3	Faculty of Social Sciences and Government	40
4	Faculty of Mathematics and Natural Sciences	46
5	Faculty of Engineering	56
6	Faculty of Sports Science	24
7	Faculty of Business Economics	61
8	Faculty of Law	31
9	Lecturers and Education Staff	36
	Total	397

Carbon Footprint Calculation

The researcher will use data on electricity and LPG energy consumption in each faculty building and the fuel used by motorized vehicles in the academic community. According to **Table 2**, the researcher uses several techniques to collect data in this study.

Table 2. Energy Consumption Data Collection Techniques

Energy	Data Collection Techniques
Electricity	Observation
LPG	Observation & Questionnaire
BBM	Questionnaire

The equation used to calculate GHG emissions from energy consumption is shown in **Table 3**.

Table 3. Equation to Calculate Emission GHG

Energy	Equation		
	CO_2	**CH_4**	**N_2O**
Electricity	$(F_{lis}*K)*Fe$	$(F_{lis}*K)*Fe$	$(F_{lis}*K)*Fe$
BBM	$(F_{bbm}*\rho*NCV_{bbm}*10^{-6})*Fe$	$(F_{bbm}*NCV_{bbm}*\rho)*Fe*10^{-9}$	$(F_{bbm}*NCV_{bbm}*\rho)*Fe*10^{-9}$
LPG	$(F_{LPG}*NCV_{LPG})*Fe$	$(F_{LPG}*NCV_{LPG})*Fe$	$(F_{LPG}*NCV_{LPG})*Fe$

Where :

F_{lis}	Electricity consumption (kWh)
F_{bbm}	Gasoline consumption (liter)
F_{LPG}	LPG consumption (kg)
K	Conversion (0.0000036 TJ/kWh)
NCV_{bbm}	Net Calorivic Value of Gasoline (TJ/Gg)
NCV_{LPG}	Net Calorivic Value of LPG (TJ/kg)
ρ	Density of gasoline (kg BBM/m^3)

Tier 1 and 2 will use the same equation in calculating GHG emissions, namely the one in **Table 3**. This is because the method used in this study is method 1, so there is no difference in the equation for calculating GHG emissions.

Energy Conservation Strategy

The researcher will also provide a questionnaire to the head of the Conservation Sub Directorate, the head of the General and Human Resources Directorate, and the electrical technician coordinator at the UNNES Sekaran Campus to obtain some information on aspects of strengths, weaknesses, opportunities, and challenges in carrying out energy conservation. The questionnaire that the academic community fills out will be processed by the researcher into the formulation of an energy conservation strategy. In formulating the strategy, the researcher will use a SWOT analysis.

3. RESULT AND DISCUSSION

Carbon Footprint

Electrical energy produces more significant GHG emissions than LPG and BBM. In the GHG emission mix from the three energy sources, electricity contributes more than 90% to GHG emissions, both from tier 1 and 2 calculations (**Figure 1**).

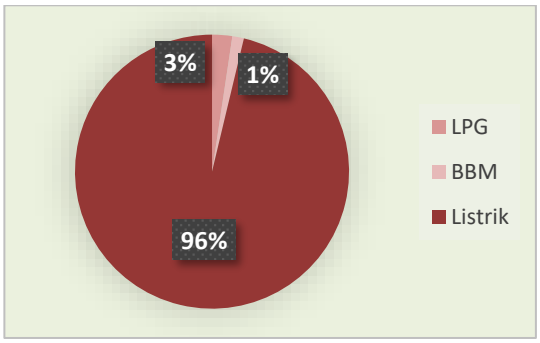


Figure 1. GHG Emission from Energy Consumption on the UNNES Sekaran Campus

That indicates that the number of academic and non-academic activities using electrical energy is more significant than other energy sources.

1. Electricity Consumption Emission

Electricity, the energy with the most significant GHG emissions, is used in every room in each faculty. The GHG emission value from electricity consumption from tier 1 and 2 calculations is 1785.85 tons of CO_2 equivalent and 1630.79 tons of CO_2 equivalent, respectively. The contribution of each faculty to electricity consumption and the GHG emissions it produces is shown in **Figure 2** and **Figure 3**.

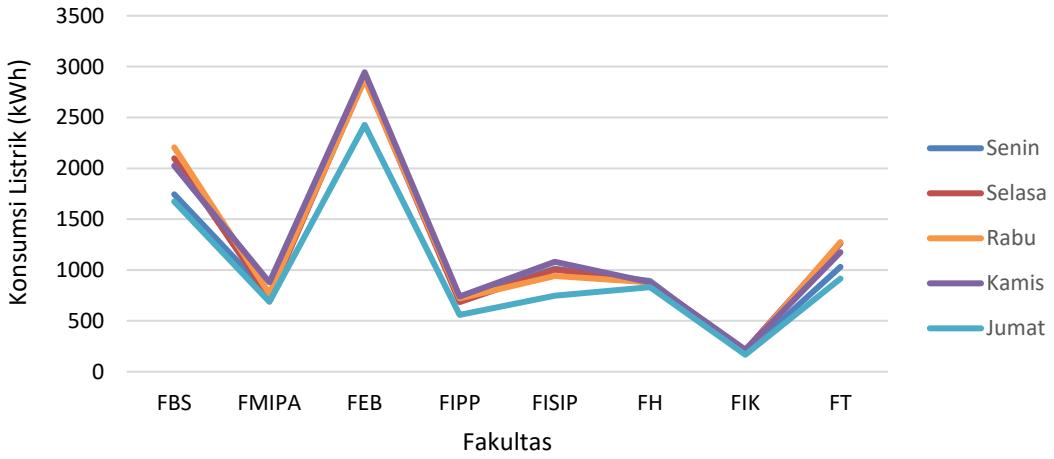


Figure 2. Daily Electricity Consumption in Each Faculty

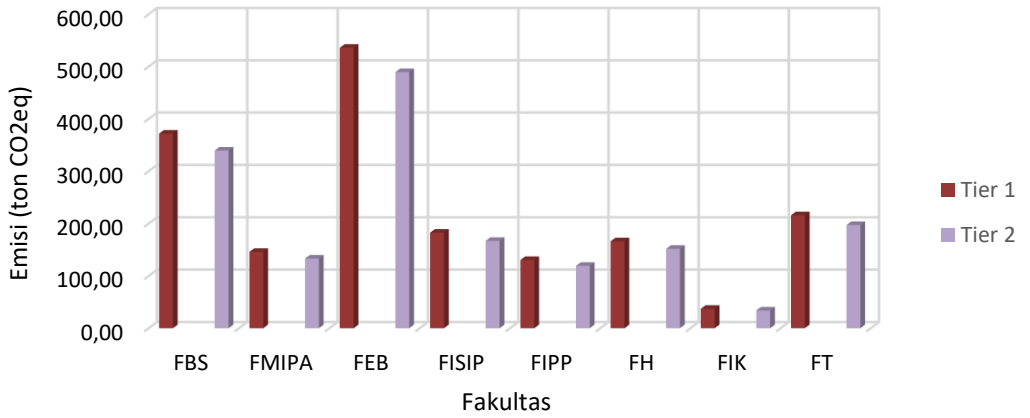
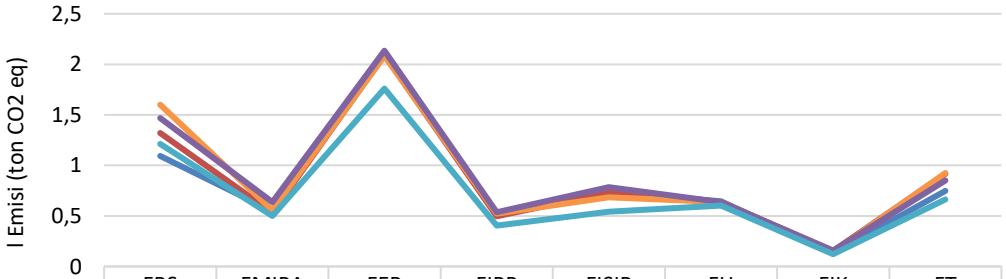


Figure 3. Daily Electricity Consumption Emissions in Each Faculty

The Faculty of Economics and Business is the most significant contributor to electricity consumption and GHG emissions. Although the number of buildings actively operating in the faculty is only four units, there are relatively more electronic devices in each room than in other faculties. In addition, there is an air conditioner in the form of a cassette AC in the lecture rooms of buildings L3 and L4. ACs of this type will consume three times more electricity than the type of AC commonly found, such as split wall ACs. The Faculty of Sports Science has the most minor GHG emissions from electricity

consumption compared to other faculties. Electronic devices in FIK lecture rooms generally only include fans, room lights, and TVs. On the other hand, most lecture rooms in other faculties are equipped with air conditioning and sound systems.

The buildings in each faculty have different schedules. However, researchers found that Thursday had the highest number of electronic device usage compared to other days. That certainly impacts the amount of GHG emissions on Thursday, which will be greater than other days (**Figure 4**).



	FBS	FMIPA	FEB	FIPP	FISIP	FH	FIK	FT
Senin	1,093	0,548	2,116	0,519	0,733	0.001	0.000	0.001
Selasa	1,321	0,531	2,093	0,496	0,729	0.001	0.000	0.001
Rabu	1,599	0,555	2,083	0,523	0,684	0.001	0.000	0.001
Kamis	1,469	0,638	2,135	0,537	0,784	0.001	0.000	0.001
Jumat	1,213	0,499	1,76	0,405	0,543	0.001	0.000	0.001

Figure 4. Total Emissions from Electricity Consumption in Each Faculty Based on Day

GHG emissions from electricity consumption are dominated by CO_2 gas, which contributes more than 95% to the gas mix in the carbon footprint of electricity consumption (**Figure 5**).

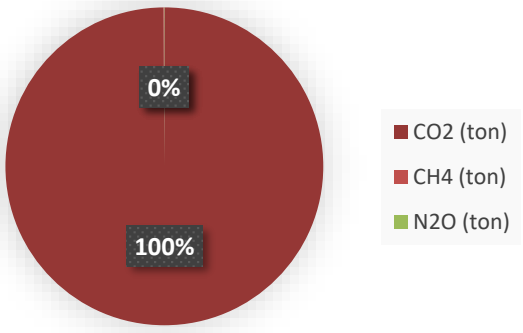


Figure 5. Gas Contribution to Electricity Consumption Emission

That is because the emission factor value of CO_2 gas is significantly different from that of CH_4 and N_2O gas. Thus, the GHG emissions produced will be more significant for CO_2 gas.

2. LPG Consumption Emission

LPG at the UNNES Sekaran Campus is used for cooking activities, both for academic and non-academic purposes. LPG consumption emissions in each faculty and

the rectorate canteen from tier 1 and 2 are 44.06889 tons of CO_2 equivalent and 44.06887 tons of CO_2 equivalent, respectively (**Figure 6**).

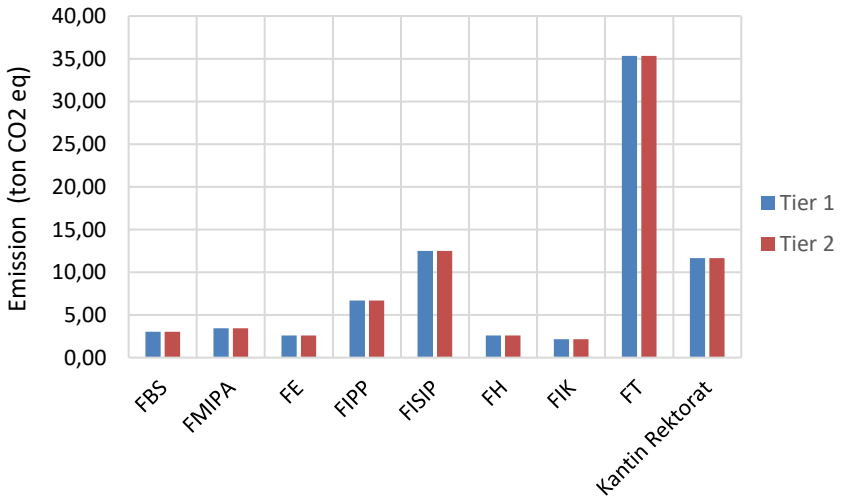


Figure 6. LPG Consumption Emissions on UNNES Sekaran Campus

The Faculty of Engineering produces more GHG emissions from LPG consumption than other faculties. That is due to academic activities in the Family Welfare Education Department, which also uses LPG for student cooking practicums. In addition, the department also receives orders for food, drinks, and snacks from outside parties. The PKK Department's contribution to the amount of LPG consumption in FT is 83%. There are also several canteen kiosks on campus. Based on this, LPG consumption and emissions produced in the faculty are more significant than in other faculties. FIK has the lowest GHG emission value in LPG consumption. There are not as many kiosks and buying and selling transactions as other faculties, so GHG emissions from LPG use are also low.

GHG emissions at tier 1 and 2 have an insignificant difference in value. The LPG emission factors published by the IPCC and the Ministry of Energy and Mineral Resources have values that are not much different, so they also have an impact on the final results of the GHG emission calculations, which are not significantly different.

3. Gasoline Consumption Emission

Fuel consumption emissions in motorized vehicles of the academic community with tier 1 and 2, respectively, are 25,329 tons of CO_2 equivalent and 24,460 tons of CO_2 equivalent (Figure 7).

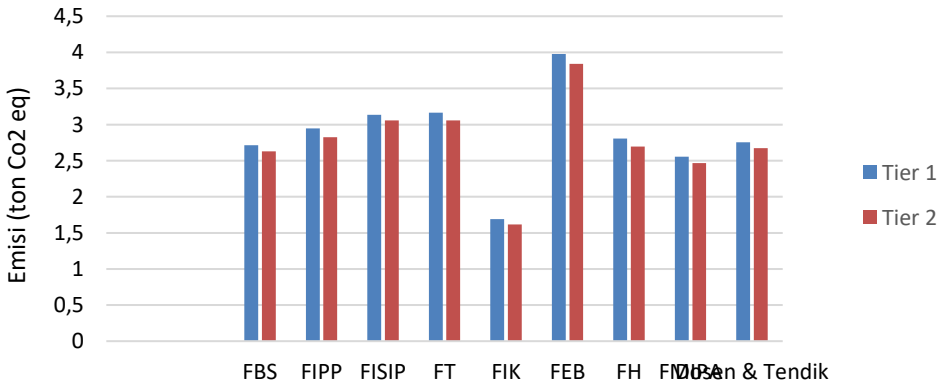


Figure 7. Emissions of Motor Vehicle Fuel Consumption on the UNNES Sekaran Campus

Motorbikes with pertalite-type fuel are the vehicles and types of fuel that contribute significantly to equivalent CO_2 emissions from fuel consumption (**Figures 8** & **9**).

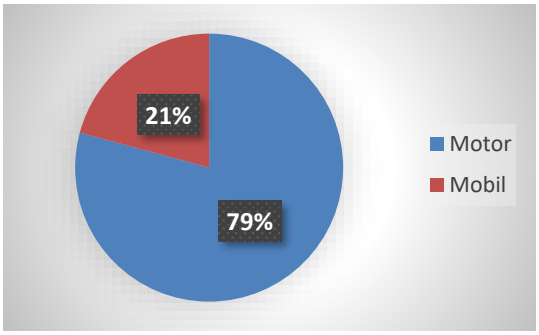


Figure 8. Emission Contribution Based on Type of Motor Vehicles on the UNNES Sekaran Campus

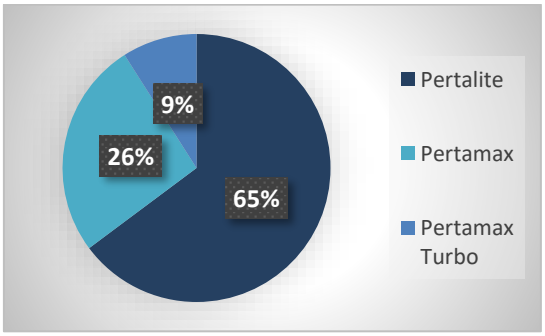


Figure 9. Emission Contribution Based on Fuel Type at the UNNES Sekaran Campus

The number of respondents in this study can affect the value of GHG emissions from fuel consumption. Faculty of Sport Science evidences that the number of respondents with the least amount of GHG emissions is the lowest amount compared to other faculties. Faculty of Economics and Business has a higher equivalent CO2 emission value than other faculties in this study. That is due to the number of FEB students who use sports-type motorbikes or have high cubic centimeters (CC) more than students from other faculties go to the UNNES Sekaran Campus. In addition, several students also use cars to go to the UNNES Sekaran Campus.

Energy Conservation Strategy

Researchers will process the questionnaires that respondents have filled out to formulate energy conservation strategies at the UNNES Sekaran Campus. The questionnaire results will become issues researchers map based on internal and external factors. These issues can be seen in **Figure 10**.

Internal	Eksternal
Kekuatan	**Peluang**
1. Pihak pimpinan mendukung dan berkomitmen terhadap pilar konservasi	1. Dukungan pemerintah terhadap upaya penurunan emisi GRK
2. Civitas akademik memahami komitmen dan program pelestarian SDAL yang dilakukan oleh UNNES	2. Teknologi hijau yang semakin berkembang dan dapat diterapkan di Kampus UNNES Sekaran
3. Slogan "Saving Energy" sering digaungkan oleh tenaga pendidik ketika melakukan KBM	3. Terbuka atas kolaborasi maupun pendaan dengan pihak eksternal
4. Pihak universitas sering mengadakan kegiatan pelatihan atau awareness terkait konservasi energi	4. Turut berpartisipasi dalam pemeringkatan kampus hijau tingkat internasional
5. Jumlah produksi energi bersih terus meningkat setiap tahunnya	5. Memiliki mitra kerja sama yang mampu meningkatkan kemampuan civitas akademik untuk konservasi energi
Kelemahan	**Ancaman**
1. Kesadaran civitas akademik yang relatif rendah untuk mematikan alat elektronik setelah digunakan	1. Biaya inverstasi penerapan teknologi hijau yang relatif mahal
2. Perbedaan SOP cleaning service di setiap fakultas	2. Prioritas pendanaan dari pihak eksternal untuk pembangunan fisik
3. Belum ada penelitian mengenai jumlah optimal pencahayaan dan pendingin di ruang perkuliahan maupun perkantoran UNNES	3. Ketidakpastian ekonomi yang dapat mempengaruhi anggaran untuk konservasi energi
4. Sistem listrik di Kampus UNNES Sekaran masih bersifat kawasan	4. Keterbatasan sumber pendanaan investasi (investor) untuk konservasi energi
5. Data mengenai penggunaan energi masih terbatas	5. Teknologi hijau memerlukan perawatan secara berkala

Figure 10. Identification of Internal and External Factor Issues

After mapping the issues to the appropriate factors, the next step is to determine the scores on the Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS) matrices using the equation developed by Nurmianto and Nasution (2004). That is to determine what factors are the advantages of the UNNES Sekaran Campus in carrying out energy conservation so that the strategies formulated will focus on these advantages. The IFAS and EFAS values based on each issue on internal and

external factors are 1.27 and 0.73, respectively. Based on these values, it can be seen that the IFAS and EFAS values are in Quadrant I of the SWOT matrix (**Figure 11**).

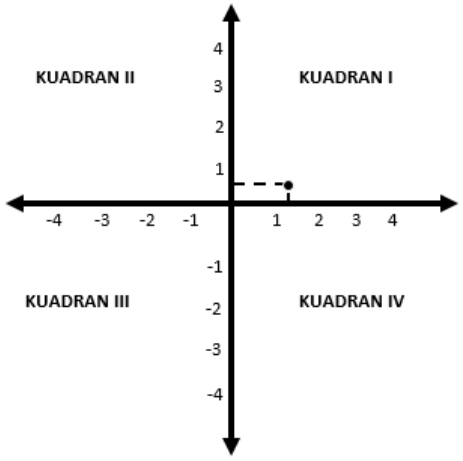


Figure 11. SWOT Quadran

Based on Figure 11, the IFAS value on the X-axis and the EFAS value on the Y-axis are in Quadrant I. This quadrant shows that the subject studied, the UNNES Sekaran Campus, has the strength and opportunity to formulate strategies related to energy conservation. The strategy formulated must support policies oriented towards aggressive growth or growth-oriented strategies. Researchers use strength and opportunity issues to formulate energy conservation strategies at the UNNES Sekaran Campus. The energy conservation strategy in this study can be seen in **Figure 12**.

FAKTOR INTERNAL	Kekuatan (S) 1. Pihak pimpinan mendukung dan berkomitmen terhadap pilar konservasi 2. Civitas akademik memahami komitmen dan program pelestarian SDAL yang dilakukan oleh UNNES 3. Slogan "Saving Energy" sering digaungkan oleh tenaga pendidik ketika melakukan KBM 4. Pihak universitas sering mengadakan kegiatan pelatihan atau awareness terkait konservasi energi 5. Jumlah produksi energi bersih terus meningkat setiap tahunnya	Kelemahan (W) 1. Kesadaran civitas akademik yang relatif rendah untuk mematikan alat elektronik setelah digunakan 2. Perbedaan SOP cleaning service di setiap fakultas 3. Belum ada penelitian mengenai jumlah optimal pencahayaan dan pendingin di ruang perkuliahan maupun perkantoran UNNES 4. Sistem listrik di Kampus Sekaran UNNES masih bersifat kawasan 5. Data mengenai penggunaan energi masih terbatas
FAKTOR EKSTERNAL	**RUMUSAN STRATEGI PENGEMBANGAN**	
Peluang (O) 1. Dukungan pemerintah terhadap upaya penurunan emisi GRK 2. Teknologi hijau yang semakin berkembang dan dapat diterapkan di Kampus Sekaran UNNES 3. Terbuka atas kolaborasi maupun pendaan dengan pihak eksternal 4. Turut berpartisipasi dalam pemeringkatan kampus hijau tingkat internasional 5. Memiliki mitra kerja sama yang mampu meningkatkan kemampuan dan kesadaran civitas akademik untuk konservasi energi	**Strategi S-O** 1. Berkolaborasi dengan pemerintah maupun stake holder setempat untuk pengadaan teknologi hijau di lingkungan Kampus Sekaran UNNES 2. Melakukan studi banding untuk memperoleh pengetahuan ataupun wawasan mengenai konservasi energi dengan perguruan tinggi lainnya 3. Meningkatkan kemampuan civitas akademik dalam konservasi energi melalui kegiatan pelatihan maupun riset dengan mitra 4. Membuat program atau kebijakan yang selaras dengan slogan "Saving Energy"	**Strategi W-O** 1. Memodifikasi alat elektronik yang terdapat di Kampus UNNES Sekaran agar dapat berada dalam mode "Mati" ketika sudah lama tidak digunakan dengan bantuan pihak eksternal 2. Melakukan kerja sama dengan PLN agar sistem kelistrikan di Kampus UNNES Sekaran dapat dikelola pada masing-masing gedung maupun fakultas 3. Melakukan audit dan desain energi yang optimal pada gedung perkuliahan maupun perkantoran di Kampus UNNES Sekaran
Ancaman (T) 1. Biaya inverstasi penerapan teknologi hijau yang relatif mahal 2. Prioritas pendanaan dari pihak eksternal untuk pembangunan fisik 3. Ketidakpastian ekonomi yang dapat mempengaruhi anggaran untuk konservasi energi 4. Keterbatasan sumber pendanaan investasi (investor) untuk konservasi energi 5. Teknologi hijau memerlukan perawatan secara berkala	**Strategi S-T** 1. Meningkatkan kerjasama dengan pihak eksternal untuk mendapatkan pendanaan maupun dukungan teknis pada penerapan teknologi hijau 2. Produksi energi bersih yang saat ini dimiliki untuk mengurangi ketergantungan terhadap energi konvesional 3. Menggunakan slogan "Saving Energy" yang sering digaungkan tendik sebagai platform untuk kolaborasi yang melibatkan civitas akademik dengan mitra industri teknologi hijau untuk proyek pilot di universitas	**Strategi W-T** 1. Mengalokasikan pendanaan konservasi energi untuk pelaksanaan audit energi dan mengembangkan sistem kelistrikan pada area kritis secara bertahap 2. Mengembangkan SOP Cleaning Servis pada setiap fakultas agar dapat melakukan efisiensi energi.

Figure 12. Energy Conservation Strategy on the UNNES Sekaran Campus

UNNES is a university based on conservation values. UNNES leadership, including the rector and his staff, supports and is committed to conservation values that are the basis for policy-making and actions. This is supported by UNNES milestones every five years, which include the study, implementation, preservation, and development of conservation values. These milestones are achieved by involving the UNNES academic community. To achieve these goals, human resources at UNNES must understand and develop skills in energy conservation (Wibowo et al., 2017).

UNNES has made various efforts to improve the understanding and skills of the academic community regarding energy conservation. Some of these efforts include collaborative activities with external parties (Phramesti & Yuliastuti, 2013). UNNES also conducts research to develop and implement renewable energy on campus and in the community. Based on the "Sustainability Report" published by the UNNES Conservation Sub-Directorate (2024), clean energy production in the UNNES Campus environment increases every year. With the commitment and efforts to conserve energy that continue to increase, UNNES has been in the top 10 in the UI Green Metric program since 2014. Based on this explanation, researchers have determined four strategies that combine aspects of UNNES' strengths and opportunities in energy conservation. However, the UNNES Sekaran Campus still has weaknesses that must be addressed to sustain energy conservation.

The increase in the number of academics at the UNNES Sekaran Campus each year can positively and negatively impact energy conservation efforts. The observation results show that the UNNES Sekaran Campus has yet to be able to optimize energy conservation through academics. That is reflected in the low awareness of the academic community about turning off electronic devices after use. Electricity, as the primary energy source, contributes significantly to total GHG emissions and expenditures. Therefore, an evaluation is needed based on the monitoring of electricity usage in each office building and faculty. The electrical system at the UNNES Sekaran Campus, which is still regional, makes monitoring difficult because the electricity consumption value on the meter is the total consumption value of office buildings and lectures on the west and east campuses. Data on other energy consumption is also limited. Generally, the available data only covers the amount or magnitude of energy consumption. Based on this, it is necessary to formulate a strategy utilizing the opportunity aspects owned by the UNNES Sekaran Campus. The researcher determined three strategies that combine the weaknesses and opportunities of the UNNES Sekaran Campus in carrying out energy conservation.

The UNNES Sekaran Campus faces threats in energy conservation, which are mostly related to the economy, such as expensive investment costs, economic uncertainty that affects the budget, and limited investors as a source of funding. Other universities in Indonesia also face the same economic issues in energy conservation (Buana et al., 2018; Muslih et al., 2022; Puspadi et al., 2016). Some universities do not even have policies based on environmental sustainability. Unlike other campuses, the UNNES Sekaran Campus's academic community understands energy conservation, which is supported by policies and increased competence from campus leaders (Wibowo et al., 2017). Educators often convey the importance of energy conservation to students. That is the advantage of the UNNES Sekaran Campus to minimize threats to energy conservation. With these advantages, UNNES Sekaran Campus can establish and improve cooperation with the government and stakeholders for technical support in applying green technology. UNNES Sekaran Campus can also conduct pilot projects on green technology with related industries. Collaboration with stakeholders in formulating

energy conservation strategies, according to the research results of Wimala et al. (2016), can minimize economic issues as a threat to energy conservation.

Researchers determine energy conservation strategies based on weaknesses and challenges at the UNNES Sekaran Campus. These include allocating funding for energy audits, developing electrical systems in critical areas in stages, and developing SOPs for cleaning services in each faculty for energy efficiency. Energy audits are needed to determine the level of energy efficiency at the UNNES Sekaran Campus. With an energy audit, activity units or buildings with the most significant energy consumption can be identified and become a priority for developing an independent electrical system. In addition, cleaning services in each faculty need to have SOPs that support energy conservation. Researchers found differences in cleaning service SOPs in managing rooms, such as the obligation for students to take and return room keys to use classrooms and the policy of turning on and off electronic devices by cleaning services according to the activity schedule.

4. CONCLUSIONS

Based on the result, the conclusion of this research is:

1. CO2 equivalent emissions from electricity, LPG, and gasoline consumption at UNNES Sekaran Campus with tier 1 and 2 respectively are 1785 tons CO2 eq, 43.42 tons CO2 eq, 25.32 tons CO2 eq; 1630 tons CO2 eq, 43.40 tons CO2 eq, 24.46 tons CO2 eq;
2. Strategies that can be used for energy conservation at the UNNES Sekaran Campus are as follows:
    a. Collaborating with the government and local stakeholders to procure green technology in the UNNES Sekaran Campus environment.
    b. Conducting comparative studies to gain knowledge or insight into energy conservation with other universities.
    c. Improving the ability of the academic community in energy conservation through training and research activities with partners.
    d. Creating programs or policies that are in line with the slogan "Saving Energy"

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