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Analysis Of Classroom Lighting Compatibility With Standard Papameters Lighting Levels, Light Power Intensity, Efficacy, Light Color Temperature, And Color Rendering Index (Case Study At Classroom Lighting At Human Resources Development Center For Electricity, New Renewable Energy And Energy Conservation)

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ABSTRACT:
The lighting system for classrooms has been standardized according to SNI-6197-2011 concerning energy-conservation-lighting-systems as has been revised to become SNI-6197-2020 concerning energy-conservation-lighting-systems. Some of the standard parameters that govern classrooms are the illuminance level of the study room of 350 lux, the intensity of lighting power of 11.95 watts/m^2, the efficacy of a T8 LED lamp of 80–90 lumens/watt and the color temperature of the white light (cool-daylight) (> 5,300 Kelvin) and a color rendering index of at least 80.
This paper aims to analyze the compatibility of classroom lighting at Human Resources Development CenterFor Electricity, New Renewable Energy And Energy Conservation henceforth named PPSDM KEBTKE with SNI-6197-2020 concerning energy-conservation-lighting-systems. The results of the analysis show that the average class room illuminance is 342 lux close to the 350 lux standard, the lamp power intensity is 5.27 watts/m2 which shows the use of electric power per m^2 of 5.27 watts, still below the maximum standard for lamp power density Classroom of 11.95 watts/m2, lamp efficacy value of 100 lumens/watt greater than standard T8 LED lamp 80–90 lumens/watt, color temperature white lamp (cool-daylight) 6500 Kelvin according to standard > 5,300 Kelvin, color rendering (Ra) index between 50 - 95 corresponds to a minimum color rendering index standard of 80.
To improve the level of lighting (illuminance) in classrooms according to standards, it is necessary to arrange study tables and study lamp positions. Improvements to the intensity of lighting power can be done by replacing lighting lamps with higher power. Meanwhile, lamp efficacy can be improved by replacing lamps with high power or choosing lamps with lower lumen values.

***KEY WORD**: SNI-6197-2020, lighting level, lamp power intensity, lamp efficacy, lamp color temperature, color rendering index.*

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I. INTRODUCTION

Energy plays an important role in everyday life. Energy can be grouped according to its type, namely primary energy and secondary energy. Primary energy is energy provided by nature and has not undergone further processing. Primary energy includes; coal, natural gas, uranium (nuclear), geothermal, and petroleum. While secondary energy is primary energy that has undergone further processing into other forms of energy. One form of secondary energy is electrical energy.

Electrical energy is used in various sectors, namely the industrial, commercial, transportation and household sectors as well as the public sector. One of the uses of electrical energy is for lighting.

The quality of light is where the level of illumination matches the needs of humans using an area. Human needs for lighting can be categorized into 6 (six) approaches, namely:

• Visual performance

• Advanced visual performance (such as reading, eating, sewing, walking)
• Social interaction and communication
• Psychological condition (happy, alert, satisfied)
• Health and safety
• Aesthetics (study of the appearance of space or lighting)

Lighting levels that are too high or too low will complicate production activities, cause employee fatigue and cause the environment to become hazardous if the location is in an industrial location, for example

The lighting system is intended to obtain optimal lighting so that in operation energy use is more efficient without having to reduce or change its designation function, occupant comfort and productivity.

The principle of energy-saving lighting systems with reference to the provisions of the lighting guidelines as stipulated in the SNI for lighting systems can be carried out to obtain a lighting system with optimal operation.

The principles of efficient lighting are related to: Standard maximum power for lighting (Watt/m2), lighting levels for various uses (Lux), power consumption of various types of lamps and ballast types (Watts), lighting system technology, lamp usability (Lumen /Watt), efficient operation and maintenance, and how to maximize natural light.

Utilization of electrical energy for lighting (lighting) needs to take into account the selection of the type of lighting lamp with the level of illumination, intensity of lighting power, efficacy and color temperature of the light as well as color rendering according to the area/location and its use function according to standards.

The Indonesian National Standard (SNI), SNI 6197: 2020 has set standards regarding energy conservation in lighting systems which, among other things, set standards for average lighting levels and minimum color rendering for various room functions. One of those standardized is educational institutions which include: Space classroom, library reading room, laboratory, computer practice room, language laboratory room, teacher/teaching room, drawing room, etc. In addition, standards are also set for maximum lamp power density, and light color temperature.

This paper aims to analyze the suitability of the lighting of the study room in one of the study rooms of the Human Resources Development CenterFor Electricity, New Energy, Renewable Energy and Energy Conservation (PPSDM KEBTKE), Human Resource Development Agency (BPSDM), Ministry of Energy and Mineral Resources (MEMR) with the Indonesian National Standard (SNI), SNI 6197:2020.

Based on the discussion above, the problem assumptions can be formulated, namely:
a. The light power intensity (Watt/m2) of the classroom is not up to standard,
b. The average lighting level (Lux) in classrooms is not up to standard
c. The efficacy of the lights (Lumen/Watt) in the classroom is not up to standard,
d. The color temperature of the light, the color rendering is not up to standard

To answer the formulation of the problem, measurements, calculations and identification of the use of lighting in the KEBTE PPSDM study room will be carried out.

The aims and benefits of this paper are:
a. Obtain data and facts on classroom lighting at PPSDM KEBTE
b. Apply the science of lighting lighting
c. Provide feedback to PPSDM KEBTE management

II. MATERIALS AND METHODS

2.1 Lighting

Lighting can be categorized into natural lighting and artificial lighting. Natural lighting is lighting that comes from natural sources, commonly known as sunlight while artificial lighting is lighting that is produced by man-made light sources, for example electric lights.

Lighting quality is a more subjective issue for lighting designers. However, it needs to be addressed because good quality lighting can be very important. Lighting quality can have a dramatic effect on occupant attitudes and performance.

Residents can be influenced to work more effectively if they are in an environment that supports a “work” atmosphere. The goal of the lighting designer is to provide the appropriate quality of light for the specific task in order to create the right "mood" for the space.

2.2 Lighting quality

Lighting quality can be divided into four main considerations: Uniformity, Glare, Color Rendering Index and Coordinated Color Temperature. In this paper, two things will be presented, namely Color Rendering Index and Coordinated Color Temperature.

2.2.1 Light Color Temperature (CCT - Correlated Color Temperature)

Color temperature is an indication of the color units of light in units of Kelvin (K). Color temperature has a psychological influence (impression) on a space that you want to create (cold and warm).

The color temperature is used to create an atmosphere and feel in space, giving a certain impression, such as formal, cool, warm and luxurious. The color temperature of the light is not an indication of its effect on the color of the object, but rather gives a sense of space.
In general, the color temperature used is usually in the range of 2000K – 6500K. The lower the temperature degree value, the color of the light produced will be more yellowish, if it is lowered again, it will turn reddish. The higher the color temperature, the whiter the color of the light produced, if it is higher, the color of the light will turn bluish.
The color temperature of the light is grouped into:
(1) group 1, yellowish white (warm) color (< 3,300 Kelvin);
(2) group 2, neutral white (warm-white) (3,300 Kelvin ~ 5,300 Kelvin);
(3) group 3, white color (cool-daylight) (> 5,300 Kelvin)

Table 1 – Color appearance with respect to colortemperature[2]

Color Temperature (Kelvin)	Appearance of Color
> 5300	white (cool-daylight)
3300 –5300	neutral white (warm-white)
<3300	yellowish white (warm)

The choice of the color temperature of the lamp depends on the level of illumination needed to obtain comfortable lighting.
The higher the required illumination level, the recommended lamp color temperature ranges from 4000 - 6500 Kelvin so as to create comfortable lighting for the users inside.
As for the need for an illumination level that is not too high, the color temperature of the lamp used is suggested to be around 2300-3500 Kelvin

2.2.2 Color Rendering

The color rendering index is the value of the ability of a light source to be able to define the true color of an object or objects. The value of this index ranges from 0-100. The higher the value of a color rendering index, the better the ability of the light source to show the true color of an object. For example, the sun has a rendering index of 100 and a fluorescent lamp has a rendering index of 60 to 90.
The effect of a light on the color of an object will vary. Lamps are classified in color rendering groups expressed by the Ra index as follows:
(1) color effect, group 1: Ra index 81% ~ 100%;
(2) the effect of color, group 2: Ra index 61% ~ 80%;
(3) color effect, group 3: Ra index 40% ~ 60%;
(4) the effect of color, group 4: Ra index <40%

Table 2 – Example of Ra value and color temperature for several types of lamps[2]

Lampu	Temperatur Warna(K)	R_a
Pijar/halogen	< 3300	95
TLD(fluoresen)	< 3300s.d. > 5500	50s.d.95
CFL/PL	< 3300s.d.> 5500	70s.d.90
MetalHalida	> 4000	>70
LPS	< 3300	25
LampuElectrodeles/LVD	> 5500	70s.d.90
LampuLED	< 3300s.d.> 5500	70s.d.95

2.3 Lamp Efficiency Parameters

The building lighting system efficiency parameters are lamp power intensity, lighting level, and lamp efficacy as shown in Figure 1.

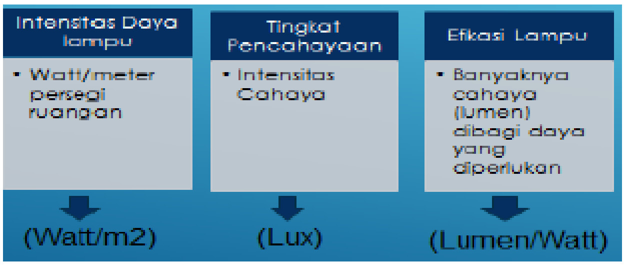

Figure 1. Lamp Efficiency Parameters[1]

2.3.1 Lighting Intensity/Level (lux)

The level of illumination (illuminance) is the incident luminous flux on the surface or the quotient between the luminous flux and the area of the illuminated surface expressed in lux. Lux is the unit size of 1 lumen of light emitted in a field area of 1 m^2 with a distance of 1 m.

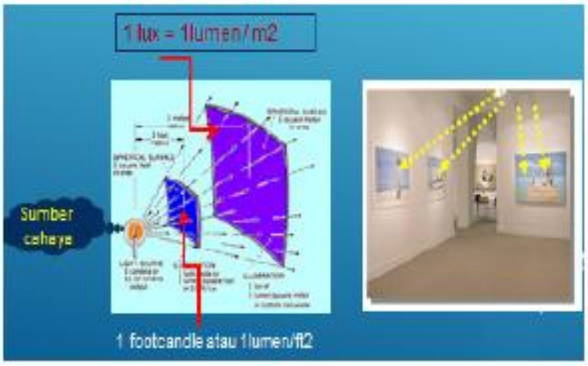

Figure 2. Lighting Levels[1]

2.3.2 Minimum Exposure Level

The level of lighting needed to carry out various activities is not always the same. Meticulous and long-term activities require a higher level of light than normal activities. The lighting level needed to carry out various activities is determined in the national standard (SNI).

The recommended minimum lighting level for artificial lighting according to the function of the room is regulated in SNI.

The recommended minimum lighting level should not be less than the lighting levels in Tables 3 and 4, unless:

(1) lighting for cinemas, TV broadcasts, audio-visual presentations, and all entertainment facilities that require technological lighting as the main element in carrying out their functions;
(2) special lighting for the medical field;
(3) indoor sports facilities;
(4) lighting required for exhibitions in galleries, museums and monuments
(5) outdoor lighting for monuments
(6) special lighting for laboratory research
(7) emergency lighting
(8) rooms that have a high level of security as stated by regulations or by security officers are deemed to require additional lighting
(9) specially designed classrooms for people who have low vision, or for elderly people
(10) lighting for directional signs in buildings
(11) display window in the shop/showcase
(12) agro industry (greenhouse), processing facilities
(13) other activities not included in the above.

Table 3 − Average Exposure, Renderance, and ColorTemperature[4]

Room Function	Luminance level (lux)	Color rendering group	Color temperature		
Educational institutions			Warna <3300 Kelvin	Warm white 3300-5300 Kelvin	Cool Daylight >5300Kelvin
Classroom	**350**	**1 or 2**		•	•
Library reading room	300	1 or 2		•	•
Laboratorium	500	1		•	•
Laboratory Computer practice room	500	1 or 2		•	•
Language Laboratory Room	300	1 or 2		•	•
Teacher's room	300	1 or 2		•	•
Gym/Sport room	300	1 or 2		•	•
Drawing Room	750	1		•	•
Canteen	200	1	•	•	•

NOTES :
1 The • mark means that it can be used.
2 Color rendering groups (1, 2, 3 and 4)

Table 4 – Exposure Levels and ColorRendering[2]

Room Function	Minimum average (E average) luminance level (lux)	Minimum color rendering
Educational institutions		
Classroom	**350**	**80**
Library reading room	350	80
Laboratorium	500	80
Laboratory Computer practice room	500	80
Language Laboratory Room	300	80
Teacher's room	300	80
Gym/Sport room	300	80
Drawing Room	750	80
Auditorium Room (exhibilition)	300	80
Lobby	100	80
Ladder	100	80
Canteen	200	80

Note a) values are measured over the working plane
According to SNI 6197:2011 Classrooms must have an average lighting level of 350 lux, color rendering group 1 or 2 (Ra index 61% ~ 80% or 81% ~ 100%) and can use warm white or cool daylight color temperatures. Meanwhile, SNI 6197:2020 requires an average lighting level of 350 lux and a minimum color rendering of 80.

2.3.3 Lamp Power Intensity (watts/m2)

The maximum electric power per square meter must not exceed the value as stated in table 5.

Table 5 – Maximum Lamp Power Density Using Room By Room Method[2]

Room Function	Maximum Lamp Power Density (watts/m2)
Educational institutions	
Classroom	**11,95**
Library reading room	10,33
Laboratorium	12,16
Laboratory Computer practice room	10,12
Language Laboratory Room	7,53

Teacher's room	10,66
Gym/Sport room	13,67
Drawing Room	6,57
Auditorium Room (exhibilition)	9,04
Lobby	5,27
Ladder	4,31

In accordance with SNI 6197:2020 concerning Energy Conservation The lighting system for Classrooms is required to use energy-saving lamps with due regard to the Maximum Lamp Power Density of 11.95 Watt/m2 and the lighting level (lux) is 350 lux which is set as the design condition.

2.3.4 Lamp Efficacy (lumen/watt)

The indicator for lamp efficiency is efficacy, namely the amount of light (lumen) produced by the lamp divided by the required electrical power (figure 2).

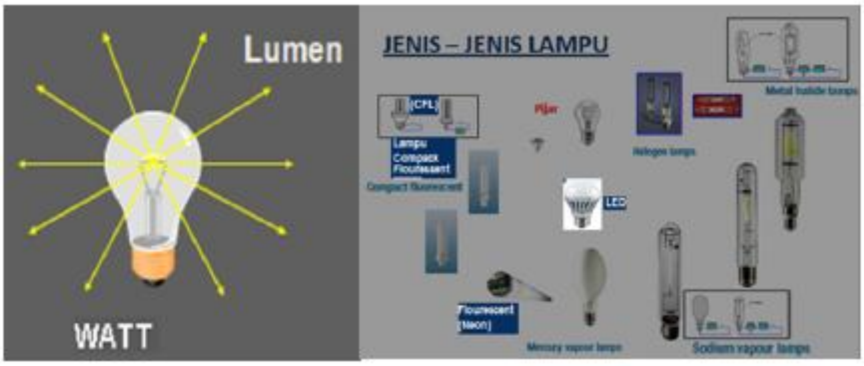

Figure 3. Lamp efficacy[1]

The efficacy of the lamp as in Table 6 is based on the lumen output where the lamp is still new and the electric power required by the lamp, including the electrical power required by the ballast which is integrated with the lamp. The efficacy (L/W) and service life of the lamp depend on the type and technology of the lamp.

Table 6. Comparison of efficacy and average life of various sample lamps[2]

Lamp type	**Efikasi(Lumen/Watt)**	**Umur rata-rata(jamoperasi)**
Halogen	15–25	2.000–5.000
Compact fluorescent (CFL)	40–80	8.000–12.000
“T8” tube fluorescent	80–90	10.000–20.000
Fluorescent tube “T5”	90–110	15.000–20.000
Low pressure sodium	70–80	18.000–25.000
LED(*LightEmittingDiode*)	100–120	35.000–50.000

Similar to efficiency, efficacy describes the output/input ratio, the higher the output (while inputs are kept constant), the greater the efficacy. Efficacy is the number of lumens per watt of a given energy source. A common misconception in lighting terminology is that a lamp with a higher wattage gives out more light. However, a high-efficiency light source can provide more light for the same amount of power (watts), compared to a low-efficiency light source. However, one of the things that need to be considered when designing lighting is to avoid overly illuminating the space.

2.4 Efficient lighting technology

Lamp efficiency can be seen from the efficacy value (lumen/watt) as shown in table 6. The use of efficient lamps is one of the efforts to stay on the corridor of energy-saving and cost-effective. One type of efficient lamp that is widely used today is the Triphosphor T-8 lamp which is used in classrooms at PPSDM KEBTKE.

T-8 fluorescent lamps are now gaining popularity as a replacement for standard fluorescents for both new construction and retrofits. With their high efficiency and improved color, these lamps will set the new standard. In addition, the price will be cheaper so it will be more economical.

Figure 4. T-8 lamp[3]

In the picture, it can be seen that the T-8 lamp uses a 1-inch diameter of rare earth phosphors mixture which will increase its efficiency. With this method the efficiency is in excess of 80 lumens per watt in magnetic ballasts and in excess of 104 lumens per watt in electronic ballasts. With rare earth phosphors, the color rendering index becomes 85 compared to 62 in a standard T-12 fluorescent lamp. However, because it operates at 0.265 amperes, it requires a special ballasts.

Table 7. Comparison of specifications for fluorescent lamps T8-T10 -T12[6]

	MANUFACTURERS' INFORMATION		
	F40T12CW	F40T10	F32T8
	Bi-phosphor	Tri-phosphor	Tri-phosphor
CRI	62	83	83
CCT (K)	4,150	4,100 or 5,000	4,100 or 5,000
Initial lumens	3,150	3,700	3,050
Maintained lumens	2,205	2,960	2,287
Lumens per watt	55	74	71
Rated life (hrs)	24,000	48,000†	20,000
Service life (hrs)	16,800	33,600†	14,000

†This extended life is available from a specific lamp-ballast combination. Normal T10 lamp lives are approximately 24,000 hours. Service life refers to the typical lamp replacement life.

2.4.1 Data on the Use of PPSDM KEBTKE Classroom Lights

Data of “T8” tube Fluorescent lamp
• Power: 16 watts
• Voltage: 220-240 V
• luminous flux: 1600 lumens
• Light color temperature: 6500 K Cool DayLight

Figure 6. "T8" Tube Fluorescent Lamp PPSDM KEBTKE Class Room

2.4.2Area of the Room

The dimensions of the PPSDM KEBTKE class room have the size of the room;

- Length: 10 meters

- Width: 8.5 meters
- Area : 85 m2

Figure 6. PPSDM KEBTKE Classroom

Classrooms which have 3 (three) rows of desks on the right and left of the room as well as desks for teachers. The room is equipped with lighting using 28 “T8” tube fluorescent lamps with 28 armatures/luminaires (1 luminaire contains 1 lamp).

III. RESULTS AND DISCUSSION

The level of illumination (illuminance), intensity of lighting power, efficacy and use of the correct lamp color temperature are the factors used in evaluating lamp lighting referring to the SNI 6197: 2020 standard concerning Energy Conservation of Lighting Systems. According to the standards, the luminance level (illuminance) of the study room is 350 lux, the intensity of lighting power is 11.95 watts/m2, the efficacy standard for T8 LED lamps is 80–90 lumens/watt and the color temperature of the white light (cool-daylight) (> 5,300 Kelvin) and a minimum color rendering index of 80

3.1 Measurement of Illuminance Levels (Illuminance)

Lay out several measurement points (on the study table) in the PPSDM KEBTKE classroom as shown in Figure 6. as follows:

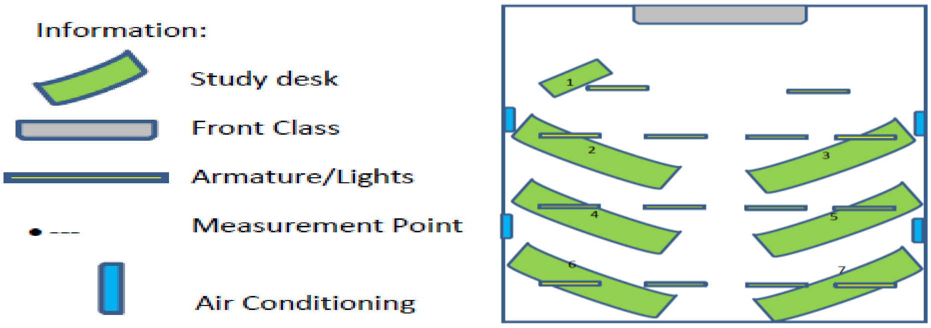

Figure 7. Plan and measurement points for PPSDM KEBTKE Classrooms

Table 8. Results of Lighting Level Measurement (Illuminance)

Measurement Point	Measurement results (lux)	Description (Standard: 350 lux)	Information Study table position
1	366	above standard	Near a semi-open window
2	374	above standard	Near a semi-open window
3	306	below standard	Near the wall
4	228	below standard	The light is not right above the study table & the window curtains are tightly closed
5	266	below standard	The light is not right above the study table
6	442	above standard	The distance between the lamp and the table is closer
7	412	above standard	The distance between the lamp and the table is closer

Average	342	Close to standard	

The measurement results at several measurement points show that there are 4 measurement points with above standard lighting levels and 3 measurement points with below standard lighting levels.
Some of the conditions that cause substandard measurement results are:
1. The surface of the classroom floor is uneven/level from the front to the back, while the height of thestudy desks is the same so that the closer to the back the distance between the study tables and the lights is.
2. The light is not right above the study table
In order for the classroom to have standard lighting levels at several measurement points, it is necessary to reposition the lamp installation.

3.2 Lamp Power Intensity
Lamp Power Intensity can be calculated from lamp data, namely lamp power (watts) @ 16 watts/lamp and the number of lamps is 28 lamps.

Table 9. Lamp Power Intensity

Type	Power (watt)	Number of lamps (lamps)	Total Lamp Power (watts) and Room Area (m^2)	Lamp Power Density (watts/m^2)
LED T8 (philips)	16	28	- 448 watt - 85 m^2	448 watt/85 m^2 = 5,27 watt/ m^2

The result of the calculation of the Lamp Power Intensity is 5.27 watts/m2 which shows the use of electric power per m2 of 5.27 watts, which is still below the maximum standard for Classroom Lamp Power Intensity of 11.95 watts/m2 (SNI 6197:2020). So that the power intensity of the classroom lights is up to standard, it is necessary to replace a larger lamp power or use a lower light (lumen) lamp.

When taking into account the design criteria of practice guidelines in determining the maximum lighting power for buildings for the type of TL daylight lamps, the result of calculating the Lamp Power Intensity of 5.27 watts/m2 shows the level of power usage per m2 which is still in the efficient range. However, standard classrooms according to SNI 6197:2020 require higher power usage per m^2.

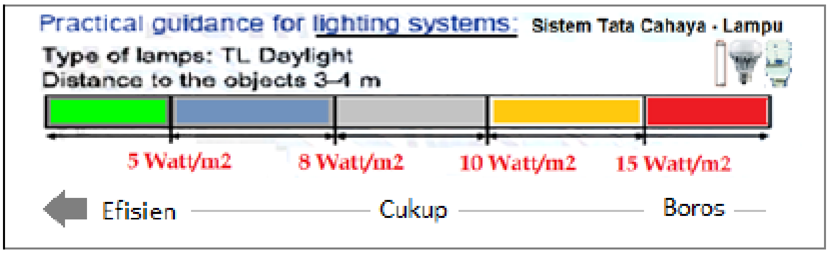

Figure 8. Building lamp power intensity reference[1]

3.3 Lamp Efficacy
To find out the efficacy value, power data and lamp lumens are used.

Table 10. Lamp Efficacy

Type	Power (watt)	Number of lamps (lamps)	luminous flux (lumens)	Efficacy (lumen/watt)
LED T8 (philips)	16	28	1600	44.800 lumen/448 **watt** **= 100 lumen/watt**

By using a T8 LED lamp (Philips) with a power of 16 watts, a light flux of 1600 lumens obtained an efficacy value of 100 lumens/watt. The efficacy value of this calculation is greater than the efficacy standard for T8 LED lamps of 80–90 lumens/watt (SNI 6197:2020).
To adjust to the standard efficacy value, you can do this by increasing the power of the lamp or choosing a lamp with a lower lumen.

3.4 Lamp Color Temperature and Color Rendering
“T8” tube fluorescent lamps use the color temperature of the light: 6500 K Cool DayLight with a white color and has a color rendering (Ra) between 50 - 95 (SNI 6197:2020). This specification is in accordance with SNI 6197:2020 for classrooms which regulates the color temperature of white (cool-daylight) lamps (> 5,300 Kelvin) and a minimum color rendering index of 80.

3.5 Lighting Technology

According to Table 6. Comparison of the efficacy and average life of various lamp samples, the use of "T8" tube fluorescent lamps can be replaced with "T5" tube fluorescents which have an efficacy value of 90–110 lumens/watt and an average life of 15,000–20,000 higher than Fluorescent tube “T8” 80–90 lumen/watt and average life (hours of operation) 10,000–20,000.

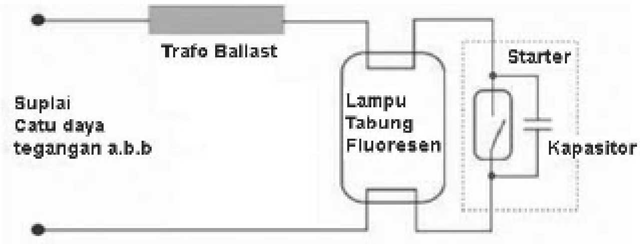

Figure 9. Series of Fluorescent Lamps[4]

Using a T5 lamp in combination with a high-frequency electronic ballast can save up to 40% in energy compared to standard fluorescent lamps

IV. CONCLUSIONS

The suitability of the lighting system with the standards can be seen from the parameters of the intensity of the lighting, the density of the applied lamp power, the efficacy, the color temperature and the color index of the light.
The value of the average lighting level (lux) is made optimal according to the standard function of the classroom by adjusting the study table and the layout of the lamp installation, with the aim that visual comfort is guaranteed and comfortable lighting is obtained.
The lamp power density value of 5.27 watts/m2 is not enough to illuminate 1 (one) m2 of classroom area, it is necessary to use 11.95 watts of power.
Optimal Lamp Efficacy can be obtained by increasing the lamp power or decreasing the luminous flux (lumen)
The higher the required illumination level, the recommended lamp color temperature ranges from 4000 - 6500 Kelvin so as to create comfortable lighting for the users inside.

REFERENCES

[1]. Directorate General of New, Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources and Environmental Support Program Phase 3 (ESP3)-Government of Denmark, (2019), “Energy Manager Training Module
[2]. National Standardization Agency, (2020), "Conservation of energy in lighting systems, Indonesian National Standard", SNI 6197:2020
[3]. TUV Nord, ASSIST, HAKE, (2013), “UPLIFT (Upgrading and Leveraging Indonesia to Fortify Energy Efficiency through Academic and Technical Trainings for Energy Management Professionals) Training Materials”, Jakarta, December 2013.
[4]. National Standardization Agency, (2011), "Conservation of energy in lighting systems", Indonesian National Standard, SNI 6197:2011
[5]. Government Regulation, (2014), National Energy Policy, Number 79 of 2014
[6]. Wayne C. Turner, (2001), Energy Management Handbook, School Of Industrial Engineering And Management Oklahoma State University, Copyright © 2001 The Fairmont Press.
[7]. Assoc. Prof. Dr. Eng. IliyaIliev, and others, (2011), Energy Efficiency And Energy Management Handbook, Bulgaria Energy Efficiency for Competitive Industry Financing Facility (BEECIFF): Project Preparation, Capacity Building and Implementation Support ISBN: 987 – 619 – 90013 – 8 – 7