Proposal for Energy Saving at the University of Colombo

Report 1: Lighting

Summary

To be the first green university in the country, the Vice-Chancellor, Professor Lakshman Dissanayake initiated a few actions to minimise the energy consumption, use of renewable energy, and recycling of waste at the university premises. This report is focusing on minimising the energy waste and harmful materials by lighting system in the University premises. As a preliminary step, this report is proposing to replace available Florescent and CFL bulbs with LED bulbs. The cost of such replacement will be paid back within a year or two. Also, it is proposing to install motion and light sensors to minimise the usage time of light bulbs at isolated places. Further, the report suggests to study the lighting requirement at each institution, plan, and decide the specification of bulbs that they need. It is important to purchase, reliable long lasting products rather than cheap, poor quality products.

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1.0 Introduction:

The University of Colombo is the oldest university in Sri Lanka. The university will celebrate its 150th anniversary in the year 2020. At the moment over 15,000 students and a few thousand academic and academic supporting staff use the university facilities daily. As a metropolitan university, the University of Colombo has to face many challenges in its infrastructure development. Limited space, restrictions of constructions, policies of various organisations have restricted the expansion of the University and its activities. In recent years, under the guidance of the Vice Chancellor, Senior Prof. Lakshman Dissanayake, University of Colombo is promoting the concept of sustainable development and becoming the first Green University of Sri Lanka.

1.1 Green University

The term **"green university**" is commonly used in the world to promote activities under the vision of "sustainable development." It also represents a significant responsibility undertaken by higher education institutions for the development of society.

The "green university" concept is becoming more and more popular lately, and the world's leading universities (Oxford, Harvard, and the University of Singapore) are practising it for some time. The concept of 'Green University' implies introducing separate waste collection and energy-conservation systems, including programs into their curricula on sustainable development, promoting ecological awareness to students and staff, etc...

The initial purpose for the development of "green university" is to reduce the adverse influence on the environment caused by the operation of university system since it uses a large amount of electricity, oil, gas, water, chemicals, and other resources. A university with a large campus and many students take more resources than a simple community and institution, or some enterprises. Besides, a large number of wastes, wastewater, chemicals, and poisonous wastes are produced during the operation of a university, causing environmental problems for the campus and its neighbourhood.

Therefore, the fundamental task for the early development of green university is to reduce the impact of environmental problems on the campus and community.

1.2 Purpose of this report

It says that on average, inside a large university building of about 30% to 40% of energy is used for lighting. Apart from electricity consumption, each year universities must spend a few hundred thousand rupees in replacing bulbs. Table 1 shows the expenditure for replacing bulbs in 2017 and 2018 until the end of September. If the available bulbs can be replaced with energy efficient, long-lasting bulbs, the university can save a considerable amount of money and contribute to minimising waste of energy. Therefore, as the initial step, this report discusses the possible ways of reducing the energy usage of the university premises by selecting proper lighting guidelines.

Table 1: Bulb replacing expenditure of the University of Colombo in 2017 and 2018

	2017			2018 (till September)		
Florescent (2 ft)	1500	LKR	145,415	0	LKR	-
Florescent (4 ft)	2500	LKR	234,990	0	LKR	-
T8 LED (2 ft)	30	LKR	17,850	100	LKR	55,000
T8 LED (4 ft)	275	LKR	189,200	250	LKR	170,000
LED	780	LKR	327,580	1350	LKR	624,375
CFL	1200	LKR	608,900	900	LKR	496,850
Incandescent	800	LKR	43,200	0	LKR	-
Total	9102	LKR	1,567,135	4618	LKR	1,346,225

2.0 Lighting

According to Wikipedia "**Lighting** or **illumination** is the deliberate use of light to achieve a practical or aesthetic effect. Lighting includes the use of both artificial light sources like lamps and light fixtures, as well as natural illumination by capturing daylight." As a metropolitan university located in the middle of the capital, the university has a less choice in designing buildings. As a result, the use of natural light and ventilation in university buildings is minimal. As such, the university has to depend on electricity for lighting and ventilation. Selection of suitable lighting source depends on a few measurable parameters.

2.1 Measurement of Lighting

2.1.1 Electricity consumption

Electricity consumption of a bulb is given in Watts (J/s). However, the wattage of a bulb is not an accurate measure of determining the efficiency of a bulb. Both electricity consumption and the luminosity should be considered for a better estimation of the efficiency of a light bulb-

2.1.2 Luminosity

Candela is the base unit used to measure the luminous intensity of the light by a point light source. The luminous flux emitted by a light source in SI units is given by Lumens. Lumens is a measure of the total quantity of visible light emitted by a source. If a light source emits one candela of luminous intensity uniformly across a solid angle of one steradian, the total luminous flux emitted into that angle is one lumen (1 cd·1 sr = 1 lm). However, for practical applications, we need to know the luminous flux per unit area, which is measured by the SI unit Lux. Depending on the distance and angle to the light source the value of flux per unit area is changed. The Lux value for various natural sources is given in table 1.

2.1.3 **Lighting Efficacy (LE):** the quotient of the total lumens emitted from a lamp or lamp/ballast combination divided by the watts of input power, expressed in lumens per watt.

2.1.4 Lifespan

The lifespan of a bulb is a significant factor in deciding the cost-effectiveness of a bulb. However, lifespan depends on various factors such as a number of switches ON/OFF operations, current, voltage, and environmental factors.

2.1.5 Colour rendering index

Colour rendering index is a measure of the quality of light emitted by the source. If the colour emitted by a source is uniform within the visible range, the user can identify the colour of an object accurately. Daylight has CRI value of 100.

2.1.6 Colour temperature

The light colour of a lamp is defined regarding its colour temperature in degrees Kelvin (K). There are three main colour groups: warm whites < 3300 K; neutral whites 3300 K - 5000 K and daylight whites > 5000 K.

2.1.7 Cost-effectiveness

Before the replacement of the already available system, cost-effectiveness should be evaluated. It gives, the profit/loss of replacing an available system with a new one.

2.2 Lighting requirement as per standards

The luminous flux per unit area for natural lights are given in table 2. The sunlight has the highest Lux value of about 32 to 100 kLux and CRI value of 100. Any artificial light that comes close to CRI value of sunlight is considered as a good light source.

Table 2: Lux value of natural lights

Natural Light Condition	Typical Lux
Direct Sunlight	32,000 to 100,000
Ambient Daylight	10,000 to 25,000
Overcast Daylight	1000
Sunset & Sunrise	400
Moonlight (Full moon)	1
Night (No moon)	< 0.01

The lighting conditions that required for day to day life is defined by the International standards EN 12 464-1 of workplaces – Part 1 (Indoor workplaces) and EN 12 464-2 – Part 2: Outdoor workplaces. Table 3 gives the essential lighting requirements for educational and office space as per above standards. As per European standards, lecture halls and libraries need a Lux value of 400 on the work table. Offices and conference rooms need a Lux value of about 320 and places like lobbies where people meet each other need at least 320.

Table 3: Lighting requirements at different places

Building Type	**Space Type**	**Average Illuminance at working level (Lux)**	**Measurement (working) Height m**
Residential	Bedrooms	300	0
Educational Building	Playroom, nursery, classroom	400	0
	Lecture hall	400	0.75
	Computer rooms	400	0.75
	Classrooms (general use)	240	0.75
	Auditorium	240	0.75
	Meeting area	320	0.75
Office Building	Offices	320	0.75
	Boardroom	240	0.75
	Conference room	300	0.75

3 Lighting Sources

In Sri Lanka lighting is mainly done using, incandescent, fluorescent, CFL and LED. Apart from the sources mentioned above, for places that need brighter lights such as stadiums, outdoor activities, security posts etc. use of halogen lamps and various types of bulbs also a common practice. Due to the energy loss and poor lighting condition use of incandescent bulbs in residential and office buildings are not any more common in Sri Lanka.

3.1 Florescent bulbs

Florescent lights are commonly used in areas, where brighter lights are essential such as offices, classrooms etc. Florescent lights compared with its predecessors' incandescent bulbs consumed less energy. However, there are a few drawbacks of them. The major issue of them is the emission of UV radiation. Even though the amount of UV emitted by a bulb is not very high for a person sitting under fluorescent lights per longer duration, there is a possible health risk.

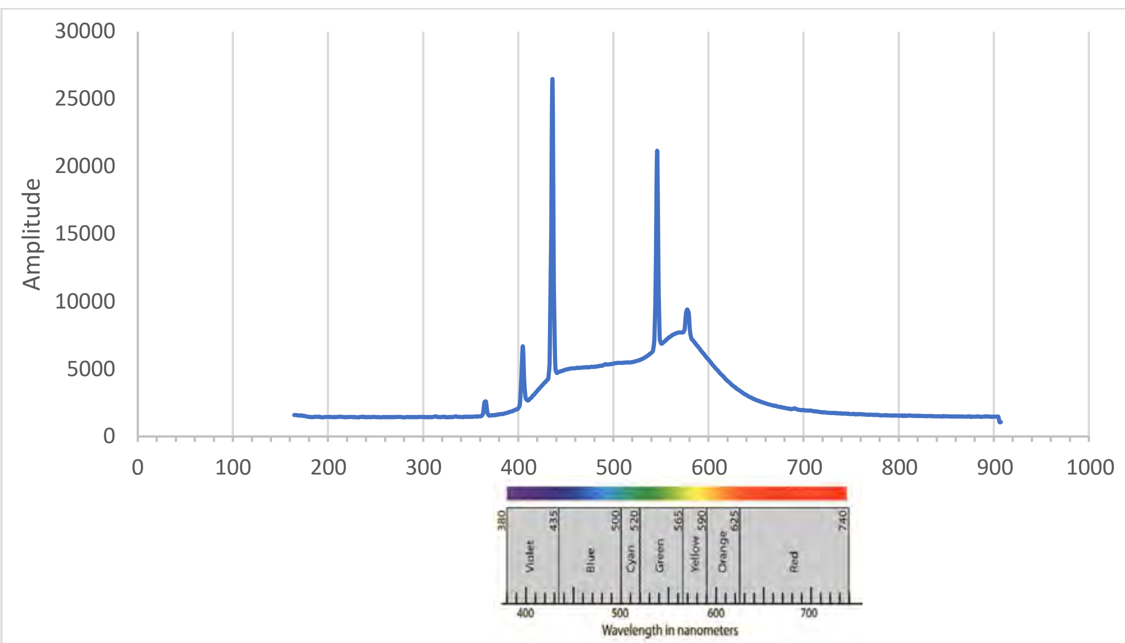


Figure 1: Frequency spectrum of the Florescent bulb (4 ft)

As shown in figure 1, a small UV peak is visible at the spectrum. Also, the spectrum of the bulb shows some peaks and violet, blue, green, and yellow regions. This makes the colour recognition under the bulb is poor. Even though the bulb is rated for 40 W, it consumes energy up to about 50 W. Also, higher energy consumption at the initial stage makes them not suitable for places that need lighting for a short duration.

Further, they are not dimmable and not ideal for lecture halls equipped with multimedia facility. Also, the lifespan of fluorescent bulbs is shorter and can be reduced further for the frequent switch on/off action. Also, the cold start time of Florescent bulb is longer.

3.2 CFL Bulbs

CFL was introduced as a solution to address a few issues of the fluorescent bulbs. They are comparatively energy efficient and can be used as with dimmers in some cases. However, the issue of UV radiation is still there. The frequency spectrum of the CFL bulb is given in figure 2. It can be seen that there are a small UV component and some peaks at a few wavelengths. This makes the colour identification under the CFL light is weaker than fluorescent bulbs. Even though the lifespan of CFL is said to about 8,000 hrs, in practice, they are varying from 2,000 to 4,000 hrs. Frequent switching off/on operations reduces the lifespan of CFL bulbs. Same as Florescent bulbs, CFL takes some time to deliver the maximum brightness.

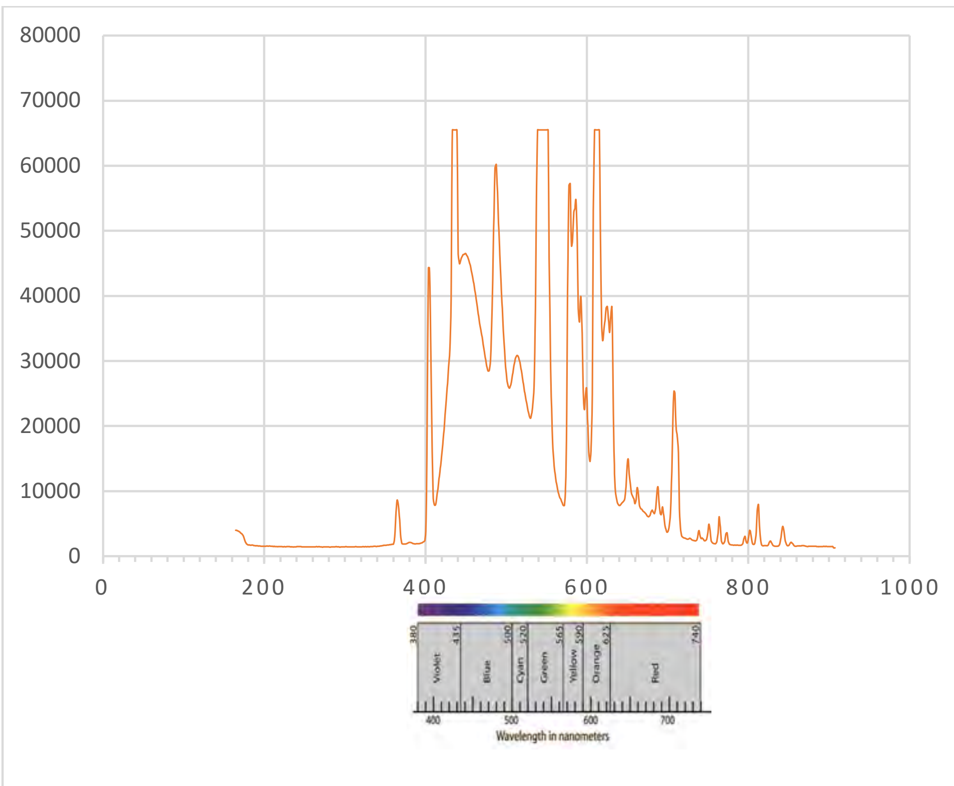


Figure 2: Spectrum of CFL bulb

LED Bulb

Bulbs have higher energy efficiency than both above types. Also, the average life span of LED bulbs is longer than the other types. Presently the initial cost of replacing LED bulbs are relatively expensive than the other two types. Figure 3 shows the spectrum of LED bulbs. As it can be seen in figure 3, there is no UV component of LED bulbs. Also, the spectrum is more or less continuing except a single peak at a blue region. As a result, the colour rendering index of LED bulbs is better than other types. Further, the lifespan of LED bulbs is higher than that of the other two competitors. It varies from 25,000 to 50,000 hrs. However, it should be noted that increasing current through LED bulbs may shorten the life of them. CRI value of LEDs varies from 80 to 100 for high-quality brands. Cheaper brands available at the market has a lower CRI value and lower life expectancy. There is no cold start time for LED bulbs.

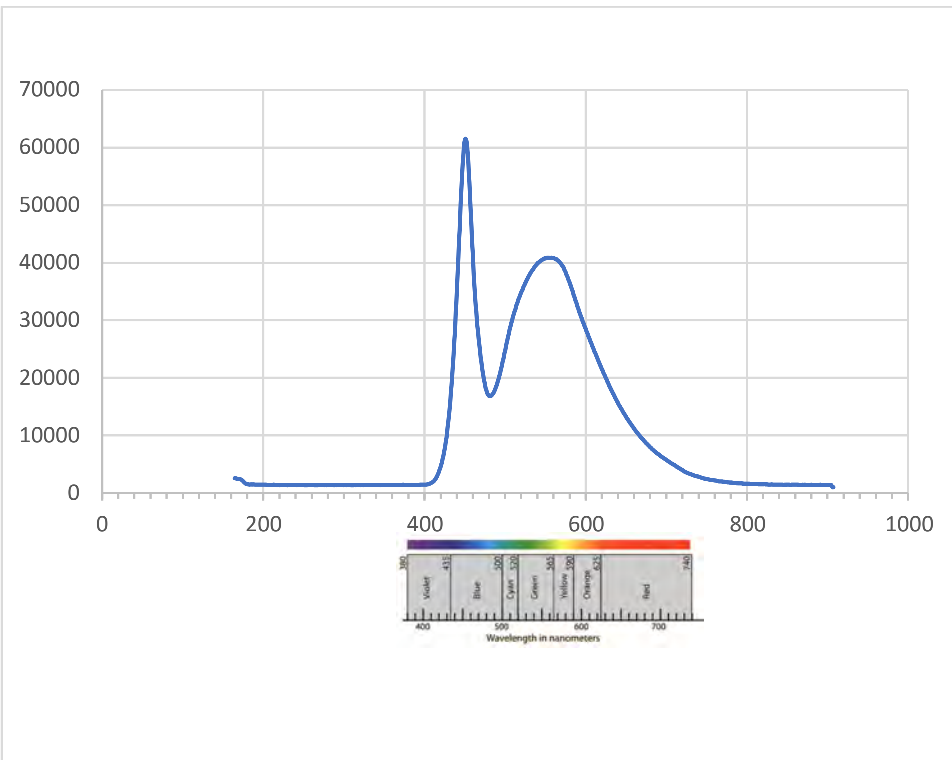


Figure 3: Spectrum of LED bulb

4 Selection criteria for suitable light

To select energy and cost-effective solution for lighting a few parameters needed to be considered.

- Light output – Requirement of light varies from place to places. As given in table 3, the required light output should be decided. If there is natural light available at the place, it should be taken in to account in selecting the light output.
- Input wattage – The wattage of the light should be decided depending on the light output and the type of bulb.
- Efficacy (lumens per watt) – Should be calculated using the above two parameters.
- Rated service life – Should be given by the manufacturer. This information is useful in calculating the cost-effectiveness of the bulb.
- Size – This should be decided depending on the place, view, the size of the area etc.…
- Colour characteristics – This depends on the usage of the light. For places such as reading areas, offices, we should select daylight bulbs. For places like living rooms, dining rooms, verandas, use of warm light or cool light is suitable.
- Electrical operating characteristics – The user should carefully decide the operating aspects of the place. For example, whether the lights are going to switch on/off frequently, lights need to be dimmed, the area needs more directional lights, flood lights etc.…
- The requirement of additional equipment – Depending on the operation, the user should decide the necessity of additional equipment such as dimmers, motion/light sensors, two-way switches covers, reflectors etc..
- Compatibility with the electrical system – Selected product should be compatible with the electrical system.
- Suitability for the operating environment – User should carefully decide the place where the bulbs are going to fix. For sites open for rainwater, dust, humidity etc. user should select the product to comply with correct IP numbers. Also, the user should choose the right products for indoor and outdoor, wall lamps or ceiling lamps, pendulum type or sunk type etc..

5. Observation & Recommendations

5.1 Observations

- Expenditure for the electricity bill
  The University of Colombo spends over a few million rupees annually on the electricity bill. Even though there is no record to identify the contribution by lighting on the bill, generally it should be about 30% to 40% of the total bill. Minimising the energy waste, the University of Colombo can reduce the electricity bill and contribute to the environment protection.
- Discarded bulbs
  The university annually spends about 1.5 million rupees in replacing old bulbs. In the year 2017 alone, the university has replaced 5200 CFL and Florescent bulbs. The fate of the discarded bulbs remains a problem to the University. There is no proper mechanism for collecting discarded CFL and Florescent bulbs at the university.
- Use of inappropriate lighting
  Use of bulbs of wrong flux density (Lumens/m^2) was observed at many places. As given in table 3, bulbs with correct flux density should be selected.
- Difficulty in finding switches
  Some places switches are located at inaccessible places. As a result, switching off lights is not possible, and they are switched on without any use.
- Use of inappropriate switching techniques
  In certain situation, the use of two-way switches is necessary. For example, at a staircase or a long corridor, the light should be able to switch on/off at both ends. In lecture halls, and rooms switching off lights should be able to do by a single main switch.
- Lighting of unattended places
  This is a major problem that was observed. In some isolated areas of the university, lights are switched on for a few days. Use of motion sensors can be minimised energy waste at such places.
- Lighting during daytime
  It was observed that places with good natural lighting are lighted by electrical bulbs. Energy waste at such places can be minimised by using motion sensors
- Poor selection of colours
  Use of bright colours (especially to ceiling) can improve the lighting condition at dark areas.
- Selection of wrong bulbs
  Bulbs should be selected with the correct rating. Outdoor lamps should be able to withstand for rainwater and dust.
- Issues of discarding CFL and Florescent bulbs
  Since both CFL and Florescent bulbs contain mercury as a substance, discarding them should be done carefully. At the moment there are a lot of bulbs are left for

Figure 4: Discarded Florescent bulbs at the Department of Physics Premises

5.2 Recommendations

I. Use of natural light
Use of natural lights always a good solution for minimising energy consumption. Buildings should be designed to maximise the benefit of natural lights and ventilation. Sustainable energy authority of Sri Lanka has prepared a code of conduct in designing energy-efficient buildings. Unfortunately, the limitation of space is a problem in designing a building as specifies in codes of conduct.

II. Use of environment-friendly bulbs
It is a known fact that CFL and Florescent bulbs contain mercury and phosphorous. Each 4 feet Florescent tube contains about 10 mg of mercury while a CFL bulb contains about 3 – 5 mg of mercury. They need to be recycled to avoid releasing mercury into the environment. The issue of electrical wastage can be minimised by using bulbs with a longer lifetime. Even though CFL bulbs are said to be having about 8,000 hrs of a lifetime, they usually failed within 2,000-4,000 hrs of a lifetime. Frequent switching off/on operations shorten their lifetime. LED bulbs are the one with the longest lifetime of 25,000 – 50,000 Hrs.

III. Use of proper interior colours
Dark interior colours are always difficult to illuminate. Use of bright colours especially for ceiling or use of reflectors will make the place brighter. Select of correct colours without harming the architectural value of the structure is advisable.

IV. Use of energy saving lights
Use of long-lasting energy efficient bulbs will help to reduce the electrical bill and the bad effects on the environment. Annexe D has given the cost-effectiveness of replacing available CFL and Florescent bulbs with LED.

V. Use of sensors

It is always advisable to install motion/light sensors at places with no monitoring to switch off/on bulbs. Lighting of common places such as corridors, lobbies, washrooms is less monitored. As a result, bulbs of those places are continuously switched on. Use of motion sensors will help to minimise the time of switch on. Also, mot of outdoor places such as roads, terraces, balconies are illuminated with high wattage bulbs and are less monitored. Use of light sensors will help in minimizing the energy wastage of such places.

VI. Selection of bulbs with correct specifications
The market is flooded with many low-quality products at a low price. Therefore, selection of the bulb should be done very carefully. The user should specify the quality of the product that he/she expects very clearly.

VII. Appoint a committee for evaluating needs for lightning
It is advisable to appoint a committee to address the selection issue of lightning at each institution. The selection process may not be the same for everywhere. Depending on the structure, requirements, preferences of individual there might be a big difference in selection. Therefore, individual institution should appoint a committee to recognise their lighting requirements.

VIII. Replacing Fluorescent with LED
As the initial step, it is strongly suggested to replace all Florescent and CFL bulbs with LEDs. As shown in Annex D, the initial cost of replacement can be covered within one year.

IX. Selection Criteria
Please refer the Annex F

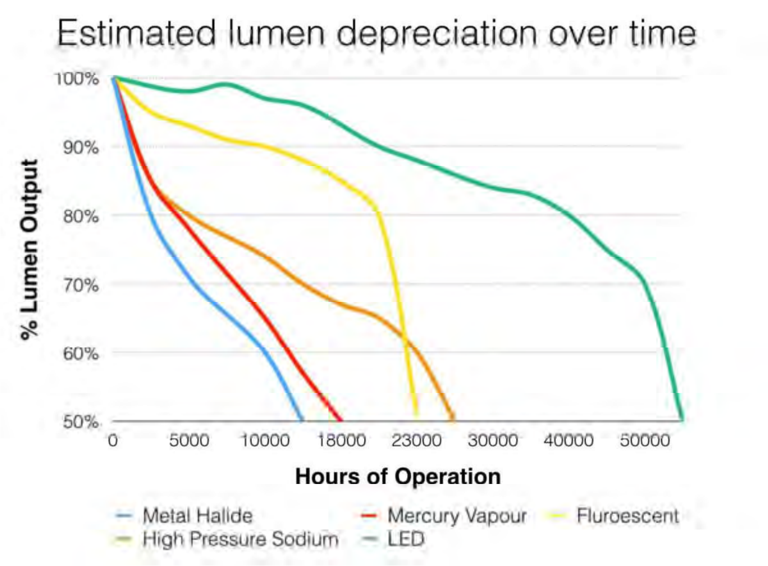
Annexe A: Electricity consumption of different bulbs for a given brightness

Lumens (Brightness)	LED Watts	CFL Watts	Incandescent Watts
400 – 500	6 – 7W	8 – 12W	40W
650 – 850	7 – 10W	13 – 18W	60W
1000 – 1400	12 – 13W	18 – 22W	75W
1450-1700+	14 – 20W	23 – 30W	100W
2700+	25 – 28W	30 – 55W	150W

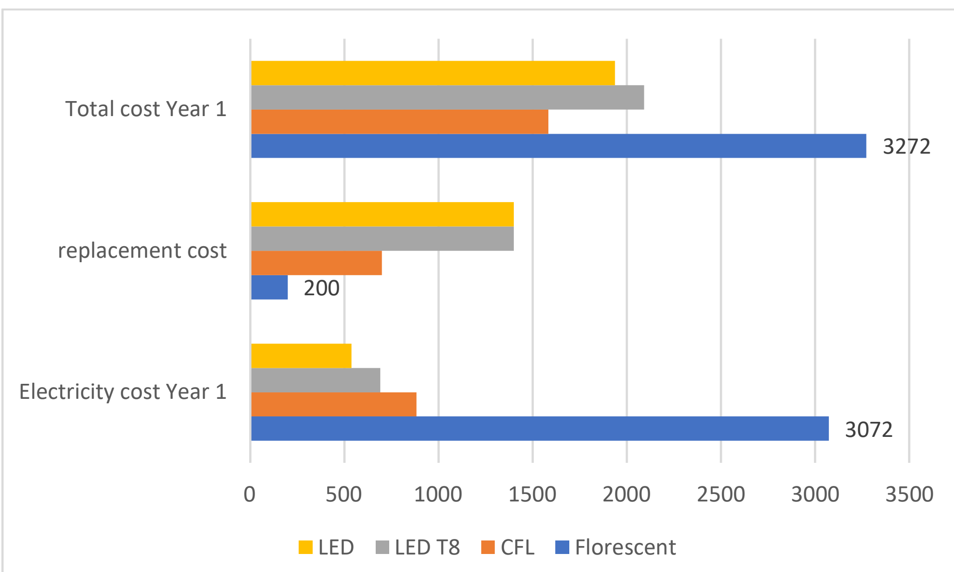
Annexe B: Efficacy and Luminous Efficiency of different type of bulbs

Category	Type	Luminous efficacy (lm/W)	Luminous efficiency
Light-emitting diode	The theoretical limit for a white LED with phosphorescence colour mixing	260–300	38.1–43.9%
Light-emitting diode	21.5W LED retrofit for T8 fluorescent tube (230 V)	172	25%
Light-emitting diode	11 W LED screw base lamp (230 V)	138	20.3%
Gas discharge	1400 W sulfur lamp	100	15%
Gas discharge	low pressure sodium lamp	100–200	15–29%
Gas discharge	high-pressure sodium lamp	85–150	12–22%
Gas discharge	metal halide lamp	65–115	9.5–17%
Fluorescent	T8 tube with electronic ballast	80–100	12–15%
Fluorescent	T5 tube	70–104.2	10–15.63%
Fluorescent	32 W T12 tube with magnetic ballast	60	9%
CFL	9–32 W (with ballast)	46–75	8–11.45%
Incandescent	15–40–100 W tungsten incandescent (230 V)	8.0–10.4–13.8	1.2–1.5–2.0%
Incandescent	5–40–100 W tungsten incandescent (120 V)	5–12.6–17.5	0.7–1.8–2.6%

Annexe C: Lifetime of bulbs



Annex D: Year 1 cost for replacing Florescent and CFL by LED



Annexe E: Cost-effectiveness of replacing Fluorescent in CFL (1600 Lumens) bulbs

	Fluorescent T8	CFL	LED T8	LED
Brightness	850 L	1600 L	1600 L	650 - 750 L
Hazardous material	10 mg of Hg	3-5 mg of Hg	0	0
Watts used	40	23	18	7
Number of bulbs needed for the fixture	2	1	1	2
Color temperature	NA	5100 K	5000 K	6000 K
CRI	NA	80	80	80
Average rated Life	8,000	10,000	30000	25000
Number of bulbs required for 24k hrs	6	1	2	2
Energy usage per 24k hrs (Kw/h)	1920	552	432	336
CO2 Emission Metric Tons	1.1376	0.32706	0.25596	0.19908
Electricity payments	38,400.00	11,040.00	8,640.00	6,720.00
Cost of replacement	600.00	700.00	1,400.00	1,400.00
Total cost	39,000.00	11,740.00	10,040.00	8,120.00
Savings	**-**	**LKR 27,260.00**	**LKR 28,960.00**	**LKR 30,880.00**

Annex F: Selection Criteria of LED

LED	2W - 4W	5W - 7W	8W - 10W	9W - 13W	13W - 18W
CFL	5W	7W	11W	15W	20W
Florescent				40 W	
Lumens (lm)					
	230 - 375 lm	400 - 500 lm	700 - 900 lm	900 - 1125 lm	1300 - 1500 lm

Information needed for the quotations

Description	**Details**	**Other Information**
Type of the bulb	LED	
Fixture type	T8/Pendulum/Ceiling mount	Should be decided depending on the type that is suitable for the place
Lumens		Should satisfy the Lux value needed for the place of interest
Number of Bulbs for the fixture	1/2/3/4	This is not necessary for the tender. This value is needed to calculating the Lumens value
Watts		Should decide on the Lumen value and the table given above
Protection against Environment	IP 65 outdoor IP 44 Indoor	To protect from Dust and rainwater
CRI	80>	Higher CRI gives better colour identification
Colour temperature	3000 K (warm) 4500 K (cool) 6000 k (daylight)	Should decide depending on the location requirement
Compatibly	**SLS 1530: 2016**	
Warranty	**Minimum 2 yrs**	

*************END***************