Energy Efficient Lighting Systems In Green Buildings: An Overview

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ABSTRACT:

This paper presents an overview of the tools used (GRIHA and ECBC) to predict Energy efficiency of interior and exterior lighting systems in buildings. The mandatory criteria in the GRIHA rating system of green building such as: design to include existing site features, providing minimum level of sanitation, reducing air pollution during construction, optimizing building design to reduce conventional energy demand etc., for Electrical and Mechanical equipment are analyzed. The lux level of a work place is compared with a reference standard. The scope of energy efficient lamps and fixtures are identified. The good practices in lighting such as: Installations of CFLs, HPSV Lamps, metal halide lamps, high frequency electronic ballasts are suggested for energy savings.

Keywords **-** Energy efficiency, Green buildings, LEED, GRIHA

I. INTRODUCTION

India has the second largest population country in the world and has three biggest cities, namely, Mumbai, Calcutta and Delhi, within the rank of 20 biggest cites in the world. It has 23 cities that has a population of above one million each [1]. India is also bulking under the pressure of steady inward migration from rural areas. To sustain this migration from rural to urban India, sustained efforts are required to create infrastructure that can sustain the ever increasing load in a much eco- friendly and pro-energy efficient ways. By 2020, India's demand for commercial energy will probably increase by a factor of 2.5 [2]. India is a chronically energy deficient country and already faces significant challenges to meet its energy needs. The growing gap between energy demand and supply emphasizes the need for a more stable, more environment-friendly energy alternatives. Another way i.e., the proactive route is to design and construct 'green buildings' to conserve the precious electricity, as the green buildings can help to reduce considerably the consumption of electricity. A 'green building' is defined as the one which uses less energy, water and natural resources, creates less waste and a healthy environment for the people living inside, when compared to a conventional building. Holistically, green building is the practice of increasing the efficiency with which a building uses the various resources- energy, water and materials-while reducing its impacts on human health and the environment, during the building's life cycle. It is better achieved through: 1)Better selection and use of site; 2)Innovation in design process; 3)Efficient use of water; 4)Prudent choice of materials and efficient construction.

II. GREEN BUILDINGS -STANDARDS

The concept of green building became popular in the '90s. In 1992, the American Association of Architects (AIA) [3] and the Environment Protection Agency (EPA) [4] released the Environmental Resource Guide. In 1993, United States Green Building Council (USGBC)[5] was founded, which launched their 'Leadership in Energy and Environmental Design' (LEED) version 1.0 pilot program in 1998. Eventually, by March 2000, LEED 2.0 was released to the market.

The USGBC's LEED really took the "lead" in establishing comprehensive, precise and measurable standards for green buildings, with focus on the more western practices of building design and execution. In India, the Energy and Resource Institute (TERI), developed 'Green Rating for Integrated Habitat Assessment (GRIHA)[6]', based on LEED for its own standards with localized flavours of design, practices and geography. GRIHA is the National

Rating System of India which was developed jointly with the Ministry of New and Renewable Energy, Govt. of India. It is a green building 'Design evaluation system' and is suitable for all kinds of buildings in different climate zones of the country.

2.1 GREEN RATING FOR INTEGRATED HABITAT ASSESSMENT (GRIHA)

The system has been developed to help 'design and evaluate new buildings'. A building is assessed based on its predicted performance over its entire life cycle – inception through operation. The stages of the life cycle that have been identified for evaluation are:

- Pre-construction stage
- Building planning and construction stage
- Building operation and maintenance stage

GRIHA rating system consists of 34 criteria categorized under various sections such as:

- Site selection and site planning
- Conservation and efficient utilization of resources
- Building operation and maintenance, and
- Innovation points

Eight of these 34 criteria [6] are mandatory; four are partly mandatory; while the rest are optional. Each criterion has a number of points assigned to it. It means that a project intending to meet the criterion would qualify for the points. Different levels of certificate (one star to five stars) are awarded based on the number of points earned Table [1]. The minimum points required for certification is 50.

2.2 SCORING POINTS FOR GRIHA

GRIHA has a 100 point system consisting of some core points, which are mandatory to be met, while the rest are optional points, which can be earned by complying with the commitment of the criterion for which the point is allocated. Different levels of certification are awarded and the minimum points required for certification is 50. Table [2] shows the Evaluation procedure of criterion of GRIHA [6].

Table 1: Points Vs Star rating

Points scored	Rating
50-60	One star
61-70	Two star
71-80	Three star
81-90	Four star
91-100	Five star

III. ENERGY EFFICIENCY PERFORMANCE ON INTERIOR AND EXTERIOR LIGHTING SYSTEMS

Energy Conservation Building Code (ECBC) [7] has been produced to assist Government of India (GOI) in the implementation of energy efficiency in buildings. It was launched by Ministry of Power in May 2007.Energy Conservation Building Code (ECBC) defines norms and standards for the energy performance of buildings and their components based on the climate zone in which they are located. It covers:

- Building Envelope
- Heating
- Ventilation and Air-conditioning Systems
- Interior and Exterior Lighting Systems
- Service Hot Water
- Electrical Power Systems and Motors

Energy Conservation Building Code (ECBC) user Guide has been prepared under the USAID ECO-III Project in close partnership with Bureau of Energy Efficiency (BEE). The code is applicable to buildings or building complexes that have a connected load of 500 KW or greater or a contract demand of 600 KVA or greater. Buildings or complexes having conditioned area of 1000 m^2 or more will fall under this category. The provisions of this code do not apply to

- Buildings that do not use either electricity or fossil fuel.
- Equipment and portions of building systems that are used primarily for manufacturing processes.

IV. RECOMMENDATIONS ON ILLUMINANCE

4.1. SCALE OF ILLUMINANCE

The minimum illuminance for all non-working interiors, has been mentioned as 20 lux. A factor of approximately 1.5 represents the smallest significant difference in subjective effect of illuminance. Therefore, the following scale of illuminances is recommended [2]:

20-30-50-75-100-150-200-300-500-750-1000-1500-2000, Lux.

4.2. ILLUMINANCE RANGES

Because circumstances may be significantly different for different interiors used for the same application or for different conditions for the same kind of activity, a range of illuminances is recommended for each type of interior or activity intended of a single value of illuminance. Each range consists of three successive steps of the recommended scale of illuminances. For working interiors the middle value (R) of each range represents the recommended service illuminance that would be used unless one or more of the factors mentioned below apply. The higher value (H) of the range should be used at exceptional cases where low reflectances or contrasts are present in the task, errors are costly to rectify, visual work is critical, accuracy or higher productivity is of great importance and the visual capacity of the worker makes it necessary. Similarly, lower value (L) of the range may be used when reflectances or contrasts are unusually high, speed & accuracy is not important and the task is executed only occasionally.

4.3. Recommended Illumination

The recommended illumination values are related to the visual requirements of the task, to user's satisfaction, to practical experience and to the need for cost effective use of energy[2]. Table [3] shows the various types of lamps along with their luminance performance characteristics.

V. METHODOLOGY FOR ASSESSING ENERGY EFFICIENCY OF LIGHTING SYSTEMS

A step-by-step approach for assessing energy efficiency of lighting systems is given below:

Step-1: Inventorise the lighting system elements & transformers in the facility. In case of distribution boards (instead of transformers) being available, fuse ratings may be inventorised along the above pattern in place of transformer KVA.

Step-2: With the aid of a lux meter, measure and document the lux levels at various plant locations at working level, as daytime lux and night time lux values alongside the number of lamps "ON" during measurement.

Step-3: With the aid of portable load analyzer, measure and document the voltage, current, power factor and power consumption at various input points, namely the distribution boards or the lighting voltage transformers at the same as that of the lighting level audit.

Step-4: Compare the measured lux values with standard values as reference and identify locations as under lit and over lit areas.

Step-5: Collect and Analyse the failure rates of lamps, ballasts and the actual life expectancy levels from the past data.

Step-6: Based on careful assessment and evaluation, bring out improvement options, which could include :

- Maximise sunlight use through use of transparent roof sheets, north light roof, etc.
- Examine scope for replacements of lamps by more energy efficient lamps, with due consideration to luminiare, color rendering index, lux level as well as expected life comparison.
- Replace conventional magnetic ballasts by more energy efficient ballasts, with due consideration to life and power factor apart from watt loss.
- Select interior colours for light reflection.
- Modify layout for optimum lighting.
- Providing individual / group controls for lighting for energy efficiency such as:
    - ❖ On / off type voltage regulation type (for illuminance control)
    - ❖ Group control switches / units
    - ❖ Occupancy sensors
    - ❖ Photocell controls
    - ❖ Timer operated controls
    - ❖ Pager operated controls
    - ❖ Computerized lighting control programs
- Install input voltage regulators / controllers for energy efficiency as well as longer life expectancy for lamps where higher voltages, fluctuations are expected.

Replace energy efficient displays like LED's in place of lamp type displays in control panels / instrumentation areas, etc.

VI. ENERGY EFFICIENT OPTIONS

High efficacy gas discharge lamps suitable for different types of applications offer appreciable scope for energy conservation. Typical energy efficient replacement options, along with the percent energy saving, are given in Table [4].The energy saving potential, in typical cases of replacement of inefficient lamps with efficient lamps in street lighting is given in the Table [5].

6.1. Some Good Practices in Lighting

Some good practices in lighting can be summarized as:

- Installation of energy efficient fluorescent lamps in place of "Conventional" fluorescent lamps.
- Installation of Compact Fluorescent Lamps (CFL's) in place of incandescent lamps.
- Installation of metal halide lamps in place of mercury / sodium vapour lamps.
- Installation of High Pressure Sodium Vapour (HPSV) lamps for applications where colour rendering is not critical.
- Installation of LED panel indicator lamps in place of filament lamps.

6.2. LIGHT DISTRIBUTION

Energy efficiency cannot be obtained by mere selection of more efficient lamps alone. Efficient luminaires along with the lamp of high efficacy can help to achieve the optimum efficiency. For achieving better efficiency, luminaires that are having light distribution characteristics appropriate for the task interior should be selected. The luminaires fitted with a lamp should ensure that discomfort glare and veiling reflections are minimized. Installation of suitable luminaires, depends upon the height - Low, Medium & High Bay. Luminaires for high intensity discharge lamp are classified as follows:

- Low bay, for heights less than 5 metres.
- Medium bay, for heights between 5 - 7 metres.
- High bay, for heights greater than 7 metres.

System layout and fixing of the luminaires play a major role in achieving energy efficiency. This also varies from application to application. Hence, fixing the luminaires at optimum height and usage of mirror optic luminaries leads to energy efficiency.

6.3. LIGHT CONTROL

The simplest and the most widely used form of controlling a lighting installation is "On-Off" switch. The initial investment for this set up is extremely low, but the resulting operational costs may be high. This does not provide the flexibility to control the lighting, where it is not required. Hence, a flexible lighting system has to be provided, which will offer switch-off or reduction in lighting level, when not needed. The following light control systems can be adopted at design stage:

- Grouping of lighting system, to provide greater flexibility in lighting control
- Installation of microprocessor based controllers.
- Optimum usage of day lighting
- Installation of "exclusive" transformer for lighting
- Installation of servo stabilizer for lighting feeder
- Installation of high frequency (HF) electronic ballasts in place of conventional ballasts

The advantage of HF electronic ballasts, outweigh the initial investment (higher costs when compared with conventional ballast). In the past the failure rates of electronic ballast in Indian industries were high. Recently, many manufacturers have improved the design of the ballast leading to drastic improvement in their reliability. The life of the electronic ballast is high especially when, used in a lighting circuit fitted with a automatic voltage stabilizer. Table [6] gives the type of luminaire, gear and controls used in different areas of industry.

VII. CONCLUDING REMARKS

The usefulness of tools such as: GRIHA and ECBC for assessing the energy efficiency of lighting systems in buildings have been highlighted. Such tools help us to fulfill the criteria of 'green buildings'. If the concept of green building are implemented, to start with in all public buildings in India, then it is possible to overcome to some extent the 'energy crisis' what India has to face in the decade ahead. Further the concept of 'green buildings' and its advantages have to be highlighted and awareness created in the minds of the people and to all the stake holders in the construction industry.

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Table 2: Evaluation Procedure of Criterion of GRIHA

List of criteria	Points	Remarks
Criteria 1: Site Selection	1	Partly mandatory
Criteria 2: Preserve and protect landscape during construction / compensatory depository forestation.	5	Partly mandatory
Criteria 3: Soil conservation (post construction)	4	
Criteria 4: Design to include existing site features	2	
Criteria 5: Reduce hard paving on site	2	Partly mandatory
Criteria 6: Enhance outdoor lighting system efficiency	3	
Criteria 7: Plan utilities efficiently and optimize on site circulation efficiency	3	
Criteria 8: Provide, at least, minimum level of sanitation / safely facilities for construction workers	2	Mandatory
Criteria 9: Reduce air pollution during construction	2	Mandatory
Criteria 10: Reduce landscape water requirement	3	
Criteria 11: Reduce building water use	2	
Criteria 12: Efficient water use during construction	1	
Criteria 13: Optimize building design to reduce conventional energy demand	6	Mandatory
Criteria 14: Optimize energy performance of building within specified comfort	12	
Criteria 15: Utilization of fly ash in building structure	6	
Criteria 16: Reduce volume, weight and time of construction by adopting efficient technology (e.g. pre-cast systems, ready –mix concrete, etc	4	
Criteria 17: Use low-energy material in interiors	4	
Criteria 18: Renewable energy utilization	5	Partly mandatory
Criteria 19: Renewable energy based hot-water system	3	
Criteria 20: Waste water treatment	2	
Criteria 21: Water recycle and reuse (including rainwater)	5	
Criteria 22: Reduction in waste during construction	2	
Criteria 23: Efficient waste segregation	2	
Criteria 24: Storage and disposal of waste	2	
Criteria 25: Resource recovery from waste	2	
Criteria 26: Use of low - VOC paints / adhesives/sealants.	4	
Criteria 27: Minimize ozone depleting substances	3	Mandatory
Criteria 28: Ensure water quality	2	Mandatory
Criteria 29: Acceptable outdoor and indoor noise levels	2	
Criteria 30: Tobacco and smoke control	1	
Criteria 31: Universal Accessibility	1	
Criteria 32: Energy audit and validation		Mandatory

Criteria 33 Operations and maintenance protocol for electrical and mechanical equipment	2	Mandatory
Total score	100	
Criteria 34: Innovation (Beyond 100)	4	
Total score	104	

Table 3: Luminous Performance Characteristics of Commonly Used Luminaries

Type of Lamp	Lumens/Watt		Color Rendering Index	Typical Application	Typical Life (hours)
	Range	Avg			
Incandescent	8-18	14	Excellent	Homes, Restaurants, General Lighting, Emergency Lighting	1000
Fluorescent Lamps	46-60	50	Good w.r.t. coating	Offices, Shops, Hospitals, Homes	5000
Compact Fluorescent Lamps (CFL)	40-70	60	Very Good	Hotels, Shops, Homes, Offices	8000-10000
High Pressure Mercury (HMPV)	44-57	50	Fair	General Lighting in Factories, Garages, Car Parking, Flood Lighting	5000
Halogen Lamps	18-24	20	Excellent	Display, Flood Lighting, Stadium, Exhibition Grounds, Construction Areas	2000-4000
High Pressure Sodium (HPSV) SON	67-121	90	Fair	General Lighting in factories, ware houses, street lighting	6000-12000
Low Pressure Sodium (LPSV) SOX	101-175	150	Poor	Roadways, tunnels, canals, street lighting	6000-12000

Table 4: Savings by Use of High Efficiency Lamps

Sector	Lamp Type		Power Saving	
	Existing	Proposed	Watts	%
Domestic/Commerical	GLS 1000 W	*CFL 25W	75	75
Industry	GLS 13 W GLS 200 W TL 40 W	*CFL 9 W Blended 160W TLD 36 W	4 40 4	31 20 10
Industry/Commercial	HMPV 250W HMPV 400W	HPSV 150W HPSV 250 W	100 150	37 35

(Source: Bureau of Energy Efficiency)

Table 5: Saving Potential by Use of High Efficiency Lamps for Street Lighting

Existing Lamp			Replaced Units			Saving	
Type	W	Life	Type	W	Life	W	%
GLS	200	1000	ML	160	5000	40	7
GLS	300	1000	ML	250	5000	50	17
TL	2 X 40	5000	TL	2 X 36	5000	8	6
HPMV	125	5000	HPSV	70	12000	25	44
HPMV	250	5000	HPSV	150	12000	100	40
HPMV	400	5000	HPSV	250	12000	150	38

(Source : Energy Conservation Building Code)

Table 6: Types of Luminarie with Their Gear and Controls Used In Different Industrial Location

Location	Source	Luminaire	Gear	Controls
Plant	HID/ FTL	Industrial rail reflector : High bay Medium bay Low bay	Conventional / Low loss electronic ballast	Manual / Electronic
Office	FTL/	FTL/CFL	Electronic /	Manu

	CFL		Low loss	al / Auto
Yard	HID	Flood Light	Suitable	Manu al
Road Peripheral	HID/ PL	Street Light Luminaire	Suitable	Manu al

(Source : Energy Conservation Building Code)