Implementation of walk-through audits for designing energy management system: A first step towards an efficient campus

Implementation of walk-through audits for designing energy management system: A first step towards an efficient campus

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Abstract. The purpose of this study is to design a concept of energy management control system (EMCS) at the UNSADA campus, Jakarta, Indonesia by utilizing the results of the previous walkthrough audit. EMCS is an important first step by involving all parties on campus to be concerned the sustainable energy savings. The energy efficiency program utilizes the campus as an energy laboratory to identify, recommend, implement and evaluate the energy consumption, so that the expected energy efficiency targeted by the top managements can be achieved. This program is motivated by several reasons, such as; to support government policies in reducing dependence on fossil energy by implementing energy conservation programs; as a reflection of compliance with the implementation of educational service buildings (including the campus in Jakarta); a vision as the efficient campus in energy consumption that has been determined by the campus management. To achieve these goals, there are four stages to be done; the preparation, the conducting audit, the audit analysis, and the recommendation for implementation. The results provide an overview of the opportunities to save the energy consumption and to develop EMCS by involving all stack-holders on campus.

Keyword: Energy concerns; energy load reduction, energy measurement; energy simulations, zero energy building.

1. Introduction

The building sector consumes approximately 40 % of the world's total energy [1]. This program is motivated by several reasons. First, to support government policies in reducing dependence on fossil energy by implementing energy conservation programs as stated in Government Regulation No.79/2014 [2] concerning National Energy Policy and Government Regulation No.70/2009 [3] concerning the energy conservation. Second, as a reflection of compliance with the implementation of educational service buildings (including the campus in Jakarta) to the Provincial Regulation No.7/2010 [4] concerning the buildings, and the Regulation of the Governor of Jakarta No.38/2012 [5] concerning the green building. Third, the vision of the green campus that has been determined by the campus management must be realized immediately by making the energy savings and renewable energy applications.

Based on regulations and recommendations from the government to carry out energy conservation programs, many campuses in Indonesia have conducted studies and energy saving activities. Prafitasiwi and Rohman [6] identified the social parameters in achieving energy efficiency in campus building using a quantitative approach. Machdijar *et al*. [7] found that the building envelope and the building direction are strongly influenced by solar radiation. Soegoto and Abioso [8] indicated that the building especially the basement area where the air circulation is quite good and a precise air fan on-off control system could reduce the cost of electricity from the continuous operating of exhaust fan and fresh air blower. Moelyaningrum and Ningrum [9] analysed the students' perception on environmental sustainability education, included the energy efficiency. Farhani and Supriyadi [10] have done the energy audit and energy consumption pattern in ITERA and proposed scheme for reducing energy consumption includes replacement for more energy efficient equipment and a better planning on people's. Mulyani *et al*. [11] have done the Energy Audit and design of Implementation of ISO 50001 based Energy Management System in Brawijaya University of Malang (UB), Indonesia and the results will be used as a reference for Best practices and energy efficiency efforts that are and will continue to be conducted by UB. Ikhsan and Saputra [12] conducted an energy audit process to calculate the use of electrical energy of a building on the campus of Teuku Umar University (UTU) Meulaboh, Indonesia then the results are compared with existing standards as a consideration of energy-saving solutions.

Setyowati *et al*. [13] analysed the concern and management of electrical energy on the UNNES (*Universitas Negeri Semarang,* Indonesia) campus with variable electricity consumption, energy-saving behaviour, concern for energy, and electricity management and the result to support one of the pillars of campus clean energy conservation. Ekasiwi *et al*. [14] examined the type of classroom, which perform comfortable lighting environment as well as saving energy by using field observation and measurements and results indicated that the factors influencing lighting energy performance in correlation to their typologies. Hamzah *et al*. [15] designed energy efficient and thermally comfortable air-conditioning system in university classrooms using respondent survey and thermal comfort simulation and recommended to set room temperature from 25 °C to a minimum of 26 °C for energy savings in the tropics area. Mujaahid *et al*. [16] reported the implementation of using energy efficient electronic devices to reduce the electricity consumption in Universitas Muhammadiyah Yogyakarta (UMY), Indonesia by replacing lighting and cooling system in all its rooms using energy saving devices would be able to reduce electricity consumption by 29.7 MW h. Tarigan [17] simulated the energy savings for a six-floor library building, University of Surabaya, Indonesia using the Excellence in Design for Greater Efficiency (EDGE) simulation software, resulted that 53 % of energy efficiency can be reached, without lowering of the building comfort, by applying of four measures at the same time are daylight photoelectric sensors for internal spaces (OFE29), radiant cooling and heating system (OFE16), higher thermal performance glass (OFE8), and external shading devices (OFE4).

Based on the literature reviews above, in general there has been a lot of research, auditing and energy saving activities carried out on college campuses in Indonesia. However, the focus of energy savings carried out is more perceptual and technical, such as; perceptions of thermal comfort in air-conditioned rooms, wasteful energy usage problems from air conditioning and lighting, energy saving opportunities through the replacement of more energy-efficient equipment, etc. Apparently, there are no studies relating to energy management control systems, which summarize all the focus of energy savings into an energy management system (EMCS). Therefore, the purpose of this paper is to design a concept of EMCS at the UNSADA campus, Jakarta, Indonesia by utilizing the results of a previous walkthrough audit. EMCS is an important first step at no cost by involving all parties on campus to be concerned about making sustainable energy savings. The results are expected to complement the energy saving studies that have been carried out on previous campuses.

2. Overview of the UNSADA building

Darma Persada University (abbreviated as UNSADA, http://www.unsada.ac.id) is a university located in Jakarta, Indonesia organized by the Melati Sakura Foundation under the auspices of the Indonesian-Japanese Friendship Association (PPIJ), as its Legal Entity. UNSADA was officially established on July 6, 1986, on the initiative and support of the Japan Alumni Association (PERSADA) organization in collaboration with the Indonesian-Japanese Friendship Association (PPIJ) organization, based on a charter of cooperation signed on February 17, 1986. Until now, UNSADA has held 15 (fifteen) study programs which are accommodated in four Faculties and one Postgraduate Program, namely; literature, economic, engineering, marine technology and renewable energy. UNSADA management has a great concern with the issues of energy and sustainability. As an educational institution that has several buildings, the topic of energy saving becomes one of the topics discussed in management meetings. Figure 1 shows the detailed buildings layout of UNSADA campus.

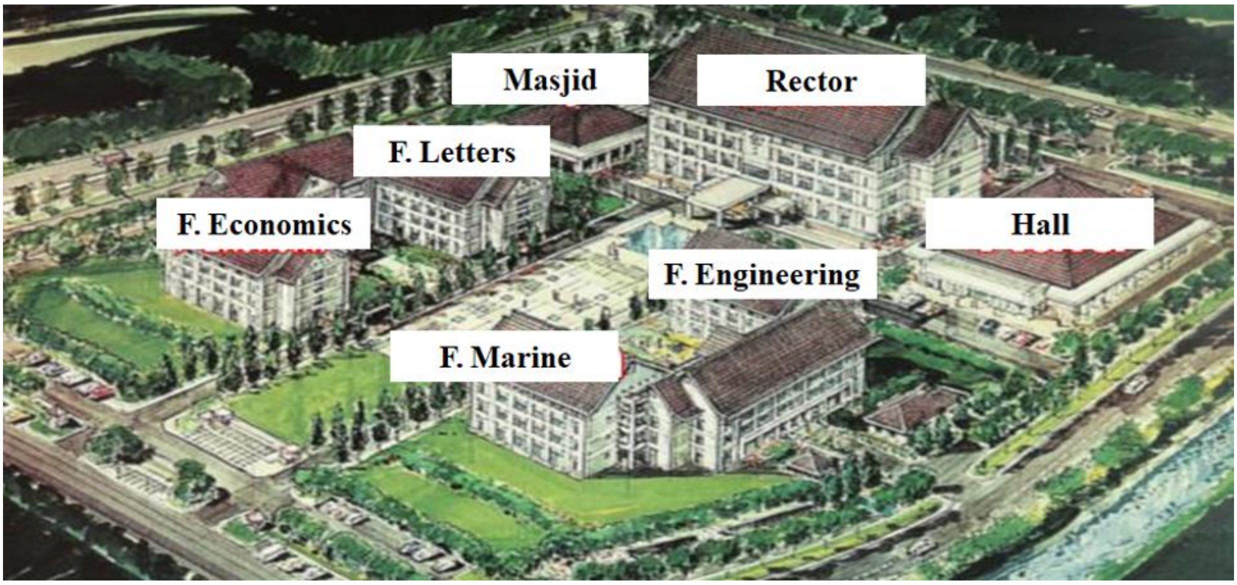


Figure 1. Buildings layout of UNSADA campus.

The detailed information related to the implementation of an energy audit for each building on the UNSADA campus can be seen in table 1.

Table 1. Detail summary of the buildings layout of UNSADA campus.

Functional Room	Rector		F. Economic		F. Letter		F. Engineering		F. Marine + RE	
	Room	*m²*	*Room*	*m²*	*Room*	*m²*	*Room*	*m²*	*Room*	*m²*
Management	5	346.5	4	220.5	1	94.5	1	189.0	3	315.0
Staff and admin	10	1 079	2	126.0	6	396.0	1	189.0	3	252.0
Lecture	11	567.0	25	1 323.0	16	1 044.0	9	567.0	17	1 039.5
Lab	-	-	3	189.0	4	346.5	10	819.0	6	585
Workshop / Test	-	-	2	94.0	1	63.0	3	94.0	-	-
Library	1	525.0	-	-	1	63.0	1	31.0	-	-
Student	-	-	2	94.5	2	94.5	6	189	1	94.5
Toilet	9	75.3	4	42.0	4	42.0	4	42.0	5	42.0
Warehouse	4	63	3	90	2	58.5	1	31.5	-	-
Total	**43**	**2 760.3**	**45**	**2 085.0**	**37**	**2 202.0**	**36**	**2 152.5**	**35**	**2 328.0**

The purpose of the energy audit in the UNSADA campus building is to get a detailed picture of the energy consumption profile for further analysis in energy savings. The purpose of this study is to explain the design of the energy management system of UNSADA, in order to become an efficient campus through the energy audit and energy efficiency program. The program is also expected to meet a minimum energy saving target that can be set by the management of UNSADA, as the effort to reduce energy costs. In addition, the program also utilizes the campus as an energy saving laboratory that is able to identify, recommend, implement and evaluate energy consumption, so that the expected energy efficiency targets are achieved. This program is expected to contribute to scientific publications, so this simple study and valuable experience can be shared with other campuses in Indonesia, even the world.

3. Materials and method

3.1 Materials

For safety reasons, students as auditors must use the safety equipment tailored to the object to be audited, such as; wear-pack, helmet, safety shoes, gloves, as shown in figure 2(a). To conduct the audit, the auditors were provided with several necessary audit tools, such as; measuring room temperature and humidity, measuring light intensity (Lux Meter), digital ampere meter, digital measurement, test-pen screwdriver, as shown in figure 2(b). For effectiveness in auditing, the auditor also prepares an audit form as shown in figure 2(c).

(a) (b)

Location				Lighting									Air Conditioner												Building Envelop				
				Lamp										Cooling		Air Load		Other Load				Beban Lain dan			OTTV			RTTV	
														Occupant		Ventilation / Infiltration		Air Conditioner Condition				Kondisi AC							
Room	No.	Floor	Area	Type	Quantity	Capacity	Switch condition	Lument	Spot observation	Start-up / Shut-down Procedure	Reflector	People in Charge	Room Temp. / RH	People	Activity	Ventilation	Infiltration	Kapasitas	Quantity	Temp. Setting	Maintenance	Componet condition	Prosedur start-up/ shut Down	People in Charge	Wall Insulation	Wall Condition	Painting Condition	Ceiling Condition	Top Insulation

SAMPLE

(c)

Figure 2. Materials required, a) Safety material procedures; b) Audit tools; c) Audit checklist (sample).

3.2 Methods

To achieve these goals, there are four steps to be done. First is the preparation, consisting of lecturing (audit energy system, certification, saving calculation, etc.), briefing/preparation (instrumentation, campus layout, energy bill, campus tour, area scope, group, role, task, schedule, etc.), auditing (cooling, lighting, behaviour, current classroom management, etc.), final presentation (finding of losses and opportunities, recommendations how to save, base measurement).

Second is the conducting audit, which consists of a walk-through audit, data collection on monthly energy consumption, monthly energy bills, layout of each building, etc. The energy savings for individual unit can be calculated by formula:

$$\boldsymbol{E_{S,u} = (C_{ue,b} - C_{ue,c}) * P_F} \quad (1)$$

where, $E_{S,u}$ is the energy cost saved (IDR), $C_{ue,b}$ is the previously energy consumed (kW h), $C_{ue,c}$ is the currently energy consumed (kW h), and C_F is the cost factor (IDR per kW h). Both $C_{ue,b}$ and $C_{ue,c}$ are calculated;

$$\boldsymbol{C_{ue,b} = W_{ue,b} * H_b} \quad (2)$$

$$\boldsymbol{C_{ue,c} = W_{ue,c} * H_c} \quad (3)$$

where, $W_{ue,b}$ and $W_{ue,c}$ are the previously and currently power capacity of energy unit (W), respectively. While, H_b and H_c are the previously and currently duration of energy unit (h), respectively. Then, the total energy saved $E_{S,tot}$ for n units can be expressed as:

$$\boldsymbol{E_{S,tot} = \sum_{i=1}^{n} E_{S,u-i}} \quad (4)$$

Third is the audit analysis, consisting of analysing all audit findings, analysing consumption data and the layout of each building, especially air conditioning and lighting. Calculation of potential savings must refer to comfort standards, both lighting and AC. Fourth is the recommendation for implementation, consisting of getting commitment from campus management, signed commitment from the management, implementation/action (TRNSYS building simulation, cooling load reduction, start-up/shut-down procedure, improved classroom management, energy awareness training and campaign, meter reading), evaluation (data collection, base to actual energy consumption, weekly energy report to management, energy system and behaviour audit).

4. Result and discussion

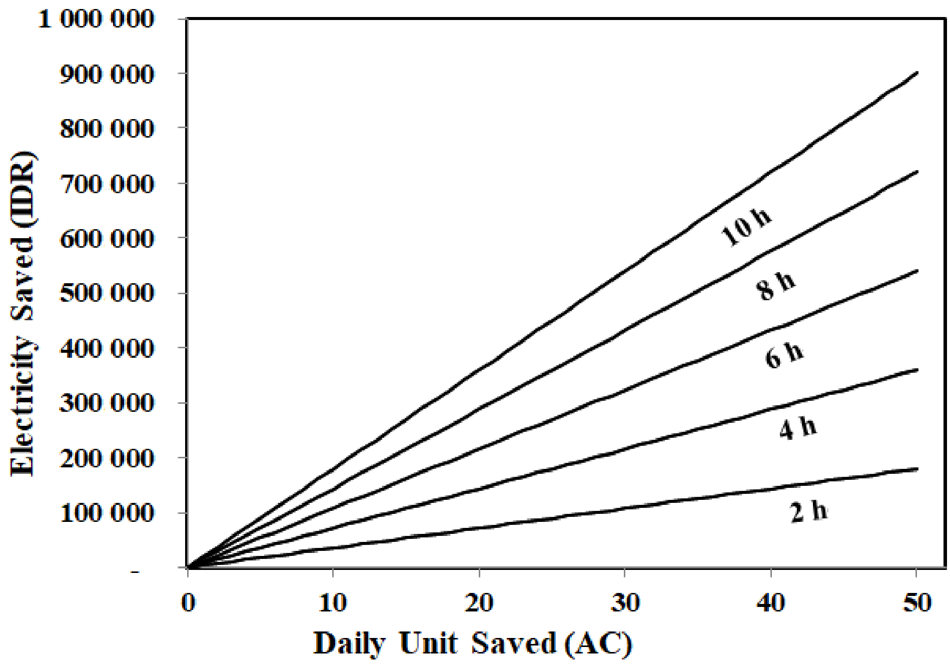
4.1. Findings and recommendations

Table 2 shows the summary of audit findings from all buildings included the recommendations, which focuses on air conditioner, lighting, and energy management. Based on the audit findings, there is a lot of potential for energy savings. For air conditioners, energy savings can be made by preventing waste, such as; the air conditioner lights up when the room is empty, the thermostat setting is at 16 °C, there are some old air conditioners, irregular AC service schedules, and some leaky windows. For lighting in several rooms, there are lights still on even though the room is empty, still using LHE lamps, some are still using the same switch, the position of the lamp is not quite right, daylight has not been used optimally. As for energy management, many system elements are incomplete and need to be developed.

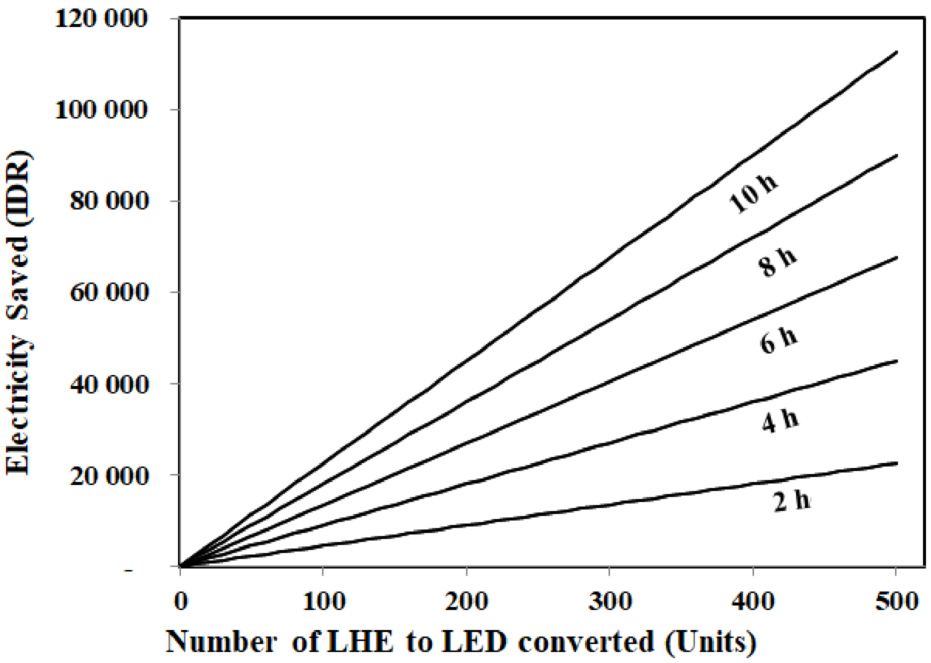
Figure 3 shows the simulation graph of daily saving for AC and lighting. Simulations carried out for 2 h, 4 h, 6 h, 8 h, 10 h. Energy savings calculations are using the Equation (1) to Equation (4). Here, assume C_F = IDR 1 500 per kW h. As seen, AC in figure 3(a) has a greater savings potential than lighting in figure 3(b).

Table 2. Summary of general findings and recommendation from audit results.

Item	General Findings	Recommendations
Air Conditioner	1. In the empty room, the air conditioning is still on.	Install switch sensor
	2. The thermostat is set at 16 °C.	Commit to the thermal comfort
	3. There are some old air conditioners.	Replace with the new and higher efficiency.
	4. Irregular service schedule.	Keep the maintenance schedule properly.
	5. There are some leakage windows.	Fix the leakage.
Lighting	6. In the empty room, some lamps are still on.	Install switch sensor
	7. Still using LHE lamps.	Change to LED lamps.
	8. There are still using common switch.	Change and adjust to the needs.
	9. There are still improper lamp placements.	Re-arrange the lamp placements.
	10. Daylight has not been used optimally for lighting.	Adjustment of window for incoming daylight.
Energy Management	11. There is no official energy saving goal yet.	Goal energy is rolled from top to bottom level.
	12. There are no regular energy meter readings.	There must be a regular energy meter reading.
	13. There is no energy base to measure energy savings.	Create energy base to measure savings properly.
	14. Energy savings have not been reported regularly.	Energy saving must be in the operational report.
	15. Class management is not oriented to energy savings.	Need to be simulated with energy savings



(a)



(b)

Figure 3. Simulation of daily energy saved, a) Saved by AC units; b) Saved by LHE to LED conversion.

4.2. Proposed energy management control system (EMCS)

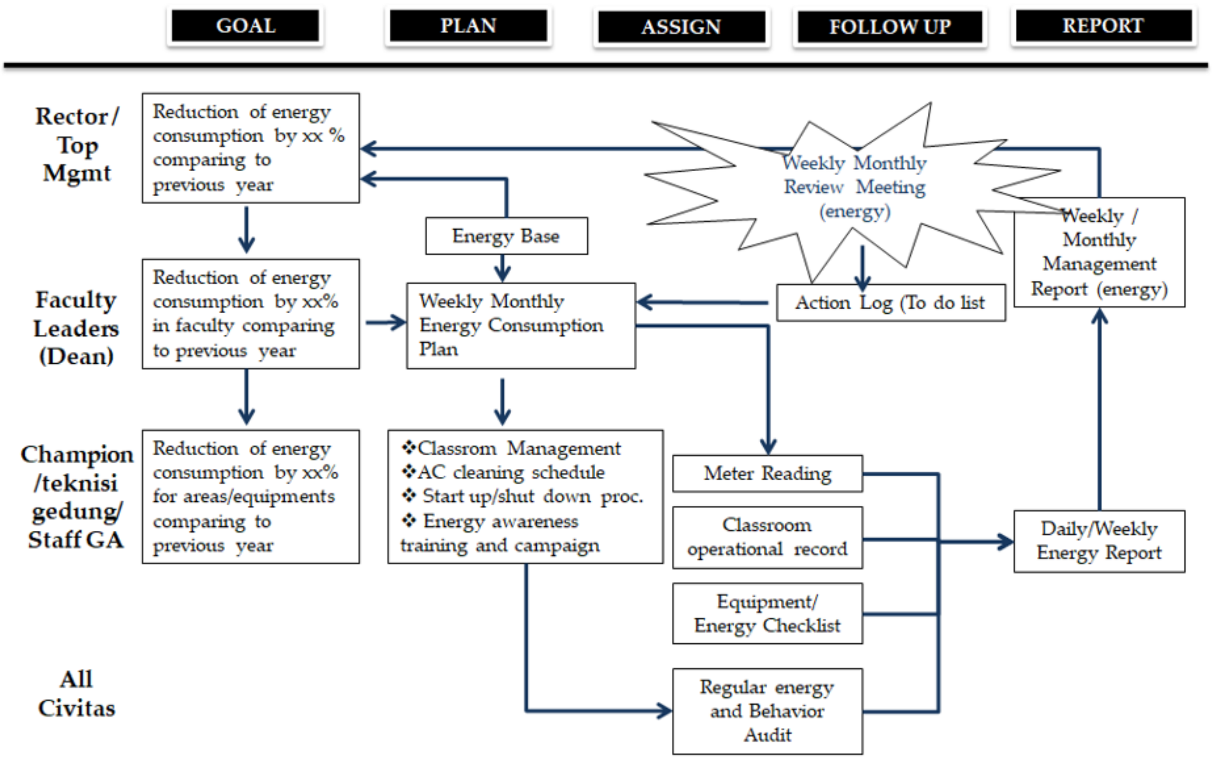


Figure 4. Proposed design of energy management control system (EMCS).

Based on the findings in table 2 and the simulation of savings opportunities in figure 3, in general the energy saving opportunities on the UNSADA campus can still be done. This is due to the lack of energy concerns as a lack of awareness due there is no the existed EMCS to achieve the expected energy savings. To realize as a Green Campus, EMCS needs to be developed seriously, involving all stakeholders in the campus. Figure 4 shows the proposed design of Energy Management Control System (EMCS), which is expected to realize sustainable savings, as one step to becoming a green campus. The detailed description for each element in the proposed design of energy management control system (EMCS) can be seen in table 3.

Table 3. Detailed description for each element in the proposed design of EMCS for each level.

System Element	System Control	Function	Responsible
University energy savings	Goal	Set and clear target	Rector
Faculty energy savings	Goal	Set and clear target	Dean
Area/department energy savings	Goal	Set and cler target	Leader/Spv
Energy base	Plan	Measurement/improvement	Rector/Dean
Regular energy meetings	Plan	Review and commitment	Dean
Classroom management	Plan	Scheduling	General Affair
AC cleaning schedule	Plan	Scheduling	General Affair
Startup and shutdown procedure	Plan	Scheduling	General Affair
Energy awareness training	Plan	Behaviour change	All civitas
Meter reading	Assignment	Data collection	Leader/Spv
Classroom operational record	Assignment	Data collection	Leader/Spv
Energy equipment checklist	Assignment	Activity Control	Leader/Spv
Regular behavior audit	Assignment	Perpetuation	Leader/Spv
Regular energy review meeting	Follow up	Review and action plan	Rector
Daily/weekly energy report	Report	Performance evaluation	Leader/Spv
Weekly/monthly mgmt. Report	Report	Performance evaluation	Dean

Energy consumption on campus is very dependent on the academic calendar from week to week, for example; lecture weeks, weeks before exams, semester exam weeks, and vacation weeks. For this reason, the energy saving calculation methods as base measurement of energy savings (BMES) as follows;

$$\boldsymbol{E_{S,tot} = (C_{retv,b} - C_{retv,c}) * V_{e,c} * P_F} \qquad (5)$$

where, $E_{S,tot}$ is the total energy cost saved (IDR), $C_{retv,b}$ is the previously ratio energy to volume consumed (kW h/unit), $C_{retv,c}$ is the currently ratio energy to volume consumed (kW h per unit), $V_{e,c}$ is the currently equivalent volume (unit), and P_F is the cost factor (IDR per kW h). For $C_{retv,b}$ and $C_{retv,c}$ expressed as:

$$\boldsymbol{C_{retv,b} = C_{ue,b}/V_{e,b}} \qquad (6)$$

$$\boldsymbol{C_{retv,c} = C_{ue,c}/V_{e,c}} \qquad (7)$$

where, $V_{e,b}$ is the previously equivalent volume (unit). Both $V_{e,b}$ and $V_{e,c}$ are calculated by equivalenting one volume unit to another volume unit into one equivalent volume unit, which is a representation of several volume units. Thus, $C_{retv,b}$, $C_{retv,c}$, and V_e are important elements that must be clearly identified from the beginning with the primary key on $V_{e,b}$ or $V_{e,c}$. P_F is a cost factor calculated from all cost components in electricity billing, not the price set by the government P_g. Then:

$$\boldsymbol{P_F > P_g} \qquad (8)$$

As shown in figure 4, the energy saving goal $G_{e,s}$ is calculated from $C_{retv,c}$:

$$\boldsymbol{G_{e,s} = (\bar{C}_{retv,b} - C_{min,retv,b})/\bar{C}_{retv,b}} \tag{9}$$

where, $\bar{C}_{retv,b}$ and $C_{min,retv,b}$ are the average and minimum of $C_{retv,b}$ during the BMES period. As seen in Equation (9), making BMES requires a more complete and more detailed data period with clear reference to the volume parameters, so that changes in savings can be properly monitored and analysed for further improvement actions. For further studies, Author reviewing the development of BMES with volume parameters, such as more detailed room usage hours for lectures in a particular semester period. This is influenced by several factors, such as; the number of lectures, the number of students and credits taken by students, etc. As an educational institution, universities need not only carry out energy saving programs, but also exploration of renewable energy [18], as support from the local government level in realizing energy security nationally [19]. Universities can directly give examples to the public how to utilize renewable energy, such as solar energy. The electrical and thermal energy needs on campus can be easily supplied by the Photovoltaic and Thermal (PVT) collector, which converts solar energy into electrical energy and thermal energy [20, 21].

5. Conclusion

To realize the government's recommendations and concern for energy savings, Author have taken the first step with a walk-through energy audit. As a result, there are many energy saving opportunities that can be done, especially electricity, only by focusing on the use of air conditioners and lighting. Energy savings from AC can be done by controlling the usage time and operating temperature. Although lighting savings are not as big as the savings from air conditioners, this is easily done by replacing the type of existing lighting with LEDs that are low in energy consumption. For the initial, inexpensive and easy step, EMCS development must be carried out to involve all parties on campus in caring energy and achieving the expected savings. As a measurement of sustainable energy savings, BMES must be developed properly so that all energy saving activities can be monitored and analysed for further improvement.

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