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COMPARATIVE STUDY OF LIFE CYCLE COST OF MODERN LIGHT SOURCES USED IN DOMESTIC LIGHTING

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Abstract: The energy crisis problem is the biggest problem faced by the developing countries nowadays. Lighting constitutes a major segment of energy consumption in the building sector whether domestic or industrial. Artificial illumination typically accounts for 40 % of the total energy consumption of domestic buildings. This article discusses a method to optimise the existing lighting system by replacement of high-power consumption lamps with energy efficient lamps by estimating and comparing their life cycle costs. The paper presents a life cycle assessment of different lighting technologies like incandescent lamps, compact fluorescent lamps (CFL) and Light Emitting Diode (LED) luminaries for the general lighting of the office or homes. The life cycle assessments are carried out considering various factors of the luminaries keeping the luminous flux constant as to achieve the same light output. Burning hours of the lamp is considered as main factor to obtain the life cycle costs. Alternative solution which has more burning hours and less life cycle cost is advised.
Keywords: Luminous Efficacy, Burning hours, Life cycle cost, LED.

1. Introduction

Lighting is an essential part of everyday life. Lighting or illumination is the deliberate use of luminosity to achieve a practical effect. Lighting includes natural illumination as well as artificial sources like lamps. Proper lighting can have positive psychological effects on occupants and increases one's ability to perform tasks. It is indeed a fact that lighting accounts around 40 % of the world's total energy consumption. It shows the dependency of human on lighting. Also, in any building the percentage of energy consumption through lighting is around 25 % [1]. Figure 1 shows the consumption of lighting energy in various building types (domestic or industrial). The office lighting accounts for a major portion of total electricity used.

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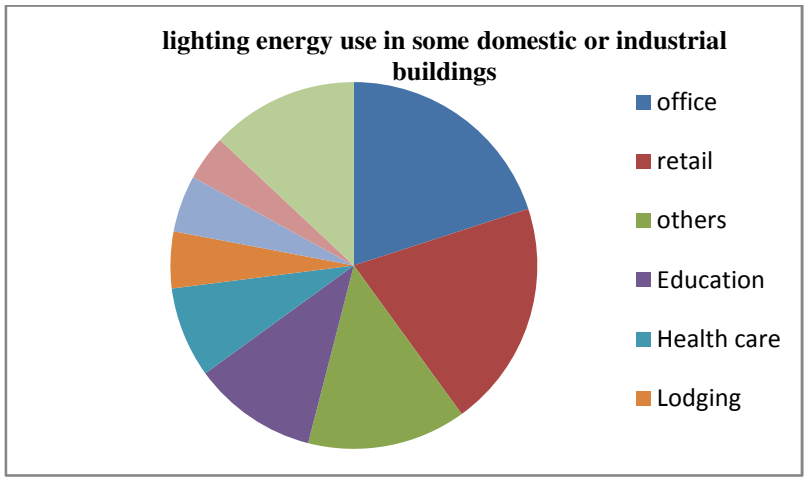

Figure 1: consumption of lighting energy in various building types

Thus, in the present energy scenario, in developing countries like India, an efficient lighting with proper techniques is used, major energy saving is possible. Also it has to be judged that which lighting is suitable according to a proper application in a particular sector. Thus implication of lamps can be done for various areas. The cost parameter has also to be kept in mind. Lighting system is categorized as Direct Lighting, Indirect Lighting and Direct/Indirect Lighting [4]. Various types of lamps used in domestic and industrial lighting are incandescent lamps (GLS), fluorescent lamps (FL), T 12 lamps, T 5 lamps, compact fluorescent lamps (CFL), light emitting diodes (LED), mercury vapour lamps, sodium vapour lamps, halogen lamps and others. Among these the major portion of domestic lighting is through GLS, CFLs, Tube lights, while the other three contribute a major portion in industrial lighting. A new lighting technology has been evolved as light emitting diodes (LEDs) that can be over 10 times more efficient than conventional-old incandescent lamps [3].

The efficient use of artificial lighting can provide energy as well as cost savings. There can be several measures that can be taken for energy savings. By controlling the lighting in such a way that the lighting level is always accurately matched to the actual need allows to save on the energy costs and to improve the human comfort and efficiency [5]. Light sources which provide significantly more light or lumens per unit of energy consumption can be used. Another method is to replace older fixtures or lamps with the new and more improved lamps which can definitely improve efficiency. Various domestic lamps which are used in common are as follows:

(i) Incandescent lamps or GLS: It is the oldest and very common lamp used in homes, indoors and outdoors especially in rural areas. Of the common lamps, it is the most inefficient. It emits light by heating a filament of wire which glows white hot when a current

is flown through it. It produces and emits much heat as compared to the amount of light. In actual, only 8-10 percent of the energy is utilised in producing light. This bulb is often used, especially in a fixture that actually controls the light output rather than scattering it everywhere.

(ii) Fluorescent lamps: These lamps are almost four to five times more efficient than incandescent lights. They are nowadays most widely used for indoor applications. Energy saving is achieved because they are lower wattage lamps and provide more lumens. It means wattage rating of these lamps reduce giving the same lumens output as of incandescent lamps. The objective is to provide maximum light output with minimum energy consumption. Fluorescent lamps are of different types such as Compact Fluorescent Lamps (CFLs), tube lights or tube lamps which are further classified into T 5, T 8 and T 12. Among these T 12 lamps are the oldest and most energy inefficient. They have the largest tube diameter also and are heavy. T 8 or T 9 lamps are comparatively new and even have less tube diameter. They are more efficient than the older ones. The most efficient and most compact among these are T 5 lamps. These are light and have less tube diameter.

(iii) LED Lamps: An LED lamp is a LED unit that is fitted into a lamp for lighting purpose. LED lamps have greater lifespan and much more efficiency than other lamps. LEDs have more efficacy than incandescent bulbs. Incandescent or fluorescent lamps often need an external reflector to collect light and direct it in a usable manner. LEDs are ideal for use where frequent on-off cycling is required. LEDs are very expensive which is the biggest disadvantage, but the payback period of installation is very less. The additional expense is due to low lumen output and the drive circuitry and power supplies needed. LED based lamp technology is relatively new as compared with conventional lamps [2].

Considering various lighting parameters the life cycle cost analysis of various domestic lamps has been done here. An effort is made to compare various lamps and judge them for suitable applications. Various lighting terms used in the calculation are defined as follows:

(i) Lumen: Lumen is the SI unit of luminous flux. It is the total amount of light emitted by a light source in any direction.

(ii) Watts:-Watts is the SI unit of total electrical power consumed by the lamp or light source.

(iii) Luminous flux:-The luminous flux is the factor used to describe the brightness of an area. It is measured in lumens.

(iv) Luminous efficacy:- Luminous efficacy is the total luminous flux or lux emitted by the light source per unit lamp wattage. It is expressed in lumens per watt (lm/W).

(v) Burning hours:- Burning hours of a lamp is the total time in hours that a bulb can work if left ON. It can also be called as life of a lamp.

(vi) CRI:- The colour rendering index (CRI), is a quantitative measure of the ability of a lamp to divulge the colour of various objects in comparison with an ideal source or natural lighting. Numerically, the highest possible CRI can be 100. It is for the black body objects especially incandescent lamps. Sodium vapour lamps have negative CRI whereas of CFLs range from about 50 to 90. LEDs have CRI more than 80.

2. Experimental methodology

For comparison of various domestic lamps at least one quantity should be fixed and that is lumens output. It means the light output required should be same for a particular application. Thus keeping lumens almost constant around 2500, comparison of other parameters is done in Table 1.

Table 1: Comparison of some technical parameters of domestic lamps

Lamp	Lumens	Watts(W)	Burning hours	Bulb/Lamp cost in Rs
Incandescent	2600	150	1200	20
CFL	2600	50	8000	700
T 5	2500	25	15000	140
T 8	2500	36	10000	48
T 12	2500	40	10000	45
LED	2600	25	50000	2000

So taking burning hours of one light source as reference (which is maximum), number of bulbs required for all other light sources and their cost are calculated. Number of bulbs and cost for light sources taking burning hours of one light source as reference can be calculated as:

(Number of bulbs/ cost) = Number of bulbs required for burning hours * Cost of one bulb

For fixed burning hours energy required can be calculated as:

Energy required in KWh= (Burning hours * Rating in watts)/1000

Taking the local tariff, cost of energy can be calculated as:

Energy cost= Energy required * Tariff

Finally the life cycle cost is calculated by adding the bulbs cost and energy cost as:

Life cycle cost=Energy cost + Bulb cost

It is clear that LEDs have maximum burning hours. The objective is that the light source should have maximum burning hours. So taking 50000 burning hours as reference, all the calculations are evaluated in Table 2.

Table 2: Life cycle cost estimation of different light sources

Lamp	Burning hours	For 50000 hours no of bulbs required	cost of bulbs (Rs)	For 50000 hours energy required (Kwh) (50000*W)/1000	Energy cost (Rs)	Life cycle cost (Rs)
Incandescent	1200	42	840	7500	38625	39465
CFL	8000	6	4200	2500	12875	17075
T 5	15000	4	560	1250	6438	6998
T 8	10000	5	240	1800	9270	9510
T 12	10000	5	225	2000	10300	10525
LED	50000	1	2000	1250	6438	8438

3. Results & Discussions

For approximately same luminous flux or lumens output, it is confirmed that luminous efficacies of LEDs or T5 lamps is maximum. For same lumens, power consumption of these two light sources is very less. For efficient light sources, this should be the objective. Finally the study shows that the life cycle cost is much more for the incandescent lamps while it is far lesser for the other lamps. The life cycle cost is very less for T5 lamps and LEDs. For an efficient light source, it should have high luminous efficacy, minimum power consumption and minimum life cycle cost. Comparative study of various parameters of light sources for same luminous flux and accordingly their performance evaluation is tabulated in

. Star rating indicates the performance of lamps according to their ability of minimum power consumption, maximum luminous efficacy and minimum life cycle cost. More the star rating, more good is the quality or performance according to these factors.

Table 3: Performance of different lamps

Lamp	Star rating	Performance
Incandescent	*	Poor
CFL	**	Satisfactory
T 5	*****	Excellent

T 8	****	Very good
T 12	***	Good
LED	*****	Excellent

4. Conclusion

The comparative study of various parameters of light sources explains that incandescent lamps are the most inefficient with maximum power consumption and maximum life cycle cost. CFLs are good alternative for incandescent lamps with somewhat lesser power consumption and very less life cycle cost. Similarly tube lamps like T12 and T8 have very less life cycle cost. LED lamps have very low life cycle cost as compared to other lamps but somewhat higher than T5 lamps. This is because their lamp cost is far higher than other lamps. If this cost would be less, they would have least life cycle cost. Only advantage with LEDs is that they have maximum burning hours. It means once the LED lamps are installed, they do not need to be replaced again and again for years. The life cycle assessment shows that replacing older lamps of high power consumption and high cost with new and innovative lamps of comparatively low power consumption and less cost could be beneficial for a particular application from the aspect of both energy and cost saving.

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