A Case Study: The Potential of Energy Efficiency in Senior High School of Semarang Regency, Central Java, Indonesia

Ana Yustika[1,*], *P* Purwanto[2], and *H* Hermawan[3]

[1]Master Program of Environmental Science, School of Postgraduate Studies, Diponegoro University, Semarang - Indonesia
[2]Chemical Engineering Department, Faculty of Engineering, Diponegoro University, Semarang – Indonesia
[3]Electrical Engineering Department, Faculty of Engineering, Diponegoro University, Semarang – Indonesia

Abstract. The increasing of energy supply trend in Indonesia seems to be a serious problem in the implementation of sustainable development. This study case research aimed to determine the potential of energy efficiency in school environment. The subject of this research was SMA N 1 Ambarawa, located on Semarang Regency of Central Java, Indonesia. The data collection was done by used documentation, observation and interview method. The results showed that the average of electrical energy consumption in this school reached 11022.008 kWh/month, which resulted in the emergence of secondary emissions of CO_2 by 9644.257 kg CO_2/month. Overall, the consumption of electrical energy in this school was very efficient, with an Intensity of Energy Consumption (IEC) average 1.7957 kWh/m^2/month. In this case, the implementation of short-term no cost, long-term no cost, middle-cost, short-term high cost and long-term high-cost recommendation could save electricity energy sequent by 3.159%; 7.536%; 9.499%; 35.278% - 36.626%; and 42.084%. In conclusion, the school environment had a big potential of energy efficiency that could reduce the energy consumption and CO_2 gas emissions.

1 Introduction

Energy was one of the key factors to increase the economic growth level in a region [1]. Therefore, energy efficiency became one of the great programs that were currently developed by many countries in the world to support the implementation of sustainable development [2]. According to the Indonesian Law Number 32 of 2009 [3], the Indonesian Government also participated in implementing of efficiency energy. There were three pillars of sustainable development was be targeted in implementation of energy efficiency program were economic, social, and environmental aspect [4].

The high population growth significantly gave impact in energy consumption [5]. Impact of this, people would always demand an increase of energy supply to fulfill the economic and social needs [6]. In accordance with this, the trend of electrical energy supply in Indonesia showed an increase of 8.85% per year [7], with the largest percentage of electric energy source was from Steam Power Plant. The used of coal continuously as a primary energy source of Steam Power Plant caused the depletion of the coal quantity as one of the non-renewable natural resources on earth [8]. In addition, the use of coal for electric energy also caused of CO_2 emissions as the main cause of global warming phenomenon [9]. However, in reality, the burning activity of fossil fuel still happened every day in every country in the world [10]. Therefore, it should be emphasized the importance of improving energy efficiency in Indonesia to fulfill the economic and social needs of society, but without harm the environment [11]. In this case, the government was demanded to make a policy as soon as possible to reduce the amount of CO_2 emissions produced in the region [12].

The construction sector was expected to have a significant impact on implementation of energy efficiency program [13]. About of 42 percent of energy supply in the world was used for operational building [14]. Therefore, the Indonesian government also adopts a policy of energy efficiency in this sector. One of them is through by Adiwiyata program for school environment which expected being ‘Adiwiyata school’ or ‘green school’.

Adiwiyata program has already begun since 2006 as a form of cooperation between the Ministry of Environment and The Education & Culture Department in Indonesia. As a result, in year 2006-2011, only 272 of the total 251,415 schools in Indonesia that successfully received a predicate as Adiwiyata School (MoE, 2012). This number indicates that the Adiwiyata program is still difficult to be implemented, so the stakeholders in 2013 revised the guidelines for the implementation of Adiwiyata program which contained in the Minister of Environment Rule Number 05 of 2013. However, it seems that the guidelines not bring significant impact in increase the number of Adiwiyata school. This is

* Corresponding author : anayustika13@gmail.com

because the guidelines not completed with the ways that can be done to determine the potential of energy efficiency which is owned by school. Based on this, this study was specifically conducted to investigate the potential of the energy efficiency in school environment.

2 Materials & Methods

This research was a study case, which aimed to determine the potential of energy efficiency in school environment. As for the high school which used as the research subject was SMA N 1 Ambarawa, located in Semarang Regency, Central Java. The data collection was done by using documentation, observation and interview method. Data analysis was done by test the statistic hypothesis by using t-test analysis [15] and SWOT analysis [16].

Planning strategy is needed to determine the steps which to be taken by a person or an agency to achieve the goal. In this case, SWOT analysis was done to determine the appropriate recommendation to improve the potential of energy efficiency in SMA N 1 Ambarawa. There are four key words in a SWOT analysis, which Strengths, Weakness, Opportunities, and Threats. Then, it can be formulated in SWOT matrix consist of four kinds planning strategies are S-O, W-O, S-T, and W-T.

In addition, data analysis was also done by calculating the Intensity of Energy Consumption (IEC), which referred to SNI 03-6196-2000 [17] and calculated the amount of secondary emissions of CO_2 which arose from the use of electrical energy in school which noticed the emissions produced by Steam Power Plant with used.

The formula calculation of CO_2 emission [18] :

$$CO_2 \text{ emission} = \Sigma A_i \times EF \quad \text{(i)}$$

With :

ΣA_i = amount of electricity consumed (kWh)

EF_i = emission factor of electricity in Central Java, Indonesia (0.857 kg CO_2/kWh)

3 Results & Discussion

3.1 Energy consumption

Electrical energy is the primary energy source used in SMA N 1 Ambarawa to support the learning activities. With an area of 6138 m^2 and the number of people in school was 1100 persons, the average of electrical energy consumption was 11022.008 kWh/month. The electricity consumption in SMA N 1 Ambarawa during past year can be seen in Table 1.

Table 1. Electricity consumption

No	Month – Year	The Number of Effective Days	Energy Subsidies from the Government (50%) (IDR)	Electricity Consumption (kWh)
1	Jan-2015	24	5,278,656	11730.35
2	Feb-2015	23	5,410,748	12023.88
3	March-2015	25	5,361,994	11915.54
4	April-2015	25	5,449,562	12110.14
5	May-15	23	5,397,015	11993.37
6	June-2015	14	3,469,587	7710.19
7	July-2015	8	3,014,779	6699.51
8	Aug-2015	26	5,086,717	11303.82
9	Sept-2015	25	5,357,083	11904.63
10	Oct-2015	27	5,459,791	12132.87
11	Nov-2015	25	5,500,139	12222.53
12	Dec-2015	17	3,774,551	8387.89
13	Jan-2016	24	5,458,071	12129.05
14	Feb-2016	24	5,419,960	12044.36

Over the past year, the highest electricity consumption amounted to 12129.047 kWh which occured in November 2015, while the lowest power consumption of 6699.509 kWh which occurred in July 2015.

Table 2. Light intensity & air temperature on each room

No	Room	Result			Standard			
		Air Temperature (°C)	Light Intensity (Lux)	Temperature Color	Air Temperature (°C) Minister of Health	Light Intensity (Lux) SNI	Light Intensity (Lux) Minister of Health	Temperature Color SNI
1	Class Room	27.5	277	Cool white	18 - 28	250	200-300	Cool white/Day light
2	Teacher Room	28.3	291	Cool white	18 - 28	-	200-300	-
3	Counseling Room	27.5	256	Cool white	18 - 28	-	200-300	-
4	UKS Room	27.6	234	Cool white	18 - 28	-	200-300	-
5	Around the Stairs	28.8	134	Cool white	-	-	100	-
6	Laboratory Room	23.7	503	Cool white	18 - 28	500	200-300	Cool white/Day light
7	Library Room	27.9	327	Cool white	18 - 28	300	200-300	Cool white/Day light
8	Canteen	30.3	319	Cool white	-	200	100	Warm white/Cool white
9	Toilet	26.6	114	Warm White	18 - 28	-	100	-
10	Praying Room	28.3	138	Cool white	18 - 28	-	100	-

The result of t-test indicated that there was no significant difference between electricity consumption in the odd semester and the second semester. This result consistent research result which showed that there is no difference in power consumption between the odd semester and the second semester on Semarang State Polytechnic [19]. This was because the effective number of days in each semester was relatively same. Meanwhile, there were significant differences between

the electricity consumption on the months in early and mid-term semester than the other months at the end of semester. This was because there were the end of semester holiday which caused the number of effective days at the end of semester to be less than the other months.

3.2 Lighting & air temperature

The procurement of air conditioner and lamps in the room according the light intensity and temperature of room that can be seen in Table 2. The light intensity and temperature color on each room in SMA N 1 Ambarawa accordance with SNI 03-6197-2000 [20] about energy conservation lighting systems of buildings in Indonesia and also the Minister of Health of Republic of Indonesia Decision Number 1429/Men.Kes/SK/XII/2006 [21] about The Implementation Guidelines of Environmental Health School. The air temperature in each room, except the teacher's room and praying room was still considered normal based on the Minister of Health of Republic of Indonesia Decision Number 1405/Men.Kes/SK/XI/2002 [22] about the Environmental Health Work Requirements in the Office and Industrial. so no circulation of air tool which needed such as fan or air conditioner. Thus, the air conditioner in SMA N 1 Ambarawa only used in computer lab and language lab as temperature, humidity, and cleanliness control and also air circulation simultaneously because these rooms were always used in tightly closed [23].

3.3 Intensity of energy consumption

Calculation of Intensity of Energy Consumption (IEC) in SMA N 1 Ambarawa which conducted in accordance with SNI 03-6196-2000, the result showed that IEC average of 1.7957 kWh/m^2/month. In overall, building in SMA N 1 Ambarawa categorized as not air-conditioner building because the extent of it's less than 10% of the total area of building. Thus, based on the criteria in The Minister Energy & Mineral Resources Rule Number 13 of 2012 [24] which presented in Table 3, the electricity consumption in SMA N 1 Ambarawa classified as very efficient.

Table 4. Electricity consumption on each room

No	Room	Tipe of Building	Amount	Area (m^2)	Energy Consumption (kWh/month)	IEC	Criteria
1	Old Class Room	Non-AC	21	2217	1672.5	0.754397835	Very Efficient
2	New Class Room	Non-AC	9	950	900	0.947368421	Very Efficient
3	Cross-Interest Room	Non-AC	2	334	200	0.598802395	Very Efficient
4	Chemistry Laboratory	Non-AC	1	274	78.8	0.287591241	Very Efficient
5	Physic Laboratory	Non-AC	1	150	42.2	0.281333333	Very Efficient
6	Biology Laboratory	Non-AC	1	150	42.2	0.282666667	Very Efficient
7	Language Laboratory	Non-AC	1	120	51.6	0.43	Very Efficient
8	Computer Laboratory I	With-AC	1	150	2662.9	17.75266667	Quite Efficient
9	Computer Laboratory II	With-AC	1	120	2268.9	18.9075	Extravagant
10	Library	Non-AC	1	144	156.275	1.085243056	Very Efficient
11	Multipurpose Room/Hall	Non-AC	1	450	234	0.52	Very Efficient
12	UKS Room	Non-AC	1	16	8.4	0.525	Very Efficient
13	Cooperative Room	Non-AC	1	16	106.5	6.65625	Quite Efficient
14	Counseling Room	Non-AC	1	62	96.05	1.549193548	Very Efficient
15	Principal Room	Non-AC	1	40	164.795	4.119875	Efficient
16	Teacher Room	Non-AC	1	170	948	5.576470588	Efficient
17	Archive Room	Non-AC	1	30	507.4	16.91333333	Extravagant
18	Administration Room	Non-AC	1	48	380.71	7.931458333	Extravagant
19	Music Room	Non-AC	1	60	4.2	0.07	Very Efficient
20	OSIS Room	Non-AC	1	12	5	0.416666667	Very Efficient
21	Scout Room	Non-AC	1	12	5	0.416666667	Very Efficient
22	Principal Room's Toilet	Non-AC	1	8	16.8	2.1	Very Efficient
23	Teacher's Room Toilet	Non-AC	1	8	3	0.375	Very Efficient
24	Administration Office Toilet	Non-AC	1	8	3	0.375	Very Efficient
25	Counseling Office Toilet	Non-AC	1	8	3	0.375	Very Efficient
26	Boy Student Toilet	Non-AC	20	114	66	0.578947368	Very Efficient
27	Girl Student Toilet	Non-AC	20	114	66	0.578947368	Very Efficient
28	Warehouse	Non-AC	1	50	8.4	0.168	Very Efficient
29	Kitchen	Non-AC	1	21	15	0.714285714	Very Efficient
30	Praying Room/Chapel	Non-AC	1	120	101.4	0.845	Very Efficient
31	Canteen	Non-AC	6	156	28.95	0.185576923	Very Efficient
32	Security Post	Non-AC	1	6	0.375	0.0625	Very Efficient
33	(School Facility)	Non-AC	-	6138	1197	0.195	Very Efficient

Table 3. Criteria of Energy Used in Office Building

Criteria	Specific Energy Consumption (kWh/m^2/month)	
	AC Building	Non AC Building
Very efficient	Smaller than 8,5	Smaller than 3,4
Efficient	8,5 up to smaller than 14	3,4 up to smaller than 5,6
Quite Efficient	14 up to smaller than 18,5	5,6 up to smaller than 7,4
Extravagant	Bigger than with 18,5	Bigger than with 7,4

The used of electrical energy and IEC in each building in SMA N 1 Ambarawa was varies widely, it depended the kinds of electronic equipment in it. The amount of electricity consumption in any room in this school in detail can be seen in Table 4. The room which used the highest electrical energy was computer lab, while the room which used the lowest of electrical energy was security post. High and low consumption of electrical energy in any room was influenced by the type and amount of equipment, the electric power used on any equipment, also the long of equipment operation. Based on IEC, almost all of rooms in SMA N 1 Ambarawa were classified as very efficient. But, unfortunately, computer laboratory and cooperatives were quite efficient. The teachers' room and the principal's office room were relatively efficient. Meanwhile, the second computer lab, storage room, and administration room were classified as wasteful.

Computers, lamps, and air conditioner were top of equipment list that used the highest electrical energy. This was supported by the results which stated that the use of electrical energy by the servers, computers, monitors, data communication equipment, and cooling systems has increased sharply in each time [25]. Additionally, a study of energy efficiency of the world also focused on building lighting systems because they had a major role of energy consumption in the world [26].

Table 6. SWOT Matrix

Internal Factor / External Factor	*Strengths* : - Number of Human Resources - The school community responded towards energy consumption was very high - The curriculum used - Energy subsidy	*Weakness* : - Environmental leadership which not yet strong - Lack of the school community was related the energy saving - Electrical power was not used as consideration when bought equipment - School had not policy which completed with strict sanction about energy efficiency - School had not electricity network area
Opportunities : - The funding source from government - Big support from the Ministry of Environment and the Department of Education & Culture	S-O : - Doing some energy efficiency efforts based school community	W-O: - Replacing the extravagant equipment with the energy efficient equipment - Cooperating with relevant agencies - Adding tools to control energy saving. The tool can be in human or sensor form - Make electricity network plan
Threats : - The scarcity of energy - Degradation of Environmental quality - Carbon tax	S-T : - Include the energy efficiency principles in learning curriculum - Streamline the use of long the equipment use which uses electricity - Do checking and improvement towards network electricity that get problem	W-T : - School makes the proper policy energy efficiency - School doing socialization related the importance of saving energy - Using electric power as a material consideration when buying the equipment

3.4 Climate change impact

Consumption of electrical energy in SMA N 1 Ambarawa indirectly caused the secondary emissions of CO_2. This was because the electricity production process from Steam Power Plant results the CO_2 gas emissions were the cause of global warming [27]. During the past year, secondary emission of CO_2 which resulted from electricity consumption at the school reach by

135,019.603 kg of CO_2. The highest emission occurred in November 2015, which amount by 10694.715 kg of CO_2, while the lowest emission occurred in July 2015, which amount by 5862.070 kg CO_2. The average emissions were reached by 9644.257 kg CO_2/month. Thus, it is known that the school environment give substantial contribution to the global warming phenomenon.

3.5 Energy savings

SWOT analysis was done to determine the appropriate recommendation to improve the potential of energy efficiency in SMA N 1 Ambarawa. The SWOT matrix completely can be seen in Table 6.

Based on this, the recommendations which offered were divided into three levels; they were no-cost, middle-cost and high-cost. No-cost recommendation which offered was school should make some policies about energy efficiency. Beside of according the SWOT analysis result, the recommendations which offered was also based on research which stated that government in many countries was always make every effort to implement the various policies related to energy efficiency in their own region [28]. The calculation basis of energy saving opportunities was long usage of lamps, LCD and speakers by the school community. Based on the data in Table 5, no-cost recommendation was divided into two kinds that called as short-term no-cost recommendation and long-term no-cost recommendation. Short-term recommendation aimed to calculate the energy saving in the rooms were wasteful of energy, but long-term recommendation aimed to calculate the energy saving in overall of SMA N 1 Ambarawa. As a result, the electrical energy which can be saved with short-term no cost recommendation was reached 3.159% and long-term no cost recommendation was reached 7.536%.

Middle-cost recommendation which offered was the school should add a controller for efficient used of time for all equipment which uses electrical energy. The calculation basis of energy saving opportunities was long usage of lamps, LCD and speakers by the school community also the duration of using the wifi router and access point, and water pump. As a result, electrical energy that can be saved was reached by 9.499%.

High-cost recommendation which offered were replacing the equipment which were still using high electric power with efficient equipment. This recommendation was supported by the research result stated that the used of LED light and lighting sensor system installation was good energy efficiency [29]. Moreover, the LED lights were known to save energy as much as 70% of electrical energy. Additionally, the concept of green-computing was one of the principles which emphasize in the importance of minimization of energy consumption in computer system [30]. The calculation basis of energy saving opportunities was the replacement of equipment become energy efficient equipment. As a result, the electrical energy that can be saved with short-term high cost recommendation was reached 35.278% - 36.626% and long-term high cost recommendation was reached 42.084%.

4 Conclusions

The school environment had a big potential of energy efficiency that can reduce the energy consumption and CO_2 gas emissions. The consumption of electrical energy in SMA N 1 Ambarawa was very efficient, with an IEC average 1.7957 kWh/m^2/month. The average of electrical energy consumption reached 11022.008 kWh/month, which resulted in the emergence of secondary emissions of CO_2 by 9644.257 kg CO_2/month. In this case, computers, lamps, and air conditioner were top of equipment list that used the highest electrical energy.

5 Acknowledgement

The authors are thankful to the Indonesia Endowment Funds for Education (LPDP) Scholarship of Indonesian Government for giving financial support to study at Diponegoro University.

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