แนวคิดในการปรับปรุงค่ากำหนดกำลังไฟฟ้าสูงสุดในการส่องสว่างต่อตารางเมตร

Improvability of Thai's Building Energy Code via Lighting Power Density Requirements

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Abstract

The Thai government plans to enforce the Thai's new Building Energy Code or BEC, which is a Ministerial Regulation in 2009 for the building to be submitted for construction or modification and it has been in forced since mid of this 2018. In order to achieve its 20-year reduction of energy intensity used in accordance with the National Energy Conservation Plan 2015-2022. BEC has been promulgated for 9 years and it has not been updated to reach the minimum standards in line with the current technology. Specifically, the lighting criteria for energy efficiency in building. Consequently, the Lighting Power Density allowance per square meter or LPD is set based on lighting technology on that day. Therefore, in order to meet the government targets, BEC should reconsider the criteria for defining the new LPD value to match with current technology for increasing the energy efficiency of buildings. This study illustrates the concept of adjusting new LPD value, to be applicable with today's technology. Simple calculation methods and case studies, which based on standard criteria of illuminance level according to ministerial regulation no.39, are set to investigate and compare the total lighting power density per specific area between three types of current lighting technologies, which are T8 Fluorescent tube, T5 fluorescent tube and LED T8 retro-fit. Result from the comparison shows that even the least energy-efficient bulbs of selected type, which is T8 fluorescent tube, the LPD value still lower than that specified in the BEC requirement almost 19% and it can be reduced up to 31% with the advantages of LED technology. The results from the study shows the relationship between the thresholds for defining LPD according to BEC and the brightness level in accordance with the ministerial regulations, but also shows trends in upgrading LPD configuration with reference to current technology. Reducing LPD value will be the key to developing the benchmark and increase the energy efficiency of the buildings in the future.

Keywords
Lighting Power Density
Energy, Efficiency
Regulation
Requirements

บทคัดย่อ

รัฐบาลไทยมีแผนที่จะบังคับใช้เกณฑ์มาตรฐานประสิทธิภาพพลังงานขั้นต่ำ (Building Energy Code - BEC) ซึ่งได้ออกเป็นกฎกระทรวงตั้งแต่ พ.ศ. 2552 โดยมีผลบังคับใช้สำหรับอาคารที่จะขออนุญาตสร้างใหม่หรือดัดแปลงตั้งแต่ช่วงกลางปี พ.ศ. 2561 เพื่อให้บรรลุเป้าหมายการลดการใช้พลังงานภายในระยะเวลา 20 ปีตามแผนอนุรักษ์พลังงานชาติ พ.ศ. 2558–2579 แต่เนื่องจากเกณฑ์ดังกล่าวได้มีการประกาศใช้มาเป็นระยะเวลา 9 ปีแล้ว แต่ยังไม่มีการปรับปรุงเพื่อยกระดับมาตรฐานขั้นต่ำให้สอดคล้องกับเทคโนโลยีในปัจจุบัน โดยเฉพาะเกณฑ์ชี้วัดประสิทธิภาพการใช้พลังงานในอาคารด้านแสงสว่าง ที่มีการกำหนดค่ากำลังไฟฟ้าสูงสุดในการส่องสว่างต่อตารางเมตร (Lighting Power Density - LPD) ดังนั้นเพื่อให้เป็นไปตามเป้าหมายของรัฐบาล จึงควรต้องมีการพิจารณาเกณฑ์ในการกำหนดค่ากำลังไฟฟ้าสูงสุดในการส่องสว่างต่อตารางเมตรใหม่ เพื่อให้สอดคล้องกับเทคโนโลยีในปัจจุบัน และเพิ่มประสิทธิภาพด้านการใช้พลังงานของอาคารให้สูงขึ้น บทความนี้แสดงให้เห็นถึงแนวคิด ที่ใช้ในการกำหนดค่ากำลังไฟฟ้าสูงสุดในการส่องสว่างต่อตารางเมตรใหม่ โดยการคำนวณด้วยสูตรอย่างง่ายร่วมกับการจำลองกรณีศึกษา ซึ่งเป็นไปตามเกณฑ์มาตรฐานของระดับความสว่างตามกฎกระทรวง 39 กำหนด เพื่อเปรียบเทียบความแตกต่างของค่ากำลังไฟฟ้าสูงสุดในการส่องสว่างต่อตารางเมตร (LPD) ระหว่างหลอดไฟทั้ง 3 ชนิดที่ได้รับความนิยมและใช้กันอย่างแพร่หลายในปัจจุบัน อันได้แก่ หลอดฟลูออเรสเซนต์ T8, หลอดฟลูออเรสเซนต์ T5 และ แอลอีดี T8 โดยผลลัพธ์จากการเปรียบเทียบแสดงให้เห็นว่าแม้แต่หลอดที่มีประสิทธิภาพในการประหยัดพลังงานน้อยที่สุดในจำนวนหลอดไฟที่ใช้การเปรียบเทียบ ซึ่งคือหลอด T8 ยังคำนวณค่า LPD ได้ต่ำกว่าที่ระบุในข้อกำหนดของ BEC เกือบ 19% และยังสามารถลดลงได้ ถึง 31% หากเปลี่ยนหลอดและอุปกรณ์อิเล็กทรอนิกส์เป็นเทคโนโลยีประเภทแอลอีดี (Light-Emitted Diode: LED) ผลจากการศึกษานี้ ไม่เพียงแต่แสดงความสัมพันธ์ในการกำหนดค่ากำลังไฟฟ้าสูงสุดในการส่องสว่างต่อตารางเมตร (LPD) กับมาตรฐานความเข้มของแสงสว่างตามกฎกระทรวง 39 แล้ว ยังแสดงแนวโน้มในการปรับลดค่ากำลังไฟฟ้าสูงสุดในการส่องสว่างต่อตารางเมตร (LPD) ด้วยการอ้างอิงจากมาตรฐานเทคโนโลยีแสงสว่างในปัจจุบัน ซึ่งจะเป็นกุญแจสำคัญในการพัฒนาเกณฑ์หรือมาตรฐานการออกแบบอาคาร และเพิ่มประสิทธิภาพการใช้พลังงานของอาคารได้ในอนาคต

คำสำคัญ
กำลังไฟฟ้าต่อหน่วยพื้นที่ประสิทธิภาพพลังงาน
ระบบไฟฟ้าแสงสว่าง
กฎหมายอาคาร เกณฑ์อนุรักษ์พลังงาน

1. Introduction

The Energy Conservation Promotion Act (ECP Act.) was first promulgated in the 7th National Economic and Social Development Plan for the year 1992-1996 (NESDP). It set the requirements on energy conservation for large commercial building in becoming mandatory (Gazette, 1995). After that, there was no energy policy in building up until the 12th NESDP for the year 2015-2021. In the current version, smaller buildings in residential and commercial sector, which used to be overlooked, become mandatory in comply with energy conservation requirement according to the new Building Energy Code (BEC). The policy in the current (12th NESDP) is also based on the Energy Efficiency Development Plan, EEDP2015 (EPPO, 2015), which is the principles of country development that contains key issues related to energy policy and plans to conserve energy and increase energy efficiency. The plan target on 30 percent reduction of energy intensity (ratio of energy consumption to GDP) within 20 years in comparison with the year 2010. It aims for overall country and also energy intensive sectors such as industrial, commercial, and residential. Accordingly, the enforcement of BEC on building sector is one of the key features of the EEDP 2015. Energy consumption in the building sector for both commercial and residential building share 23% of the country's total energy consumption (Thai-German Programme on Energy Efficiency Development Plan (TGP-EEDP), 2016). Both energy demand and consumption results in this sector is considered to be rapidly growing (Toomwongsa, 2018). Since lighting is a primary component that occupied 15-25% of electricity used in a building (Chindavanig, 2003), limiting power consumption on lighting is able to provide significant opportunity to reduce both energy consumption and operating cost for a building. Which is a key to achieve the country's energy conservation goals. Limiting power consumption in lighting in the form of the maximum allowance of Lighting Power Density (LPD), is one of an energy requirements in the BEC. However, those requirements need to be reconsidered since they were adopted and have not been updated to raise the minimum standards in line with the current technology for 9 years. Dramatically improved of current lighting technology will indicate a guideline to the new energy efficiency benchmark. Which may be the key to achieve the target of the country's energy reduction faster and more directly.

2. Objectives of study

This paper aims to point out the possibility of reducing BEC's minimum requirement value that determines the maximum lighting power density per square meter (LPD), by using the current lighting technology as a basis for the calculation. In order to provide a guideline for further improvement of Building Energy Code (BEC).

3. Concepts of the study

In order to raise the standard of LPD requirements in BEC, the changes have to not affect the level of brightness required for an area. Therefore, the minimum lighting illuminance level in ministerial regulation no.39 (see Table 2) will be firstly considered and used as the key to help estimating energy consumption in building. Lighting technology is the factor in determining the relationship between BEC and ministerial regulation, which can be clearly presented by lumen method calculation. This is an important part for obtaining the results of this study. Therefore, building regulations related to lighting design and lighting technology are the scope of this study.

3.1 Building Energy Code (BEC) and the Ministerial regulations

BEC sets the minimum energy efficiency benchmark for the designated building that are submit for construction or modification. It will monitor the use of energy from the design stage in accordance with the law, so that the building can be constructed or modified. The new BEC adopted the second revision of ECP Act in 2007 and promulgated as a part in the ministerial regulation B.E 2552 (Gazette, 2009). Prescriptive requirements for building envelope, air-conditioning, ventilation and lighting were adopted from the American Society for Heating Refrigerating and Air-conditioning Engineer or ASHRAE 90.1(ASHRAE, 2013). Amount numbers of building between 2,000-10,000 m^2 in residential and commercial sector, which are noticeably overlooked from the Royal decree B.E. 2538, will became in focus. In the enforcement plan which will start in 2018, new buildings with an area greater than 10,000 m^2 are subjected to the code. New buildings with an area between 5,000 m^2 and 10,000 m^2 will have to comply with the code in 2019. Then new and retrofitted buildings with total area greater than 2,000 m^2 must be comply with the code in 2020 (Praiwan, 2018). The new BEC limit the maximum allowance of Lighting Power Density (LPD), which revised the value and types of building from the ministerial regulation B.E 2538. In general, LPD allowance limits the total energy use in lighting for a building. Moreover, it also an indicator of a lighting system performance in a building. The smaller the LPD value shows the greater the performance of each lighting system. LPD measures in watt per square meter based on specific type of building and operating hours per day. The results from overall building area divided by the total load of lighting equipment should not be exceed the maximum allowance as shown in Table 1.

The LPD allowance specified in BEC is limiting the energy use in lighting for a building, while lighting level should be maintained according to the minimum requirement in Ministerial regulation no.39. The lighting level is described through the illuminance values recommended in Ministerial regulation no.39, which are defined as maintained illuminance values, E_m over the task area or on the reference surface to fulfil visual comfort and performance need. The average illuminance for each task should not fall below values given in Table 2. All value of illuminance specified in ministerial regulation no.39 (Gazette, 1994), were adopted from ISO 8995:2000/CIE 008/E-2001.

3.2 Lighting calculation

From the above data, it can be seen that BEC and ministerial regulation has its relation. In order to calculate the Lighting Power Density - LPD, it is important to define the number of luminaire that maintains restrict light level first. The most widely used method is a formula called "lumen method" as shown in the following equation 1.

$$\mathrm{E\ (lux)} = \frac{\Phi(\mathrm{lumen})\times \mathrm{n}\times \mathrm{N}\times \mathrm{CU}\times \mathrm{MF}}{\mathrm{A}(m^2)} \quad (1)$$

The lumen method is a simplified method to calculate light level (illuminance, E) in a room, together with the total numbers of both lamps (n) and luminaire (N) for uniform light in a defined area (A) at the same time. Luminous flux (Φ) is the quantity of luminous energy per unit area in lumen (lm). In general, lumen output of each luminaire is provided by manufacturer in luminaire data sheet. Maintenance factor (MF) is defined as the ratio of illuminance produced by the

Table 1. Maximum allowance lighting power density of 3 groups of building types.

Type of buildings	Group 1 Office, Educational	Group 2 Theater, Convention Hall, Place of entertainment service, Department store	Group 3 Hotel, Hospital, Condominium
Operate hours/ day	9 hrs. (8.00-17.00)	12 hrs. 10.00-22.00	24 hrs.
Ministerial B.E. 2552	$\leq$ 14 W/m^2	$\leq$ 18 W/m^2	$\leq$ 12 W/m^2

Source: Gazette, R. T. G. (2009). Ministerial Regulation Prescribing Type or Size of Building and Standard, Criteria and Procedure in Designing Building for Energy Conservation B.E. 2552.

lighting system after a certain period to the illuminance produced by the system when it is new. MF is based on how often the lights are cleaned and replaced. It can be accounted such factors as decreased efficiency with age, accumulation of dust within the fitting itself and the depreciation of reflectance of walls and ceilings age. MF values lies between 0-1, however, it is usually given as three options: clean room (0.8), normal room (0.67) and very dirty room (0.5). Co-efficient of utilization (CU) or Utilization Factor (UF) is the efficiency of a luminaire in transferring luminous energy to the working plane and it is unit less. CU is affected by type of light, light fitting, color surface and reflectance of walls and ceiling, mounting height of lamps and area to be illuminated. However, CU value can be determined by selecting from luminaire's coefficient of utilization index table, provided by luminaire's manufacturer. Typically, for white painted room, its value lies between 0.4 and 0.6 for direct fittings and it varies from 0.1 to 0.35 for indirect fittings (IESNA, 2011). In terms of lighting design, this method is often used to determine the number of specific bulbs or luminaires that are considered to be used for uniform light in a defined area. By specifying the required illuminance level according to the regulation from Table 2, numbers of fixtures can be identified by substitution all known values in equation 2.

$$\mathrm{N} = \frac{\mathrm{E} \times \mathrm{A}}{\Phi \times \mathrm{CU} \times \mathrm{MF}} \tag{2}$$

Total numbers of fixtures give also the total wattage of fixtures for a defined area, by multiply total number of fixtures and the fixture wattage consumption. However, beside lighting fixtures, other lighting equipment supporting each fixture e.g. transformer or ballast must be taken into account, since they are also consuming some electric power. Technically, total wattage (W) of all lighting appliance by a defined area in square meter (m^2) represents the total load of lighting power as show in equation 3.

$$\mathrm{LPD} = \frac{\text{total wattage (W)}}{\text{Area } (m^2)} \tag{3}$$

Table 2 Minimum lighting illuminance level, specified by type of area

	Location (Type of Area)	Illuminance Level, E_m (Lux)
1	Parking	50
2	Corridor (Common Housing Building)	100
3	Room (hotel, Common Housing Building)	100
4	WC (industrial plant, school, hotel, office, theater, Common Housing Building	100
5	Theater (audience sitting place)	100
6	Corridor (industrial plant, school, hotel, office, place of treatment)	200
7	Public transportation terminal (passenger waiting area)	200
8	Industrial plant	200
9	Department Store	200
10	Market	200
11	Wash room and toilet (theater, place of treatment, public transport terminal, department store, market)	200
12	Library, study room	300
13	Conference room	300
14	Working area in office	300

Source: Gazette, R. T. G. (B.E. 2537). Ministerial Regulation No. 39 (B.E. 2537)

3.3 Lighting technology

Globally, lighting technology and devices has been improving in the last decade with low energy consumption, high lumen package and longevity maintenance. Especially Light Emitting Diodes (LEDs), advantages of LED including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching. It has been proved by many case studies and recommended by all sustainable and green building certified programs. The Electricity Generating Authority of Thailand (EGAT), led the campaign to change from incandescent bulbs which consume at least 60 watts to 46 and 36 watts fluorescent over 20 years. Since then, fluorescent tube become fundamental for lighting in both household and public building. Until the last 5 years, EGAT has been promoting the adoption of LED devices instead. However, Fluorescent tubes are remaining widely use in Thailand compare to LED mainly because of the initial price are much lower. In order to present that the LPD values can be configure lower even with the current lighting technology. The comparison is therefore based on fluorescent tubes, that is the most commonly used in Thailand for more than 20 years, and the LED retro-fit tube, which is gaining popularity and having the market share of up to 52% (MGRonline, 2017). The popularity of LED retro-fit is mostly from the advantage of the least modification in case of changing from conventional lighting on the existing lighting fixture.

3.3.1 Fluorescent tube

Fluorescent lamp is a low-pressure mercury vapor gas discharge lamp, which convert electrical energy into standard visible light by ionizes mercury vapor, producing UV light that causes a phosphor coating on the glass tube glow. Fluorescent tubes are categorized according to their wattage, shape and diameter, typically identified by a code “Tx”, where T is for tubular shaped and x is number indicates the tube diameter in $^{1}/_{8}$ inches. Currently, the most commonly use in Thailand is either T8 or T5. Both are account as an energy-saving lamp with high efficiency. In fact, T5 tubes are 40% smaller than T8 tubes, and are 7-15% more efficient than standard T8. In other words, more T8 tubes are needed to produce the same amount of light generated by significantly fewer high output T5 tubes. T5 tubes have a lower mercury content, potentially reducing disposal cost and more eco-friendly. The significant disadvantage of T5 is the differ in length and socket size from T8, and they also generally cost more, which lead to limit used of T5 tubes to niches application or new construction. In the fluorescent lighting system, a ballast is required to regulate the currents flow through the lamp and provide sufficient voltage to start the lamp. Ballast is available in two types, conventional magnetic ballast and electronic. Though, both types are use in Thailand but the conventional one is more popular because of the much lower price. However, the electronic type was claimed of the greater advantage in energy saving and longer lifetime. Lighting fixture with fluorescent tubes and specular louver is mostly use for general lighting in educational building, office space and other premises, because of its effective in maintaining a high degree of anti-glare protection, its uniformly illuminates for the whole space and the efficiency of energy saving.

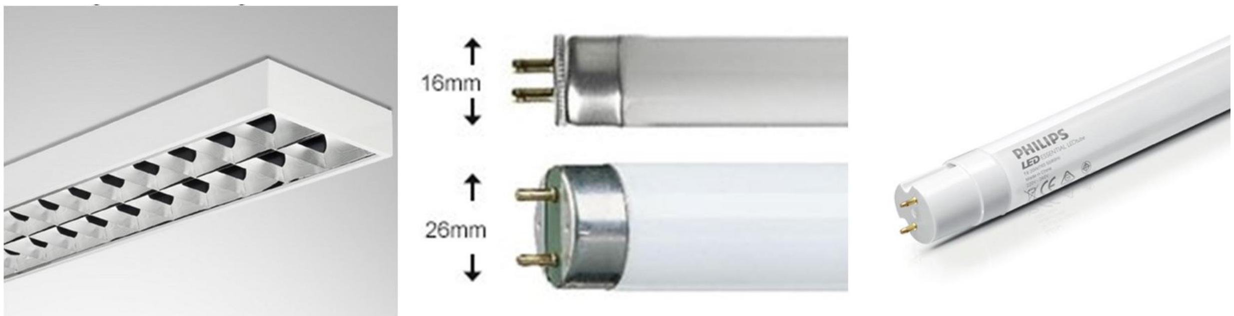
3.3.2 LED Fluorescent Retro-fit

Light Emitting Diode (LED) is a semiconductor light source that emits light when current flows through. LED is considered as electric energy converter, emitting much more of their input energy. LED modules are typically small in size; thus, they were developed into varieties of conventional bulb shapes in order to replace those of incandescent bulb, halogen bulb, compact fluorescent bulb or fluorescent tube. LED replacement bulbs are often called “retro-fit”. Retro-fit is a term often used for those conventional shape converted light sources from outdated lighting technologies such as halogen, incandescent or fluorescent to a newer energy efficient technology like LED system. Therefore, LED fluorescent retro-fit is a complete set of LEDs and hardware in a form of typical commercial fluorescent tube (T8, T5) that are able to be used as a replacement tube for existing lighting fixture. Advantages of using LED retro-fit tubes comparing to fluorescent tubes are both evidentially better in terms of eco-friendly and energy efficiency. LED tubes contain no hazardous chemical unlike fluorescent tube. They are typically made of durable plastic and aluminum that cannot be shattered, which means that they are safer for both human and environment. Moreover, the technical development of LED tubes has been fast throughout their entire marketing period. In terms of energy efficiency, it can be described by luminous efficacy, which is a measure of how much a light source produce visible light for a given amount of electric power. At present, luminous efficacy of LED had reached 150 lm/W., which is 60 percent brighter than conventional T8 tube and it is reaching 200 lm/W of luminous efficacy recently without compromising on light quality (Philips, 2013). Theoretically, LEDs 4000K can be reaching more than 300 lm/W (DIAL GmbH, 2016). Thus, the average luminous efficacy of LED luminaires will certainly continue to improve. It can be said that LEDs is the most energy efficient at the moment. LED retro-fits are available in fluorescent tube style in both T8 and T5 tube. However, LED T8 tube is much more commonly employed compared to T5 tube, since T8 is considered as the standard size and typically be installed in place of former fluorescent tubes in compatible luminaires with consideration of manufacturer and lamp-specific restrictions. Due to the differences in diameter and total length of LED T5, interchange between T5 and T8 is not an ideal replacement.

4. Research Methodology

In order to illustrate the possibility of reducing the allowance value of LPD without causing insufficient light, requirement of light level per area according to ministerial regulation No.39 is concerned as a base illuminance. The total LPD will be calculated with the up-to-date lighting technology system. Results will show the different between the calculated values and the restricted value, which is able evaluated how to reduce the allowable LPD value. As a case study, an educational building was chosen with the minimum standard classroom size as specified in Private school Act B.E. 2550 (Gazette, 2007). The minimum of classroom area is 48 m^2, or a rectangle room with 3.0 m. height (Gazette, 2000). The classroom was assumed to be painted all in white, table (work plane) height is 0.8m. from the floor and the luminaire is mounted on the ceiling surface, which gives the room index of 1.6. The total load of lighting equipment should not exceed the maximum allowance of 14W/m^2 as specified in group 1 (Table 1). A classroom requires the illuminance at least 300 lux (Table 2), which is the highest illuminance specified in the regulation that will clearly show the possibility of reducing LPD value even with the high illuminance requirement. Modular fluorescent fittings for ceiling surface mounted is the typical fixture using widely in educational buildings and offices for general lighting (see Figure 1). This modular fitting requires 2 of T8 fluorescent lamps. In order to compare the results even from the slightest modification, which can be applied in any existing building. This case study therefore chose to compare only by replacing lamps without changing the fixture. Thus, selection of lamps is based on the equivalency to T8 fluorescent lamp whether in length or sizing that able to fit in the fixture.

Number of fixtures can be precisely calculated by lumen method which gives precise number of the installations will be perform with three types of fluorescent tube light, magnetic ballast and electronic ballast were selected under the same brand to ensure the same factory quality for the efficiency comparative study. CU value can be referred from the CU index table which can be found in IES handbook, together with the computed value of room index of 1.6 and the type of luminaire used, which is 0.46. While MF is set to 0.67 or normal room. The above specification and factors can be summarized in Table 3.



Source: Retrieved from http://www.lighting.co.th/product/ledlelsst300, http://www.lighting.philips.com

Figure 1. (left) Ceiling mounted fluorescent fixture, (middle) T8, T5 fluorescent tubes, (right) LED T8 retro-fit

Table 3 Criterion of an example of a classroom with $48m^2$

LPD allowance (W/m^2)	14
min. Illuminance (lux)	300
Area (m^2)	48
max. wattage allowance (W)	672
co-efficient of utilization factor	0.46
maintenance factor	0.67

The highest wattage for T8 fluorescent lamps that can be found in Thai's market is 36W. Which perfectly fit for T5 fluorescent lamp 28W with adaptor. and LED T8 16W Replacing lamps in existing fittings with LED equivalents is one of the easiest ways to make energy savings. As shown in Table 4, there are technical data of (1) Philips TL-D LifeMax Super80 36W with HF Performer ballast, (2) Philips TL5 Essential HE Super80 28W with TL5 electronic ballast and (3) Philips Essential LED T8 16W.

From the above table, the total number of lighting fixture can be determined by performing equation [2]. Multiplying the result and the combined wattage of a lighting fixture and ballast in Table 4 will give the total electric power use for the area. To defined LPD, total power used is divided by the combined area with same type of area usage by using equation 3.

5. Result and Discussion

Based on the minimum lighting illuminance requirement at 300 lux in Table 2, all selected fluorescent tubes in Table 4 have lower LPD values than the specified requirement of 14 W/m^2 and even less than the lowest allowance value at 12 W/m^2, as presented in Table 1. Number of luminaires needed calculated by lumen method for all tubes are also less than the estimation, especially the LED T8. Based on the maximum wattage allowance at 672 watts, T8, T5 and LED T8 tubes saving electric power 19%, 24% and 31% respectively.

Table 4. Specification of selected fluorescent tubes with compatible devices and criterion.

Lighting fixture and device	Specification	TL-D (T8)	TL-5 (T5)	LED T8
Lamp	Wattage	36	28	16
	Lumen/Watt	90	94	100
	Total Lumen	3240	2632	1600
	Price/Piece (Bath)	90	105	350
Ballast	Magnetic	3.74	-	-
	Electronic	-	2.1	-
Fixture	**Total Lumen/watt**	**6480**	**5264**	**3200**
(2 lamps+1 ballast)	**Total wattage**	**75.74**	**58.1**	**32**

Table 5. Results of each selected fluorescent tubes from equation 1-3.

Calculated results of each fixture	TL-D (T8)	TL-5 (T5)	LED T8
Actual wattage used (W)	546.11	515.69	467.23
Estimate number of luminaire (by maximum wattage allowance)	8.87	11.57	21.00
Total number of luminaire needed by lumen method	7.21	8.88	14.60
Total LPD (W/m^2)	11.4	10.7	9.7

Table 6. Comparison of LPD values in 7 countries building code

Country	Code/ Standard name	LPD (W/m^2)
Thailand	Building Energy Code B.E.2552 (BEC)	14
Singapore	Singapore Standard (SS 531-2)	12
India	Energy Conservation Building Code (ECBC)	11.2
USA	The American Society of Heating, Refrigerating and Air-Conditioning Engineers(ASHRAE)	9.4
China	The China Design Standard for Energy Efficiency in Public Building (GB50189)	9
Australia	Green Star- Performance V.12	8

Source: United State-ASHRAE Standard 90.1-2013; Australia-Green star performance V.12; China-GB50189; India-Energy Conservation Building Code(ECBC); Singapore Standard SS 531-2; Thailand-BEC B.E.2552

Since BEC adopted requirements from ASHRAE standard, it is interesting to compare the allowance value with the original source as well as other countries in Asia to evaluate possibility to reduce the value for more energy efficiency. Table 6 below shows different LPD allowance for classroom from 7 countries. Based on the results it can be assumed that, indirectly, LED lighting devices are compulsory in order to meet the requirements for the US, Australia and China, while in India and Singapore, using only conventional T8 tubes in a project may result in over LPD limited. These clearly illustrate that the LPD requirement used in a building is not only limit the use of electric power in a building but also the type of light sources and devices maintenance. In comparison, Thailand has the highest LPD allowance among the others. This also means the least efficiency. However, the more potential of reducing power consumption can be done by lowering LPD allowance to at least meet the minimum lighting intensity requirement. At the very least, to ensure that there is no over-power lighting installation and limit types of tubes to be more efficient.

6. Conclusion

With the dramatically improvement on lighting technologies and the implementation of synergistic design approaches, it could be expected that the average luminous efficacy of LED luminaires will certainly continue to improve. Accordingly, LPD allowance in BEC are proven to be able to tighten down. As the case study of the class room, LPD can be reduced from 14 W/m^2 to 11.5 W/m^2 based on the calculation of conventional T8 tube. With the different of 2.50 W/m^2, it can be accounted for 18% reduction from the based LPD allowance at 14 W/m^2. Consider reducing the LPD allowance with the same proportion to other group of building type, 3.2 W/m^2 and 2.6 W/m^2 are the reduction for group 2 and 3 respectively. Based on the same strategy, suggestive LPD allowance revision for T5 and LED-T8 are also shown in Table 7. This is an example guideline for updating LPD allowance according to today's lighting technology. Moreover, this is also indirectly indicating that requirements in BEC should be considered on reviewed more frequently based on technology development.

Table 7. LPD allowances guideline based on the calculation of 3 lighting technologies results.

LPD Allowances Guideline	Group 1 Office, Educational	Group 2 Theater, Convention Hall, Place of entertainment service, Department store	Group 3 Hotel, Hospital, Condominium
Based on Ministerial B.E. 2552	$\leq$ 14.0 W/m^2	$\leq$ 18.0 W/m^2	$\leq$ 12.0 W/m^2
Suggested LPD based on T8	$\leq$ 11.4 W/m^2	$\leq$ 14.8 W/m^2	$\leq$ 9.8 W/m^2
Suggested LPD based on T5	$\leq$ 10.7 W/m^2	$\leq$ 13.9 W/m^2	$\leq$ 9.2 W/m^2
Suggested LPD based on LED-T8	$\leq$ 9.7 W/m^2	$\leq$ 12.4 W/m^2	$\leq$ 8.3 W/m^2

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