p–ISSN: 2723 - 6609 e-ISSN: 2745-5254
Vol. 5, No. 3 March 2024 http://jist.publikasiindonesia.id/

An Analysis of Energy Consumption In The Goverment Buildings' In Indonesian Border

Syarifudin, Andrial Imran
Politeknik Negeri Nunukan, Indonesia
Email: syarifudin@pnn.ac.id, andrial.imran@pnn.ac.id

*Correspondence: syarifudin@pnn.ac.id

Keywords:
energy audit, IKE, conventional building, thermal comfort

ABSTRACT

In this research, energy consumption analysis was conducted at the Main building regent's office of nunukan. The analysis was conducted on the main variables of energy efficiency, namely: measurement of temperature and relative humidity, calculation of Overall Thermal Transfer Value (OTTV) and Roof Thermal Transfer Value (RTTV), calculation of Energy Consumption Intensity (IKE) in air-conditioned and non-air-conditioned rooms as well as an analysis of opportunities to increase the efficiency of energy consumption in the buildings. Based on the calculation and result of IKE in both buildings, they are still considered in the category of EFFICIENT. However, based on the measurement of temperature and relative humidity, it shows that in both buildings air conditioning is still necessary to achieve the level of thermal comfort, therefore an increase of efficiency in the load is needed to avoid wastage.

Introduction

Nowadays it cannot be denied that energy has become a basic need that has an important role as a stimulus of almost all economic and social activities in the society. As a means of infrastructure supporting those activities, buildings also have a high level of need for energy for their operational activities (YULIATNA, 2015).

Energy consumption in buildings should have been planned and agreed upon from the initial planning between planners, owners and contractors/implementers so that material selection, determination of design as well as electrical equipment used such as lights, air conditioners and electrical appliances are more energy efficient (Sambodo & Novandra, 2019). For buildings that have been built conventionally, there should be an effort to review energy consumption through energy audits to determine the profile of energy usage and energy savings opportunities so that it can increase the efficiency of energy usage (ESDM., 2016).

The main Office building regent's office of nunukan should have applied the savings or efficiency in the use of energy in the operational activities of the buildings. Considering that there has been no calculation analysis of energy consumption, used as administrative building, the energy use in both buildings cannot be categorized as efficient, yet. Therefore, energy audit activities are necessary to be carried out (Nasional, 2011).

Literature Riview

Energy consumption refers to all the energy used to perform an action, manufacture something or simply inhabit a building. it is essential to understand that energy consumption does not necessarily come from a single energy source. Indeed, it is a common misconception to think that to save energy you have to save electricity whereas it could be a totally different energy source that has the greatest impact on a certain process (Andadari, Mulder, & Rietveld, 2014).

Calculating energy consumption helps to come up with two very interesting figures if you plan to save energy: (Satwiko, 2009)

1. Knowing how much you would have to invest in an energy management system that would help you achieve continuously, verified savings.
2. Understanding the savings potential of the building you live or work in, and understanding where to begin saving.

Research Methods

To figure out the value of Energy Consumption Intensity and the existing energy usage profile in the operational activities of the Main building regent's office of nunukan in the last 2 years, 2021 and 2022.

To figure out the application of several major variables of energy efficiency namely; temperature setting and relative humidity of air, value of OTTV and RTTV at the Main building regent's office of nunukan

To determine alternative methods of energy conservation to make energy savings as well as cost savings based on real conditions.

Results and Discussion

Based on the variables described previously, results were obtained and then discussed.

Measurements of temperature and relative humidity

Measurements of temperature and relative humidity were conducted directly at the Regents Office building. Measurement of these two variables were performed using a *Thermohygrometer* by taking some of the main rooms on each floor as samples. In each room, the measurement took approximately 5 to 10 minutes while the air was not being conditioned (AC turned was off). Measurements were conducted on holidays (Saturdays and Sundays) 3 times with a three-week rest at each measurement in each of the buildings between November 2021 - January 2022. Measurements were carried out in the morning at 07.00-09.00 am, noon at 11.00-13:00 pm and the afternoon at 15.00-17:00 pm (No, 24AD).

By the time of the measurement, it was figured out that the sun inclining on the south side of the building, thus affecting the measurement results conducted on the rooms located on the south side of the building. Result recapitulation of temperature and relative humidity measurement in Regents Office building is presented in Table 1.

Table 1 Result of Temperature and Relative Humidity measurement in Regents Office building

No	Time			Temperature (°C)	RH (%)
1	Day 1 28/11 /22	Morning	07:00 to 09:00	27.5	63
		Noon	11:00 to 13:00	28.5	62
		Afternoon	16:00 to 18:00	29.4	62
2	Day 2 11/28 /22	Morning	07:00 to 09:00	27.2	66
		Noon	11:00 to 13:00	28.3	62
		Afternoon	16:00 to 18:00	29.8	60
3	Day 3 28/11 /22	Morning	07:00 to 09:00	27.3	62
		Noon	11:00 to 13:00	28.3	61
		Afternoon	16:00 to 18:00	29.5	63
	Average			28.4	62

Table 1 shows that the average air temperature of the Regents building is 28.4 with a relative humidity (RH) of 62%. Based on the standard by SNI regarding thermal comfort that the relative humidity is about 60% and the temperature is between 20.5 - 22.8 (comfortably cool), 22.8 - 25.8 (Optimum Comfort), 25.8-27, 1 (almost comfortable), it was revealed that air conditioning are still needed in both buildings (So, 2014).

OTTV dan RTTV Calculation

OTTV calculations on this building were done directly on the 2nd and 3rd floors. The calculation was not performed in the 1st floor because it is an open space since there is no wall so that calculation was not applicable. In addition to OTTV calculations, roof RTTV calculations were also performed (Kotaji, Schuurmans, & Edwards, 2003).

The material used in the 2nd floor wall of the north side is normal solid concrete as thick as 152 mm ($\alpha_w = 0.86$), brick specific gravity (ρ) = 2400 kg.m3, transmittance (U) = 3.58W/m3℃, with slightly shiny white colour finisihing ($\alpha\rho$=0,30), window glass is clear glass with shading coefficient (SC) = 0.86. So, the weight of the wall per m2 is: (Burke & Miller, 2019)

ρ = weight /volume

weight = (ρ)(Volume)

= (2400 kg.m3)(1m x 1m x 0.152m)

= 354.8 Kg

for 354.8 > 195, equivalent temperature difference obtained (ΔT_{eq}) = 10 K

Wall Absorption is combination between the absorption of wall materials that is normal solid concrete and absorption coat paint (white slightly shiny) (Szokolay, Krishan, Baker, & Yannas, 2001).

Wall Absorption (α) = ($\alpha_w + \alpha\rho$) / 2

= (0.86 + 0.30) / 2
= 0.58

Window Size L2 (A1)
= (1.8m x 21.4m)+(4m x 4m)
= 54.52 m2

Wall and window size L2 (A2)
= (5 m)(77.2 m)
= 386 m2

Window to wall ratio (WWR)
= 54.52 / 386
= 0.14

Solar factor (SF) north side = 130 W/m2

$OTTV_{North} = \alpha$ [(U(1-WWR)] ΔT_{eq} + (SC)(WWR)(SF)
= 0.58 [(3.58(1-0.14)] (10) + (0.86)(0.14)(130)
= **33.51 m2**

Then, with the same calculation method, calculations are performed on all floors for each orientation, with the results as shown in Table 2 below.

Tabel 2 Recapitulation of OTTV value in regents office of nunukan Building

No	**Area**	**OTTV value orientation**			
		North	***East***	***South***	***West***
1	1st Floor	33.51	24.62	29.54	27.73
2	2nd Floor	36.24	27.53	31.42	44.29
3	3rd Floor	33.51	24.62	29.54	27.73
4	4th Floor	32.51	23.62	30.54	28.73
5	5th Floor	36.24	27.51	31.52	42.29
Average		34.88	26.08	30.48	36.01

Based on the conducted OTTV calculation and on the standard set by SNI with maximum OTTV value of 45 W/m2, it was revealed that the OTTV value of the whole orientation of the wall of the regents office building is still below the specified threshold (Deringer & Busch, 1992).

Then, RTTV calculation in the Regents office building by using the following method; roof material is clay tile with transmittance value (U) = 1.7 W/m2℃ dan α = 0.8. Roof area = 1982.4 m2. Shading coeficient (SC) and solar factor (SF). Weight roof per m2 is determined by calculating the total weight of all components per m2. From the calculation result, it is assumed that weight per m2 = 200 kg, so that ΔT_{eq} = 20 K or ℃.(Singgalen, Sasongko, & Wiloso, 2018)

RTTV = [(A_r) $(U_r)(\Delta T_{eq})$ + (A_s) $(U_s)(\Delta T)$ + (A_s) (SC)(SF)]/(A_r + A_r)
= [(1982.4)(1.7)(20) + (0) + (0)] / (1982.4 + 0)
= 34 W/m2

$OTTV_{total}$ = [(A_{north} x $OTTV_{north}$) + (A_{east} x $OTTV_{east}$) + (A_{south} x $OTTV_{south}$) + (A_{west}x $OTTV_{west}$) + (A_{roof} x $OTTV_{roof}$)] / (A_{north}+ A_{east}+ A_{south}+ A_{west}+ A_{roof})
= [(782 x 34.88) + (412 x 26.08) + (782 x 30.84) +(412 x 36.01) + (1982.4 x 34)] / (782+ 412+ 782+ 412 + 1982.4)
= 17.61 W/m2

Based on the conducted calculation, results of OTTV and RTTV calculations on Regents Office building on each wall orientation are; the north wall of 34.88 W/m2, the east wall of 26.08 W/m2, the south wall of 30.84 W/m2 and the west wall of 36.01 W/m2 and RTTV roof at 34 W/m2 (Eilenberg, 2014).

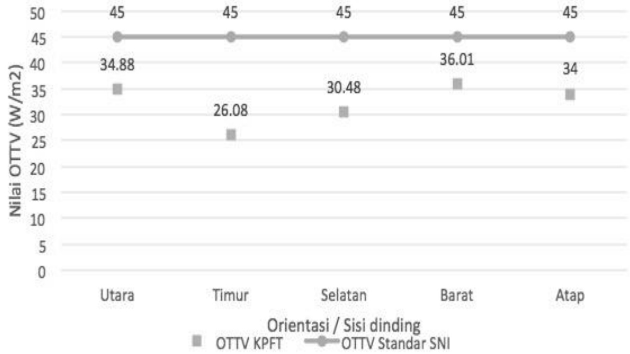

Figure 1 Comparison Ottv Value With Sni On Regents Office Building

The comparison chart Figure 1 shows that OTTV value of all orientation of the entire wall of Regents Office building is still below the threshold of the SNI, which amounted to 45 W/m2.

IKE Gross Calculation

With the basis of the secondary data of monthly electricity bills, calculation of IKE gross in 2021 and 2022 on Regents Office building with an area of 5519 m2 was done. To figure out the level of energy efficiency in each month in every year, a calculation was conducted based on this equation IKE = (total kWh/month/gross area). For example, to calculate the IKE of November 2021, this is how the calculation (Langer, Quist, & Blok, 2021).

Based on Table 3 and table 4 regarding data of monthly energy consumption in 2021 and 2022 as shown, it was found out that the monthly Energy Consumption Intensity in Regents Office building based on IKE standards for air-conditioned buildings that have been determined is still in the category of EFFICIENT.

Table 3. IKE based on Electricity Account Bill of Building 2021

Month	2021		
	Electrical Consumption (kWh)	**Electrical Cost (Rp)**	**IKE (kWh/m2 /month)**
January	16600	14,641,200.00	3.01
February	16160	14,253,120.00	2.93
March	16080	14,182,560.00	2.91
April	19680	17,357,760.00	3.57
May	18720	16,511,040.00	3.39
June	15480	13,653,360.00	2.80
July	14960	13,194,720.00	2.71
August	16720	14,747,040.00	3.03
September	19560	17,251,920.00	3.54
October	18160	16,017,120.00	3.29
November	22320	19,686,240.00	4.04
December	20880	18,416,160.00	3.78
Average	**17943**	**15,826,020.00**	**3.25**

Table 4 IKE based on Electricity Account Bill of Building 2022

2022		
Electrical Consumption (kWh)	**Electrical Cost (Rp)**	**Building IKE (kWh/m2/month)**
19000	18,098,640.00	3.44
19320	18,403,459.20	3.50
19200	18,289,152.00	3.48
20120	19,165,507.20	3.65
23280	22,175,596.80	4.22
18680	17,793,820.80	3.38
8680	8,268,220.80	1.57
21240	20,232,374.40	3.85
19840	18,889,790.40	3.59
18400	17,527,104.00	3.33
23240	20,479,680.00	4.21
17680	15,593,760.00	3.20
19057	**16,807,980.00**	**3.45**

Calculation of IKE in AC and Non AC room

The proportion of areas of air-conditioned and non-air-conditioned rooms in Regents Office building for each floor can be seen in Table 8.

Table 5 Air Conditioned and unconditioned room area in building

No	**Floor**	**Area Total (m2)**	**Conditioned Area (m2)**	**Unconditioned Area (m2)**
1	1st Floor	1993	1115	630
2	2nd Floor	1961	2014	653
3	3rd Floor	1965	1322	643
4	4th Floor	1890	1346	546
5	5th Floor	1980	1450	576
Total		**7519**	**4130**	**3389**

This calculation is conducted to get the nett IKE value in the Regents Office building. To calculate the IKE in the rooms, it is necessary to firstly observe and collect the data of electronic device types, power capacity (watt), and the amount contained in the room.

Assumed that the operational activity (total working hours) is for 8 hours (07:30-15:30), the load requirement for 5 days in a week (22 effective days in one month) equal to 70%. Daily energy consumption for Regents Office 5th floor (Light + AC + other loads) = 32.09 kW x 8 hours x 0.70 = 179.71kWh/day.

Consumption of electric energy per month,

= 179.71 kWh/day x 22 days = 3953.49 kWh/month.

The are of air-conditioned room on the 3rd floor is 1322 m2. IKE of AC room in 3rd floor = 3953.49 kWh/month/1322 m2 = 2.99 kWh/m2/month.

The first floor (typical) of the Regents Office building is an open hall without walls, so the calculation of the electrical load is only done on the load of light and other loads without HVAC load with the following details.

Lighting load = 2628 watts/day or 2,628 kW/day

HVAC load = 0

Other loads = 1000 watts/day or 1.00 kW/day
Total electrical load
(Lighting + HVAC + other loads)
= (2628 + 0 +1000) = 3628 Watts/day = 3.628 kW/day.

Calculation of energy consumption on the 1st floor is assumed starting when the lights are turned on until the end of the activities in the hall which is at 17.00-22.00 pm every day. So, daily load on the 1st floor can be calculated: 3628 x 5 = 18140 watts/day or 18.14 kW/day and per month 18140 x 30 = 544200 Watt/month or 544.20 kW/month. The are of the first floor is 2093 m2. Therefore, the consumption of non-air-conditioned room on the 1st floor is 544.20 kW/month/2093 m2 = 0.26 kWh/m2/month.

Recommendation on Opportunities for Energy Efficiency Increase

The need for air conditioning to create comfort in the rooms of both buildings has resulted in energy consumption, in this case the electrical load, for air conditioner becomes greater than the electrical energy consumption of other electrical equipment. High electrical loads on air conditioner equipment results to an increase of operational expenses in both buildings.

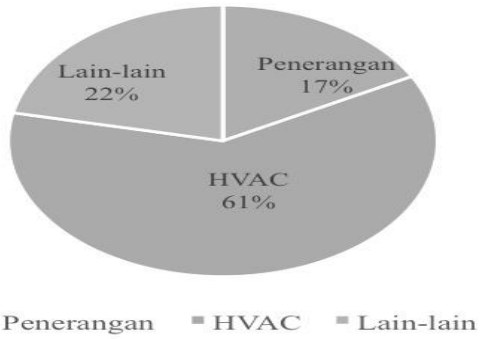

Figure 2 Percentage of Electricity Expense Regents Office Building

Based on the profile of energy usage in Regents Office building, in order to avoid waste and to improve the efficiency of energy consumption in the air conditioning activities without having to reduce the comfort level for the building occupants, it takes some efforts of repair, replacement and addition of components in the building, and also the application of better procedures for the building occupants.

- Analysis on the Implementation of Opportunities for Energy Efficiency

As an effort to increase the efficiency of electrical energy consumption in air conditioning load in the Regents Office diation based on the type of window glass used in the building in order to reduce heat absorption into the room.

As a matter of fact, the hall located on the 2nd floor or known as R. 2.3 of the building has a window as big as 10.8 m2. Using clear glass for the window, the average solar radiation is (I) = 700 W / m2. Since the angle of the sun towards the window is 30 °, clear glass has a coefficient of shade θ = 0.7. Based on those data, heat penetrating the glass can be figured out;

The heat penetrating through the glass

$$Qs = AI\theta.W$$
$$= 10.8 \times 700 \times 0.7$$
$$= 5292 \text{ W}$$

This type of clear glass provides a fairly high transmission that is about 90%.

As an effort to decrease the amount of heat that penetrates through the glass, the

glass can be replaced with rayben glass type which has a shading coefficient θ = 0.7. The result of the calculation is as follows;
The heat penetrating through the glass

$$Qs = AI\theta.W$$
$$= 10.8 \times 700 \times 0.57$$
$$= 4309.2 \text{ W}$$

Replacement to Rayben glass type (tinted glass) is proven to reduce the amount of heat since it has a fairly high heat absorption which is about 55%, so it will reduce the load on air-conditioning (HVAC) and give comfort to building occupants.

Using the same calculation method, furhter calculations are done to some other room as presented in Table 13.

Table 6 Result of calculation of cooling load regents office of nunukan building

Ruang		Luas Jendela (m2)	Radiasi Matahari rata-rata (W/m2)	Koef Peneduh		Panas Menembus Kaca (W)	
				Kaca Bening	Kaca Rayben	Kaca Bening	Kaca Rayben
Lantai 2	R. 2.1	32,24	700	0,7	0,57	15797,60	12836,76
	R. 2.2	14,40	700	0,7	0,57	7056,00	5745,60
	R. 2.3	10,80	700	0,7	0,57	5592,00	4309,20
	R. 2.4	10,80	700	0,7	0,57	5592,00	4309,20
	R. 2.5	14,40	700	0,7	0,57	7056,00	5745,60
Lantai 3	R. 3.1	29,12	700	0,7	0,57	14268,80	11618,88
	R. 3.2	19,92	700	0,7	0,57	9760,80	7948,08
	R. 3.3	27,04	700	0,7	0,57	13249,60	10788,96
	R. 3.4	27,04	700	0,7	0,57	13249,60	10788,96
	R. 3.5	19,92	700	0,7	0,57	9760,80	7948,08

Conclusion

The average temperature of the Regents Office building is 28.4°C, while its average relative humidity is 62%. Meanwhile, , while its average relative humidity is 65%. Based on those results, it can be concluded that in order to achieve thermal comfort which temperature is around 24°C and relative humidity is around 60%, a quite intensive air conditioning is still needed in both buildings.

OTTV value of the Regents Office building is 17.61 W/m2. Those values are still below the standard of SNI which is 45 W/m2.

The IKE gross value indicates that the Regents Office building has average IKE value per month as much as 3.25 kWh/m2 in 2021 and as much as 3.45 kWh/m2 in 2022. in the year of 2108 and as much as 0.79 kWh/m2 in 2022 which are still in the category of EFFICIENT. The significant lowering of IKE value of regents office building is affected by the fact that there was some replacement of electronical appliances in the building in 2022, specifically replacement of the airconditioner to a more energy-efficient airconditioner, while no such replacement was done in the building.

A couple of efforts to improve the efficiency of electrical energy consumption in airconditioning activity (HVAC) in regents office building that can be taken are 1) replacing the air conditioner (AC) 2) replacing the glass window with a better heat absorbance glass.

Bibliography

Andadari, Roos Kities, Mulder, Peter, & Rietveld, Piet. (2014). Energy poverty reduction by fuel switching. Impact evaluation of the LPG conversion program in Indonesia. *Energy Policy*, *66*, 436–449.

Burke, Lisa A., & Miller, Monica K. (2019). Taking the mystery out of intuitive decision making. *Academy of Management Perspectives*, *13*(4), 91–99.

Deringer, J. J., & Busch, J. F. (1992). *Asean-Usaid Buildings Energy Conservation Project Final Report Volume I: Energy Standards*.

Eilenberg, Michael. (2014). Frontier constellations: Agrarian expansion and sovereignty on the Indonesian-Malaysian border. *Journal of peasant studies*, *41*(2), 157–182.

ESDM., Kementrian. (2016). Media Komunikasi Kementrian Energi dan Sumber Daya Mineral 3. *Energi*.

Kotaji, Shpresa, Schuurmans, Agnes, & Edwards, Suzy. (2003). *Life-Cycle Assessment in Building and Construction: A state-of-the-art report*, *2003*. Setac.

Langer, Jannis, Quist, Jaco, & Blok, Kornelis. (2021). Review of renewable energy potentials in Indonesia and their contribution to a 100% renewable electricity system. *Energies*, *14*(21), 7033.

Nasional, Badan Standarisasi. (2011). *SNI 6197: 2011 tentang Prosedur Audit Energi pada Bangunan Gedung*. Jakarta: Badan Standarisasi Nasional.

No, Departemen Pekerjaan Umum. (24AD). *Tahun 2008 tentang Pedoman Pemeliharaan dan Perawatan Bangunan Gedung*. Jakarta.

Sambodo, Maxensius Tri, & Novandra, Rio. (2019). The state of energy poverty in Indonesia and its impact on welfare. *Energy Policy*, *132*, 113–121.

Satwiko, Prasasto. (2009). *Fisika bangunan 2 edisi 1*.

Singgalen, Yerik Afrianto, Sasongko, Gatot, & Wiloso, Pamerdi Giri. (2018). Tourism destination in remote area: problems and challenges of tourism development in North Halmahera as remote and border areas of Indonesia-Philippines. *Journal of Indonesian Tourism and Development Studies*, *6*(3), 175.

So, Park Young. (2014). Implementasi kebijakan konservasi energi di Indonesia. *E-Journal Graduate Unpar*, *1*(1).

Szokolay, S. V, Krishan, Arvind, Baker, Nick, & Yannas, Simon. (2001). *Climate Responsive Architecture; A Design handbook for Energy Efficient Building*. New Delhi: Tata McGraw-Hill Publishing Co. Ltd.

YULIATNA, FERY. (2015). *Analisis Perbandingan Konsumsi Energi Pada Kegiatan Operasional dan Pemeliharaan Bangunan Gedung dengan Konsep Green Building dan Bangunan Gedung Konvensional*. Universitas Gadjah Mada.