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Draft National Lighting Code of India

Part 7 Energy-Effective Lighting Systems
Section 1 Energy Efficiency in Lighting

First Revision of SP 72 (Part 7 / Section 1)

Illumination Engineering and Luminaries Sectional Committee, ETD 49

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FOREWORD

(Formal clauses of the draft will be added later)

Energy saving in lighting become a top priority all over the world with the tremendous energy crunch in the 1970s. For India, it has been considered even more important, as the demand for electricity is going up every year, what with the need for rapid industrialization and all- round growth. With the rise in demand and depleting natural resources, energy will be dearer and scarcer. On the other hand, the cost of setting up electric power generating capacity is also going up, making funding extremely difficult.

The total consumption for lighting in all the sectors; domestic, industrial, commercial and public utilities is quite substantial.

As energy prices continue to increase, energy legislation is enacted and energy codes become more restrictive, energy efficiency in design and practice has become essential to a successful lighting system. It has also created lucrative investment opportunities for corporative and institutions, who can make capital investments to upgrade their existing lighting systems to generate energy savings that provide an economic return.

Energy efficiency in lighting is a straightforward concept: achieving lighting design goals with equipment and methods that consume less energy results in ongoing cost savings for the owner. Essentially, the high operational costs of inefficient systems can be avoided. However, the challenge lies in the initial investment—some energy-efficient equipment may have a higher upfront cost, and certain technologies, like advanced controls, may require specialized installation expertise.

Despite these initial costs, energy-efficient lighting offers significant long-term benefits. For instance, advanced lighting controls can cut energy consumption by up to 50%. When considering the total lifecycle cost—encompassing initial investment, operational expenses, and maintenance—energy-efficient lighting proves to be a smart financial decision, delivering a strong return on investment. Most importantly, these savings typically offset the initial costs within a desirable payback period of one to three years, making energy-efficient lighting both economically and environmentally advantageous

Draft National Lighting Code of India

PART 7 ENERGY-EFFECTIVE LIGHTING SYSTEMS
SECTION 1 ENERGY EFFICIENCY IN LIGHTING

(First Revision)

1 SCOPE

This section of the code (Part 7/ Sec 1) covers the energy conservation measures applicable to any lighting installation or system.

2 REFERENCES

For the purpose of this section, the references in Part 1 of this code shall apply.

3 TERMINOLOGY

For the purpose of this section, the definitions given in Part 1 of this code and those given in IS 1885 (Part16/Sec 1) shall apply.

4 ENERGY CONSERVATION MEASURES

4.1 Energy management in lighting involves implementing low-energy, effective lighting solutions for various applications, whether for refurbishment, replacement, or new installations. This process considers all lighting parameters, including both quality and quantity aspects, tailored to the space, task, and people involved. The fundamental philosophy is that the goal of light energy saving should never compromise the quality of light.

In lighting energy management strategies, there are three primary options, with a fourth option being a combination of the three. These options include:

a) Day light,
b) Lighting system,
c) Controlling system,
d) Combination of all above three

Integration of daylighting is crucial for energy savings, especially when combined with an appropriate control system in buildings or premises where natural light is available. This integration requires a collaborative effort between civil /architectural professionals and lighting experts.

4.2 Several simple implementations thought process can be adopted for energy-effective lighting in existing installations, commonly called an "upgrade" or "retrofit."

Besides this many computer apps are now available and also being supplied by companies for doing this calculation for the whole buildings / premises. But basic process remain as follows:

a) A survey of the existing installation is very important before start of the work. Feedback of the survey result to owner /user about the possible scope and need of energy saving. A simple format can be made with respect to the condition of the existing installation with respect to lighting level, condition of system, energy consumption, maintenance, etc

b) Determine the required maintained light level. As the industry proverb goes, "Light is for people, not buildings." The lighting system's first task is to provide sufficient quantity and quality of light for occupants to perform relevant tasks. In existing installations, this will require a lighting systemaudit.

c) Incorporate daylight into the lighting scheme as much as possible; there are many ways that help daylight penetration into the building and distribute the light; glare controls should be provided anddaylight harvesting controls can be specified for significant energy savings

d) Determine the qualitative lighting requirements. Identify all quality issues such as glare, colour, aesthetics, distribution and attendant factors (such as surface reflectance, ceiling heights, etc.) that must be given priority during equipment selection and design. In existing installations, this will require a lighting system audit.

e) Identify equipment options that produce the desired maintained quantity and quality of light and also save energy. Equipment options will include high efficient system configuration together with lamps, ballasts, drivers, luminaries and advanced controls devices (occupancy sensors, dimming controls, photocells, lighting management systems, etc.) & finally now with the aid of IoT based lighting etc.

f) Identify strategies that support the goal of reducing energy consumption, such as planned lighting maintenance, repainting room surfaces to give them a higher reflectance (if appropriate) and developing a written lighting energy policy.

g) Choose the best package of equipment and strategies that will achieve the desired lighting goals while delivering desired economic performance.

h) In new construction or renovation projects, the interior designer can affect the overall efficiency oflight distribution by providing finishes that give proper ceiling, wall and task reflectance values.

j) All lighting components must be compatible to operate properly.

k) All applicable safety requirements and regulations should be strictly adhered to, when any work is done on an electrical system.

l) Consider a planned lighting maintenance programme and opening retrofit opportunities that reducelight output and energy consumption.

m) Ensure that all retrofits are permanent and understood by the maintenance personnel in a written and communicated lighting policy, so that old components are not reintroduced back into the lighting system later.

n) Be sure to include provisions for legal compliance in disposing of any lighting waste

p) Finally human centric lighting concept and sustainability as a total system for a responsibility towards our society are added in this concept which is need of the day when energy saving with LED has been granted.

q) Ensure compliance with Energy Conservation Act and other statutory Regulations for the country.

5 METRICS

All lighting systems require electrical power, measured in watts (W). As the system operates, it consumes energy, which is calculated by multiplying power by time and expressed in kilowatt-hours (kWh). One kWh is equivalent to using 1 000 watts for one hour. Electric utilities charge based on two key metrics: the building's total electrical load in kilowatts (kW) and the energy consumed in kilowatt-hours (kWh). Consequently, when upgrading lighting, the goal is to reduce both power consumption and, where possible, operating hours.

5.1 Demand Charge

The monthly electricity cost is determined by the building's connected electrical load. Utilities measure actual demand through metering, with charges based on the peak demand during the month. To minimize cost, it is beneficial to reduce both wattage and consumption during peak load periods, which typically occur around midday.

5.2 Energy Use Charge

5.2.1 This is the monthly charge for the electrical energy consumed by the building's electrical systems, measured in kWh. Therefore, the lighting energy management goals can be clearly defined as:

a) Reduce wattage (power) required by the lighting system; and
b) Reduce energy (power x time) consumed by the lighting system.

To measure the energy performance of lighting systems, a variety of metrics can be used:

a) *Total wattage* — For all lighting equipment (does not include impact of controls).
b) *Total energy consumed* — For all lighting equipment.

5.2.2 *Watts Per Square Meter*

This metric, called Light Power Density (LPD), is determined by dividing total watts by the space's total area in square meter. Lighting requirements in National Building Code (NBC)and Energy Conservation Building Code (ECBC) typically set restrictions on Light Power Density.

5.2.3 *KWh Per Square Meter*

This metric, called the energy utilization index, is determined by dividingthe total kWh of energy consumed by the lighting system in a space by the interior space's total area in square meter. The advantage of using the energy utilization index is that it includes the factor of time, andencourages the use of lighting controls that reduce the amount of time the lighting system operates when itis not needed.

5.3 Relevant Formula

Using local environmental data and system performance data from manufacturers, the following formulas given in Table 1 may be used to determine the energy characteristics of an application:

Table 1 Electrical Relevant Formulas
(*Clause* 5.3)

Sl. No (1)	**Relevant Formula** (2)
i)	Demand for Power (kW) = System Input Wattage (W) x 1.000
ii)	Energy Consumption (kWh) = System Input Wattage (kW) x Hours of Operation
iii)	Energy Consumption (kWh) = System Input Wattage (kW) x Hours of Operation
iv)	Lighting System Efficacy (Lumen per Watt or LPW) = System Lumen Output ÷ Input Wattage
v)	Light Power Density LPD (W/m 2) = Total System Input Wattage (W) ÷ Total Area (Square metre)
vi)	Watts (W) = Volts (V) x Current in Amperes (A) x Power Factor (pf)
vii)	Voltage (V) = Current in Amperes (A) x Impedance (Ohms) [this is called Ohm's Law]

6 COMPARING SYSTEMS

6.1 It is always recommended to consider a variety of energy-saving solutions based on multiple factors to ensure a rational and optimal decision for the user, customer, or ESCO company.

a) Compare efficacy - For various light sources and lighting systems.

b) Compare power requirements

c) Compare the lighting goal - Determine the light level goals and compare various options that achievethese goals at the lowest wattage possible. From this we can also compare LPD, (or watts per squaremetre). To follow the standard or certification norm as required and demand by the user/customer.

d) Compare energy usage - Determine the light level goals and compare various options that achieve these goals with less energy consumption. This is advantageous as it includes various automatic lighting controls, which reduce operating time, not watts. From this we can also compare energy utilization index, or kWh consumed per square metre. Here day light linking is an important for newinstallation.

e) Economics - Finally economics is most importance for decision making process mainly used for replacement or upgradation but with all modern system of lighting this is equally important for anynew installation. Often this has been seen in the case of Smart City lighting system implementation.

6.2 When upgrading an existing installation, a capital investment is made that results in energy savings, ultimately delivering a return on investment (ROI) and a payback period. Several economic analysis methods can be used to compare lighting systems, with the most common being simple payback and ROI for screening purposes.

a) To calculate the initial cost and energy savings for the new lighting system, follow these steps:

i) Determine the Initial Cost of the New Lighting System –

Initial Cost (INR) = Equipment Cost + (Installation Hours × Labour Rate

ii) Calculate Annual Energy Savings -

Annual Energy Savings = (A − B) × Energy Rate Charged by Utility

where,

A = [Existing System Wattage (kW) \times Annual Operating Hours (hrs)]

B = [New System Wattage (kW) \times Annual Operating Hours (hrs)]

b) To determine the Simple Payback**,** 3 to 5-Year Cash Flow**,** and Simple Return on Investment (ROI**)**, the following steps can be followed as guidelines for the calculations:

i) Simple Payback on an Investment (Years) = Initial Cost ÷ Annual Energy Savings (INR).

ii) 5-YearCash Flow (Rs) = 5 Years – Payback (Years) × Annual Energy Savings (INR) and

iii) Simple Return on Investment (%) = [Annual Energy Cost Savings (INR) ÷ Net Installation Cost (INR)] × 100.

c) To effectively compare lighting systems, it is important to focus on cost efficiency, expressed as Rupees per Lumen-Hour, and calculate the Total Cost of Ownership (TCO) over the system's life cycle**.** This allows a clear understanding of long-term financial implications. Here’s an approach for comparison:

i) Cost of Light/Lumen-Hour = (Initial Cost + Total Operating Cost) ÷ (Total Lumen Delivered × Hoursof Operation).

Total Operating Cost and Hour of Operation are set for any period of time that the specifier or owner wishes to consider.

ii) Simple Life-Cycle Cost = Initial Cost + (Annual Operating Cost × Life of System in Years).

where,

Annual Operating Cost = Annual Energy Cost + Annual Maintenance Cost

Life of System in Years- The expected operational lifespan of the system. Typically, 20-year lifespan is assumed, but this can vary based on the system's components.

Once initial comparisons are made, the next step is to determine which lighting system offers the best economic value for replacing the existing system. Following this, a comprehensive economic analysis can be conducted, incorporating life-cycle costing and return on investment (ROI). This analysis should account for various economic factors, such as the future value of money, inflation, and other financial considerations.

7 COMPARISON OF DIFFERENT LIIGHTING SYSTEM COMPONENETS

This clause outlines the key components of a lighting system, focusing on their energy-saving potential, quality, and practical usage. While numerous innovative approaches can be applied by experts, these guidelines reflect the best current practices. Given the rapid pace of technological advancement, they remain adaptable to future improvements in lighting technology and systems.

7.1 Light Sources

7.1.1 *Absolute Efficacy of Light Sources*

The theoretical maximum luminous efficacy of an ideal light source, which converts electromagnetic radiation into light without any energy loss, is 683 lumens per watt (lm/W). This ideal lamp would emit light at a single wavelength where the human eye is most sensitive during photopic vision, around 555 nm.

In practical applications, monochromatic light can approach this maximum efficacy. For white light, which consists of a blend of wavelengths, the theoretical maximum efficacy without energy loss was calculated by Ohno in 2004 to be between 350 and 450 lm/W. However, it is observed that white discharge lamps typically do not exceed 105 lm/W.

7.1.2 *Commonly Available Light Sources Applications*

a) *Incandescent lamps* — General lighting applications.

b) *Tubular fluorescent lamps* (T12, T8, T5) — The different generation with improved energy efficacy, life and quality parameters — General lighting applications & commercial lighting

c) *Halogen lamps low voltage & mains voltage* — The different generation on increasing life and safety

- shop and area lighting

d) *Compact fluorescent lamps (CFL)- retrofit/integral* — For residential applications mainly.

e) *Compact fluorescent lamps (CFL)- non retrofit* — For commercial, street and solar applications.

f) *Induction lamps* — Very high life , used for petrol pump, industry, street and public area lighting

g) *High pressure mercury vapour lamps (HPMV)* — Improved from blended lamp to pure mercury - utility area like post of of lantern & environmental applications

h) *High pressure sodium vapour lamps (HPSV)* — Latest generation very high life and low deprecation -Utility area lighting like street & area lighting and industry lighting where colour selection activityis not important

j) *High pressure metal halide Lamps (HPMHL)* — Improvement in generation from quartz to Ceramic on efficiency & quality - sports lighting, shop lighting.

k) *Light Emitting Diode LED applications* — In all areas and superseding & replacing all lamps.

7.1.3 *Technical Data sheet on Comparison for Commonly Available Light Sources (As a Guide Line)*
A technical data sheet comparing commonly available light sources can be found in Table 1 of Part 3 of this code.

When working on energy-efficient lighting solutions, it's essential to understand the specific tasks and requirements of both the people and the spaces targeted for energy-saving efforts. Each area has established norms for lighting levels, color temperature, and color rendering. Often overlooked, the Unified Glare Rating (UGR) is particularly important, especially in retrofit solutions for street lighting. Furthermore, considerations such as lumen maintenance and sustained lighting levels, along with cost comparisons over the life of the solution, are crucial. With a broad range of product variations available, selecting the right one is key for effective energy management design.

In the Indian context, it's important to offer guidance on energy-saving initiatives, especially when lamp wattage is often used as a reference for replacements (e.g., replacing a 100W GLS bulb with a 9W LED lamp). The term 'watt' is commonly ingrained in purchase decisions, both in domestic settings and national energy-saving schemes. However, it's critical to move beyond 'watt' as the primary metric in discussions about energy efficiency. This is especially important for solid-state LED technology, which continues to improve in efficacy year after year and has significant untapped potential. A true replacement should not only improve energy efficiency but also enhance the quality of life.

The reliance on ‘watt’ terminology in retrofit replacement processes, particularly in commercial and street lighting applications, is misleading and should be corrected.

7.2 Control Gear (Ballast, Driver), Sensor Dimmer, Dimmable Ballast & Controller

7.2.1 *Control Gear*

This device regulates the operation of the light source, typically through electromagnetic or electronic ballasts. In the case of LEDs, this component is referred to as a Driver. Achieving desired lighting levels at various activity points doesn’t always require full illumination. For this purpose, dimmable drivers are commonly used. Operational details are provided in the relevant chapters of the national lighting code. Regarding energy efficiency, low-loss magnetic ballasts are available, consuming only 4 percent to 8 percent of the lamp power, depending on construction and cost, compared to conventional electromagnetic ballasts, which can consume over 12 percent.

Electronics High Frequency ballasts are the ideal choice for low-pressure discharge lamps and lower wattage metal halide lamps (up to 150W). Electronic drivers or transformers are always recommended for halogen lamps in energy-saving schemes.

Key considerations such as compatibility, power factor (PF), inrush current, immunity, electromagnetic compatibility (EMC), and temperature ratings - tailored to the specific application area—are vital in energy-saving initiatives. Additionally, factors like reliability and safety must be carefully evaluated. In the Indian context, features like wide voltage operation and surge protection devices are of particular importance.

7.2.2 *Sensor*

Various types of sensors, such as time sensors, occupancy sensors, and astronomical sensors, are essential for reducing energy consumption by ensuring that lighting is activated only when and where it is needed. Depending on specific requirements, a variety of sensors can be employed, including wall-mounted switches, ceiling-mounted sensors, simple photo-sensors, light control panels with integrated clocks and automatic switches, occupancy-based plug load controls with remote operation, and astronomical switches that can be controlled remotely through IoT-based systems.

7.2.3 *Dimmable drivers*

Dimmable drivers provide the flexibility to adjust lighting levels based on specific needs. All modern dimming controllers/devices are electronic, ensuring seamless integration across various light sources. Dimmable drivers are particularly significant in energy-saving applications, with daylight linking and automatic lighting control being effectively utilized by energy managers for over two decades.

There are two methods of dimming: Mains dimming and regulation. Mains dimming reduces the input power to the compatible driver by using a phase-cut dimmer before the driver. In contrast, regulation achieves dimming by electronically adjusting the output power of the driver to the LED lamp or array of lamps. This adjustment can be done through analog (1-10V) or digital (DSI, DALI) methods. These devices are connected separately to the driver, regulating the power output while maintaining a constant power input to the driver within its internal circuitry.

a) Mains dimming types involve either reducing the amplitude of the current, pulse width modulation, or a combination of both.

b) Regulation types include Analog 1-10V, DALI 1, DALI 2, DSI, DMX (Digital Multiplex), etc.

c) Building Management System (BMS) oversees large-scale control of lighting and various other equipment such as fire, water, pollution, security, etc.

d) Various wireless technologies like ZigBee, Bluetooth, WLAN, Ethernet, Wi-Fi, RF, GSM, LoRa, NB-IoT are utilized for specific applications ranging from home and building energy management to street lighting, scene creation for motivational effects, and even entertainment, all while ensuring energyefficiency. Sensors and dimmable systems are chosen according to the project's scale and specific requirements.

The question of whether to implement dimming control often arises due to concerns about additional investment, maintenance, and the need for operational expertise. However, lighting control systems have evolved into essential tools for energy management projects. Costs have decreased, a wide range of products is now available, and knowledge continues to expand, aided by contributions from new-generation IT professionals. Additionally, the direct impact of dimming control on energy savings is now measurable and evident.

Modern systems have become automatic and programmable, with remote access capabilities and the ability to collect and analyze data, including feedback on fault conditions. Data is centrally stored, providing both on-site information and operational feedback. From simple on/off switching and dimming to presence and daylight-dependent activation, and even fully integrated building control systems where all devices exchange information, lighting and building control systems today offer comprehensive solutions tailored to every need.

In addition to LED technology with various dimmable drivers, the ability to create millions of colors for dynamic effects and ambiance positively impacts health and performance. This capability plays a key role in promoting sustainability within society.

The scale of the building project is a critical factor. For smaller projects or individual rooms, a room-based control solution may be sufficient. It's important to assess whether the property is large enough to warrant a building-wide control system, as well as evaluate the feasibility of integrating the existing system. Other considerations include the integration of emergency lighting, the need for energy-saving solutions for rental spaces (such as shopping malls and shared offices), and the flexibility required in individual workspaces. Additionally, evaluating whether luminaires should gather data on factors like occupancy, room usage duration and intensity, oxygen/CO2 levels, and temperature highlights the growing importance of comprehensive building management.

The lighting control landscape, aimed at enhancing efficiency, can be summarized as follows:

a) For individual activity areas and single-room applications, wireless network/lighting control options include Bluetooth, Wi-Fi, ZigBee, Actilume, Lify, RF, etc.

b) For entire floors and their various utility areas, incorporating daylight linking through sensors, options include DSI, DALI, 1-10V analog, ZigBee, etc.

c) For entire buildings and multiple buildings with comprehensive infrastructure needs, wired networks with building control systems manage lighting, sun control, heating, ventilation, facade lighting, area lighting, etc., utilizing technologies such as KNX or equivalent proprietary solutions.

Below Fig.1 shows potential savings of interior lighting, Fig 2 shows potential savings of exterior lighting, Fig. 3 shows examples of a components of a power line or wireless lighting management system and Fig. 4 shows examples of lighting controls.

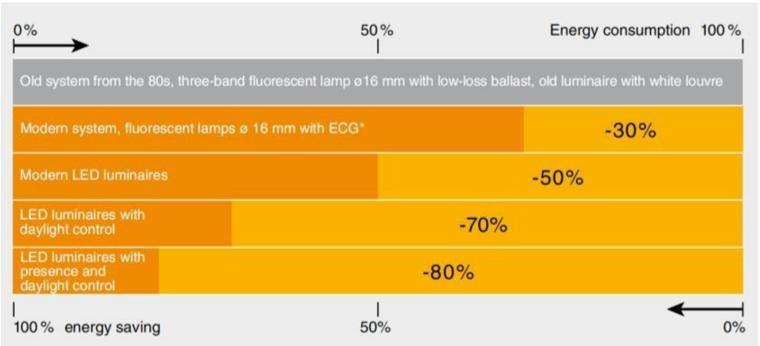

Fig. 1 Potential Savings in Interior Lighting

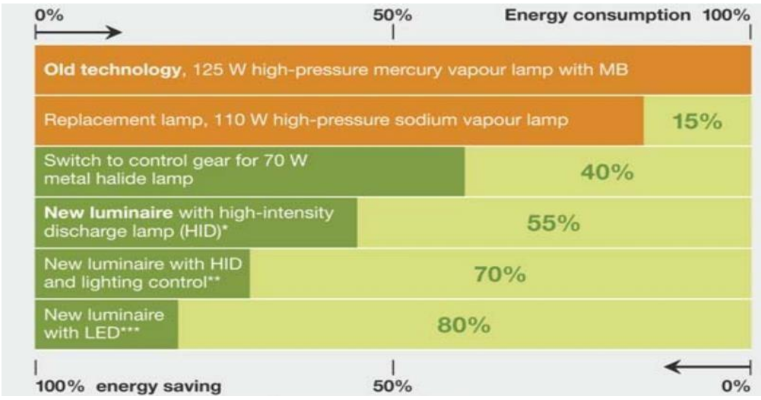

Fig. 2 Potential Savings of Exterior Lighting

Fig. 3 Examples of Components of a Powerline or Wireless Lighting Management System

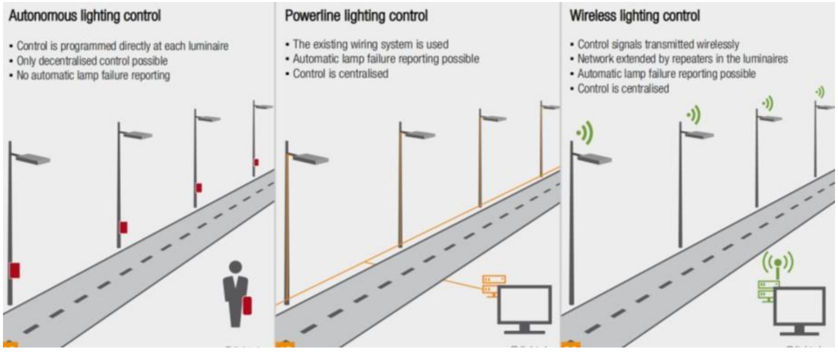

Fig. 4 Examples of Lighting Controls

7.2.4 *Luminaire*

LED technology has become the standard in energy-efficient lighting applications, surpassing traditional light sources. An LED luminaire integrates LED lamps, drivers, and control systems, unlike traditional lamps. This integration system is influenced by both internal and external factors, affecting quality of life and other parameters. Factors such as luminaire system efficacy, depreciation over its lifespan, and color shift are influenced by thermal management. Moreover, achieving the right light distribution is essential, determined by the optical system's light distribution curve (as per LM 79 lighting calculations). Additionally, internal and external parameters like electrical, mechanical, chemical, thermal, radiation, and IP protection play vital roles in LED lifespan and operation. LED systems boast long lifespans and require minimal maintenance, primarily limited to surface cleaning. Maintenance costs are nominal compared to traditional lamp replacements. Energy professionals should consider factors like efficacy, maximum operating temperature with lumen depreciation curves, light distribution, as well as safety and reliability factors when recommending a luminaire system.

7.2.5 *Luminaire Efficiency*

There are presently no universally recognized standards for evaluating the performance and efficiency of luminaire systems. One method gaining traction is the NEEMA system, which employs metrics like Luminaire Efficiency Ratio (LER). Alternatively, the Target Efficiency Rating (TER) can be considered. TER factors in variables such as ballast factor, temperature impact, and coefficient of utilization (COU) based on different room reflectance levels. Notably, TER values differ for indoor and outdoor lighting systems. However, it's essential to highlight that while these metrics provide quantitative data, they may not fully encompass the quality considerations that professionals must address.

Below is a simple formatted questionnaire to guide whether a project has the potential to start energy management for any existing installation. If even one area answers "Yes," it's worth starting the project. The more "Yes" answers, the greater the potential for energy savings.

a) Is the installation older than 10 years?
b) Is annual operating time more than 2,500 hours, or the daily operating time is more than 8 hours?
c) Does a large number of lamps use traditional and first-generation models?
d) Are the luminaires still operating with old electromagnetic devices, such as ballasts or transformers?
e) Is a diffuser used in the luminaire?
f) Is the power consumed by lighting is more than 18 percent of the total energy consumption?
g) Is uneven uniformity in lighting levels causing reduced efficiency or the user dissatisfied with lighting environment ?
h) Is luminaire using retrofit 2 pin CFL or G12 CFL?
j) Is indirect lighting used with tube light or CFL?
k) Is day light provision not being used properly but there is potential to incorporate it?

Below is a simple questionnaire for refurbishment checklist.

Eight questions about the condition of your lighting installation Yes?

Maintenance

1. Have individual lamps failed?
2. Are the luminaires soiled?
3. Do lamps flicker when activated or in operation?

→ *If the answer to any of the above questions is YES, you should clean the luminaires and replace faulty lamps.*

Refurbishment

4. Is your lighting installation more than 15 years old?
5. Is there too little light at your workplace?
6. Do your feel dazzled when you are working?
7. Do you see reflections or mirror images on your screen?
8. Do you wish you had a way of switching or dimming the lighting?

If the answer one of questions 4 to 8 is YES, you should check the lighting installation
→ *If the answer to two or more of the questions is YES, it is time to think of refurbishment.*
→ *If you answered YES to all four questions, you should call a professional straight away and arrange for a refurbishment concept to be drawn up .*

8 SOLAR LIGHTING

Solar photovoltaic (PV) technology and lighting are synergistic partners in the pursuit of energy efficiency.Solar PV cells offer another avenue for energy conservation, and the combination of solar PV and lightinghas proven effective in both grid and off-grid applications. Initially, solar PV gained popularity in off-grid areas, particularly for street lighting and home lighting, including solar lanterns. However, with advancements in technology and decreasing costs, solar plants are now emerging as alternative solutions for electricity generation. Solar panels and lighting systems complement each other in the energy-saving drive, operating independently to conserve energy. Together, they play a significant role in promoting sustainability. Solar photovoltaic cells function by converting light into electrical energy, representing a reverse mechanism compared to solid-state lighting, where electrical energy is converted into light energy.Both technologies are based on semiconductor principles.

9 DECISION MAKING PROCESS

The decision-makers responsible for evaluating lighting projects often prioritize profitability or return on investment (ROI) without fully grasping the potential of modern lighting systems. It may lack familiarity with the range of opportunities and possibilities offered by these systems and may struggle to understand the technical aspects and assumptions presented by consultants or proposers. Additionally, theremay be uncertainty regarding the reliability of technical data sheets, as they often only present theoretical calculation values rather than real test results. Decision- makers may also fail to recognize the benefits to people's well-being, productivity, and environmental impact, including CO2 emission reduction, which is also their social responsibility.

Energy-saving projects inherently involve some degree of uncertainty and economic fluctuation in the analysis. Even for decision-makers who recognize the benefits and are willing to invest, the initial financial outlay can be a significant constraint. The failure of previous energy-saving initiatives, such as those duringthe CFL era, like Clean Development Mechanism (CDM) and Demand Side Management (DSM) projects, to deliver satisfactory results and subsequent abandonment underscores the challenges faced in implementing such projects.

Starting from 2000, there was a significant global discourse and widespread implementation of the Clean Development Mechanism (CDM), which began in India in 2004. The CDM was designed to encourage and assist project owners in generating profitable returns from environmentally friendly projects. Under this mechanism, project owners receive Carbon Emission Reduction (CER) certificates for every reduction in carbon dioxide (CO_2) emissions, which can be traded on the National Commodity and Derivatives Exchange (NCDEX) market. This process operates in accordance with the United Nations Framework Convention on Climate Change (UNFCCC). However, over time, the market value of carbon credits has declined, leading to a loss of momentum in CDM initiatives. Below Table 2 describes for planners-product and system criteria for quality assessment.

Table 2 For Planners: Product and System Criteria for Quality Assessment
(*Clause* 9)

Sl. No.	**Data Sheet Specifications**	**Office**	**Industry**	**Retail Outlet**	**Public Lighting**	**Home/ Hotel**	**Museum**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

i)	Luminaire output: W	Relatively important	Extremely important	Very important	Relatively important	Minor importance	Relatively important
ii)	Luminaire luminous flux lm	Relatively important	Very important	Relatively important	Relatively important	Not important	Minor importance
iii)	Luminaire luminous: lm/W	Very important	Extremely important	Minor importance	Extremely important	Minor importance	Minor importance
iv)	Color rendering index: CRI or R_a	Very important	Relatively important	Very important	Minor importance	Very important	Extremely important
v)	Correlated colour temperature/ CCT or TCP: K	Very important	Relatively important	Extremely important	Minor importance	Extremely important	Extremely important
vi)	Color tolerance (initial, MacAdam): [Number]	Very important	Minor importance	Very important	Minor importance	Very important	Extremely important
vii)	Median useful life: L_x	Very important	Extremely important	Relatively important	Extremely important	Minor importance	Relatively important

10 LIGHTING SERVICE COMPANY

With the introduction of LED technology, energy savings of 50% to 80% over traditional lighting products are now achievable. When combined with controlling devices, such as sensors or dimmers, savings can be further improved to 70% to 80%. Additionally, the advent of Centralized Control and Monitoring Systems (CCMS) or built-in energy meters allows for precise measurement of these savings. These technological advancements have paved the way for 'lighting as a service' projects, where companies invest in the initial setup and operation, enabling greater adoption of this business/service model. These service providers are commonly known as Energy Service Companies (ESCOs).

ESCOs typically invest the initial capital for the project and manage its operation until the end of the contract period, after which they transfer the system to the owner at no additional cost. This arrangement benefits both parties, as ESCOs generate revenue through the energy savings achieved by the installed lighting systems. In India, this approach has been particularly successful, aided by government initiatives led by entities like Energy Efficiency Services Limited (EESL). EESL has played a pivotal role in the nationwide retrofit of LED lamps, street lighting, and lighting in industrial and commercial sectors. Despite the progress, there remains substantial work to be done to scale up these efforts.

ESCOs typically offer the following services:

a) Installation and maintenance of energy-efficient equipment.
b) Measurement, monitoring, and verification of the project's energy savings.
c) Development, design, and arrangement of financing to ensure the success of energy-saving projectsor investment from their end.
d) Occasionally, ESCOs also assume the risk associated with projected energy savings for a specific period, which can be challenging in different socioeconomic conditions, such as in India or other developing countries.

With the increased volume and dynamic market, the cost of LED products has significantly decreased, providing decision-makers with added benefits in terms of Total Cost of Ownership (TCO) over the product's lifespan. However, this is also a critical time where quality assessment becomes paramount and requires extra care for any energy-saving projects. Quality testing and reliable test results are crucial for thesuccess of the project over its lifespan, and this directly impacts the credibility of the ESCO Company. In lighting, ESCOs typically provide warranties of more than 5 years, covering parameters such as lifespan, wattage, depreciation, lighting level, color temperature, color rendition, and IP class.

11 PERFORMANCE MEASUREMENT & AUDIT

The quality of the product is paramount and must be an integral part of project tenders and contracts to ensure that the agreed-upon specifications are met. This process is critical for building trust and confidence among users and stakeholders. By emphasizing quality in every phase, from design to execution, energy management projects can ensure long-term performance, reliability, and customer satisfaction. Incorporating strict quality control measures and clear specifications into the tendering process is essential to achieving successful outcomes and maintaining the integrity of the project.

12 TIME CONSTRAIN

Unfortunately, many logistical decisions are often made under significant time pressure, which can make it difficult to consider superior quality alternatives. These higher-quality options typically offer greater long-term value, benefiting both the environment and the users. They come with well-defined product profiles and extended service lives. While they may appear more expensive initially, they ultimately provide higher returns on investment by reducing maintenance costs, improving energy efficiency, and contributing to sustainability over time. Therefore, it is crucial to prioritize quality and long-term value over short-term cost savings in decision-making processes.

13 TRIAL INSTALLATION

Another solution before committing to a final large-scale investment is to conduct a trial installation. Trial installations offer numerous benefits and provide valuable practical experience. Total Cost of Ownership (TCO) calculations are crucial for making informed decisions. TCO encompasses the sum of total direct and indirect expenses incurred throughout the entire life cycle analysis of owning or using certain large- scale assets, sometimes referred to as life cycle cost. Direct costs include expenses from the purchase of the asset all the way to decommissioning. This typically encompasses all possible investments, such as the costof installation, deployment, operation, upgrading, building, and maintaining the asset, and includes the interest cost of the investment.

Key benefit of lighting control in TCO calculations:-

a) low initial cost
b) Failure based reporting,
c) reduced light pollution,
d) most & simply Plug & play
e) increased Lamp life
f) Maintenance and Repair saving
g) Power saving
h) Easy expansion
j) no Photocell required

Draft National Lighting Code of India

Part 7 Energy-Effective Lighting Systems
Section 2 Sustainability

First Revision of SP 72 (Part 7 / Section 2)

FOREWORD

Secure the future for our next generation" encapsulates the essence of sustainability. The role of lighting in sustainability has become a central focus for the lighting community, especially with the significant advancements in LED technology that have greatly enhanced energy efficiency. The successful G20 summit in India highlighted the importance of achieving zero emissions, sparking discussions and commitments from member nations around the world. This global momentum underscores the need for continued innovation in energy-efficient lighting solutions as part of a broader effort to reduce environmental impact and secure a sustainable future.

Draft National Lighting Code of India

PART 7 ENERGY-EFFECTIVE LIGHTING SYSTEMS
SECTION 2 SUSTAINABILITY

(First Revision)

1 SCOPE

This section of the code (Part 7/ Sec 2) covers the concept of sustainability, the analysis and methodology behind sustainable practices, and the recommendations being implemented globally. Its purpose is to guide users and government agencies in understanding the necessary requirements and actions to make India's environment more sustainable. The lighting community, in particular, should embrace lighting sustainability as a self-imposed goal, contributing to the collective effort towards reducing environmental impact and fostering long-term ecological balance.

NOTE — Sustainable lighting is a type of energy-efficient lighting that uses natural light and smart controls to reduce energy consumption and light pollution.

2 REFERENCES

IS No.	***Title***
IS/ISO 14001	Environmental Management Systems — Requirements with guidance for use (*Second Revision*)
IS/ISO 50001	Energy Management Systems — Requirements with guidance for use (*First Revision*)
ISO 45001	Occupational health and safety management systems — Requirements with guidance for use

3 TERMINOLOGY

For the purpose of this section, the definitions given in Part 1 of this code shall apply.

4 CONCEPT OF SUSTAINABILITY

Let us begin by understanding the three-pillar concept of sustainability.

The first pillar is the economics of the installation, which has been thoroughly covered in Part 7, Section 1. For sustainability in lighting, it is essential to focus on energy efficiency and the entire life cycle cost, starting from product selection to disposal. The rise of energy-saving green systems, driven by LED and modern lighting technologies, has led to the widespread adoption of 'Green Buildings.' However, a more advanced concept, the 'Blue Building' system, is emerging. This system provides a more comprehensive balance of sustainability principles, ensuring that materials used and product disposal meet stringent environmental criteria.

The second pillar is environmental conservation, which encompasses nature preservation, climate protection, responsible resource utilization, light pollution reduction, emission control, and recycling. These practices ensure that lighting solutions not only save energy but also contribute to a healthier environment.

The third pillar is social responsibility, which includes aspects such as health, safety, improved quality of life, and the overall well-being of individuals and communities.

Sustainability in lighting goes beyond just saving energy, it is about safeguarding the planet and its inhabitants. The initial focus on kilowatt savings stemmed from the need to reduce CO_2 emissions that strain the environment.

Today, sustainability extends beyond the traditional three-pillar concept. It requires the participation of every occupant, user, and owner in sustainability programs. Lighting system design must consider functional, technological, process-related, and locational factors. Both natural and artificial light play crucial roles, and designers must effectively utilize the intangible qualities of light. Architects and lighting specialists should work together to achieve seamless integration. A truly sustainable lighting concept is not just about energy savings or efficiency; it combines environmental protection, cost-effectiveness, comfort, and human health ensuring a holistic approach to sustainability.

5 COMPONENTS OF SUSTAINABILITY LIGHTING

The main Focus areas include:

a) Energy-efficient, long-life light sources with low maintenance requirements and economicallyviable payback periods.
b) High interchangeability, replace ability, and modernization potential.
c) Easy operation, preferably with automatic and programmable features.
d) High quality, visual comfort, and human-centric design.
e) Very low direct environmental impact, incorporating maximum possible recyclable components, low pollution during production, minimal stray light pollution, and environmentally friendlydisposal at the end of the product's life.

6 VALUE CREATION IN LIGHTING

Sustainability in lighting is an ongoing process, where every stakeholder plays a crucial role in creating a cohesive ecosystem design. Sustainable lighting systems must be maintained across the entire value chain, from initial concept to end-of-life. A Total Cost of Ownership (TCO)-based project design, which considers factors like raw material selection, manufacturing, distribution, and installation, is essential. However, true sustainability cannot be achieved unless this approach is consistently applied and followed at every step of the process. It is only through continuous collaboration and adherence to sustainability principles that lighting systems can deliver long-term environmental, economic, and social benefits.

6.1 Process

Project management follows a structured process, starting with concept initiation, design, and planning. This leads to project approval, tender preparation, contract award, and purchasing. Next is installation and commissioning, followed by project handover and closing. Finally, the project enters the operation and maintenance phase to ensure long-term functionality.

In the sustainable lighting project life cycle, there will be number of actors play their role individually and as cumulatively. They are like project owner/ project authority/ building owner/financing agency, supplier of all products and component, contractors, designers, planner, purchaser, operators and skilled personnel etc Specifically for lighting systems, additional players include product designers, raw material producers,procurement specialists, manufacturers, storage and distribution experts, transport and delivery teams, lighting system designers, automation manufacturers, electrical designers, and system integrators. All these actors are guided and bound by a set of national and international regulations and standards. Statutory requirements such as state and central government contracts, safety norms, building codes, and voluntary standards and certifications/ star label plan provide significant advantages for all participants from projectinitiation to completion.

6.2 End to End Solution for Lighting Products

Sustainable lighting must be considered from the selection of raw materials to the disposal of the product at the end of its life, covering all intermediate stages. It's crucial to recognize that energy is consumed andenvironmental impacts occur at every step before the lights are even turned on for energy savings at the site. The raw materials, chemicals used for paint or soldering, and production processes all affect the environment and human health. Factory waste and the disposal of lighting systems, especially those containing batteries, mercury, lead, and electronic hardware, pose significant challenges.

To address thesechallenges, raw materials should be recyclable, such as using the right quality aluminium for LED heat sinks, or other metals, glass, halogen-free plastics, and halogen-free wiring. Ensuring these factors makes luminaires easier to recycle. Packaging materials should also be reusable or recyclable. The production and assembly processes should include water treatment and filtration.

Beyond recycling, proper disposal processes are critical. The best way to manage this is through an organized collection process. While transportation costs are minimal, this aspect is often neglected. The full energy balance of a lighting system encompasses raw material preparation, production, transport, usage, and recycling. While modern lighting technologies already contribute significant energy savings, focusing solely on disposal and recycling addresses only a small portion of the overall energy cost. Efficient management across all stages, from production to disposal, is essential for maximizing energy efficiency (*see* Fig. 1).

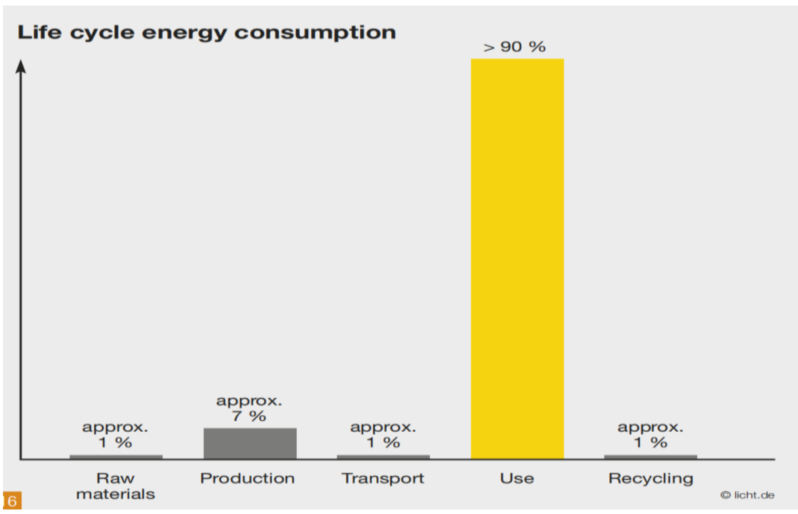

Fig. 1 Life Cycle Energy Cost of the Total Lighting

6.3 Environmental Product Declaration (EPD) for a Lighting System

This is the statement from the product company outlines the environmental impact of their product/system. For sustainability projects, this data is essential during the initial design stage to guide product selection. The Environmental Product Declaration (EPD) is provided in Fig. 2.

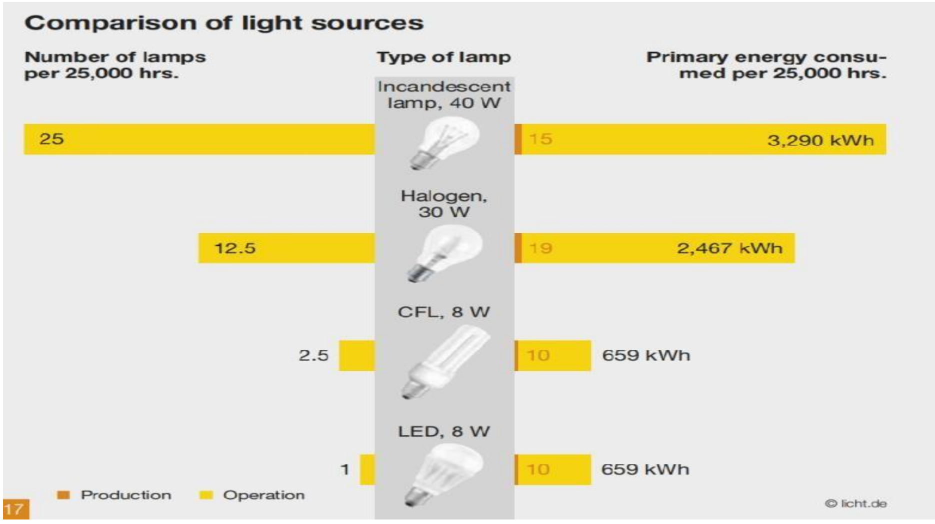

Fig.2 Light Source Declaration

Example of CO_2 emission calculation, investment vs operating cost and average consumption in per sq. meter and year in KWH is given in Fig. 3. Data comprises of old calculations for a specific lighting system of T8 lamps, LED diffuser system, ledsystem and with Controlling the light. This is for interior calculations.

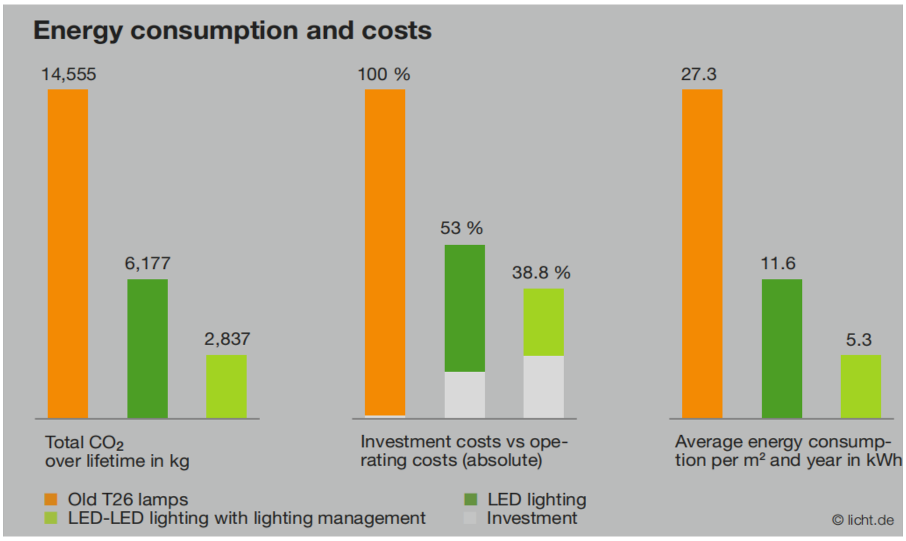

Fig. 3 Energy Consumption Chart Courtesy

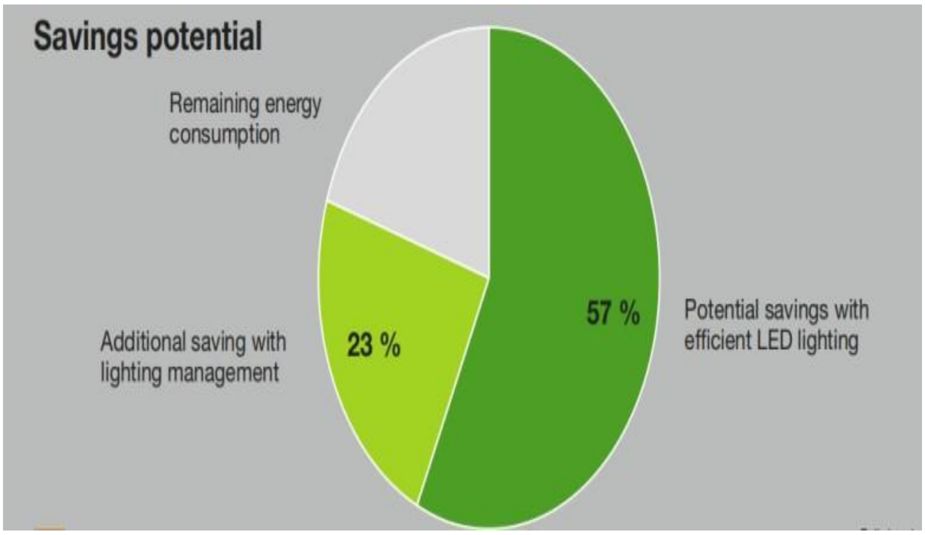

Fig. 4 Saving Potential

Fig. 4 illustrates the comparative saving potential.

EPD declaration for luminaire consist of detailed information as given below:

a) *Description* — Product name, application, mains power supply details
b) *Materials used* — Type and grade of the materials like Aluminium, iron, glass, plastic, wires, pasteetc.
c) *Production* — Place of manufacturing, process and paint /solder materials used etc.
d) *Delivery* — Area and transport conditions, any precaution required, packaging materials, dimensionand weight
e) *Use* — Life time years, service life, power rating, special effects if there is thermal loading
f) *Recycling* — Details of recycled components
g) *Disposal* — Details of disposal of non-recyclable components, weight ratio of recyclable to non-recyclable components.

In conclusion, the data offers a comprehensive overview of the environmental impacts throughout the product's life cycle. The Environmental Product Declaration (EPD) assessment provides clear insights into the product's environmental contributions, alongside its inherent benefits. Its impact is analysed against defined standards, legislation, and certification criteria to offer precise and reliable information.

6.4 Lighting Comfort

An ideal lighting requirement entails a holistic approach where lighting design prioritizes both comfort andenergy efficiency throughout the entire life cycle of the installation. As a guideline, sustainable lighting canbe viewed as a combination of economic lighting, accounting for 60 percent, and quality criteria, comprising 40 percent.

In 60 percent of economic lighting criteria, the different components like price, energy, maintenance and others components is given in Table 1.

Table 1 Lighting Cost Component
(Clause 6.4)

Sl. No	**Components**	**Percentage (%)**
(1)	(2)	(3)
i)	Price	35%
ii)	Energy	35%
iii)	Maintenance	20%
iv)	Others	10%

In the case of 40 percent quality criteria, different components that are taken into consideration include quality of light, product quality, biological effect, aesthetics, users comfort, environment and resources as given in Table 2.

Table 2 Quality Component
(*Clause* 6.4)

Sl No.	**Components**	**Percentage (%)**
(1)	(2)	(3)
i)	Quality of light (CRI, CCT, Uniformity, Glare etc.)	20%
ii)	Product quality	20%
iii)	Biological effect	10%
iv)	Aesthetics	10%
v)	Users comfort	20%
vi)	Environment and Resources	20%

The role of lighting professionals has significantly expanded to oversee all aspects of lighting installations. There are currently no specific regulations, but these guidelines will assist professionals in approaching the subject in a structured manner. Modern lighting systems, managing both the economic and quality aspects has become easier. A German court ruling has emphasizedthat both aspects should be given equal weight, each accounting for 50 percent. Fig. 5 illustrates the Holistic installation model.

Fig. 5 Holistic Installation Model

6.5 Light Pollution

Light pollution is commonly experienced firsthand from our bedrooms, often due to streetlights, garden lights, or security lighting. While light enhances our lives, improper use, installation, or maintenance can lead to irritation and environmental harm. Mitigating light pollution requires careful attention to all three stages – product design, selection, installation, and maintenance – with designers and maintenance personnel playing particularly crucial roles.

The term "light pollution" or "light smog" refers to light emitted upwards, brightening the night sky in urban areas. These stray lights not only disrupt sleep but also harm the nocturnal habitats of birds, animals, and plants. Artificial lighting for purposes like sports, city decorations, gardens, advertisements, and security can negatively impact both humans and nature if not implemented thoughtfully.

Fig. 6, Fig. 7 and Fig. 8 show the street lighting glare, Glare from post of lantern and Road-Junction Street lighting effect respectively.

Fig. 6 Street Lighting Glare

Fig. 7 Glare from Post of Lantern

Fig. 8 Road- Junction Street lighting Effect

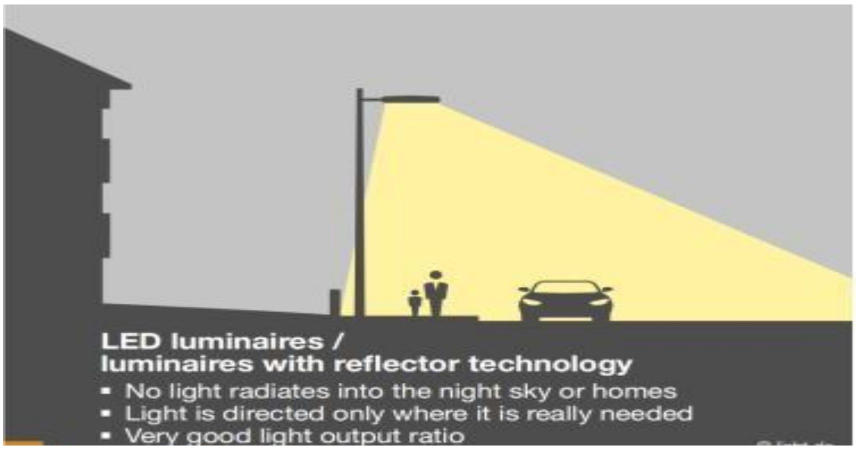

Fig. 9 Right Reflector for Glare Control

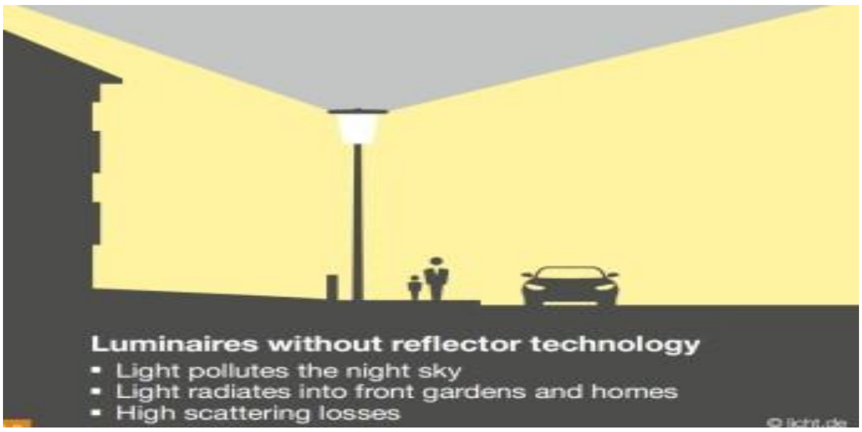

Fig. 10 Luminaire without Light Control

To minimize the adverse effects of stray artificial lighting on the night sky, it's crucial to consider five keyaspects when designing, selecting, and maintaining lighting systems:

a) *Use the Right Light in the Right Place* – Choose application-specific lighting products. For example, retrofitsolutions like street and flood lights are commonly used for garden and area lighting, but they may not always be suitable. For path lighting, use bollard types; for security, select fittings that suit the area with the correct pole height and spacing. Avoid using the same lighting across different application, as logistical and inventory constraints can disrupt ecological balance. The right selection is often more cost-effective in the long run. Additionally, consider both daytime and nighttime impacts on architecture to prevent excessive nighttime glare.

b) *Targeted Light Beams* – Avoid scattered light that disturbs neighbouring humans, trees, plants, andbirds. Assess the area to determine the appropriate beam type and light distribution. Optics are crucial in sustainable lighting design. Sometimes, lighting guards or shields can prevent unwanted light spread. Fig. 9 depicts the use of right reflector for glare control and Fig. 10 depicts theluminaire without light control.

c) *Use Standard Lighting Levels* – Over-illumination is common but unnecessary. Excessive light notonly consumes more energy but also disrupts the harmony between nature and humans, as reflectedlight highlights the sky. Lighting should adhere to established standards to avoid these issues.

d) *Color Temperature* – Research shows that nighttime is a crucial resting period for plants, birds, and animalsalso. Therefore, using warmer color temperatures and avoiding blue-rich white lighting is preferable.

e) *Control the Light* – Use lighting only when necessary and dim lights according to demand using various controllers and gadgets. BUG (backlight, uplight, and glare)-rated luminaires can help create a controlled lighting environment.

6.6 Protecting the Insect Habitats

Insects are drawn to artificial light, which often results in their death and causes disturbances for those around the lighting system. This negatively impacts natural habitats as many insects perish due to this attraction.

Nocturnal insects, being more sensitive than humans to brightness and spectral composition, are especially attracted to ultraviolet (UV) light. Fluorescent, mercury vapor, and metal halide lamps emit UV light, which mimics the pale moonlight that insects use for navigation, causing them to swarm around these lights.

In contrast, high-pressure sodium vapor lamps emit light in the orange and red spectrum, making them less attractive and nearly invisible to insects. LED lights, which do not emit UV light, are also less appealing to insects, making them more "insect-friendly." Fig. 11 illustrates the light source-wise insect attraction.

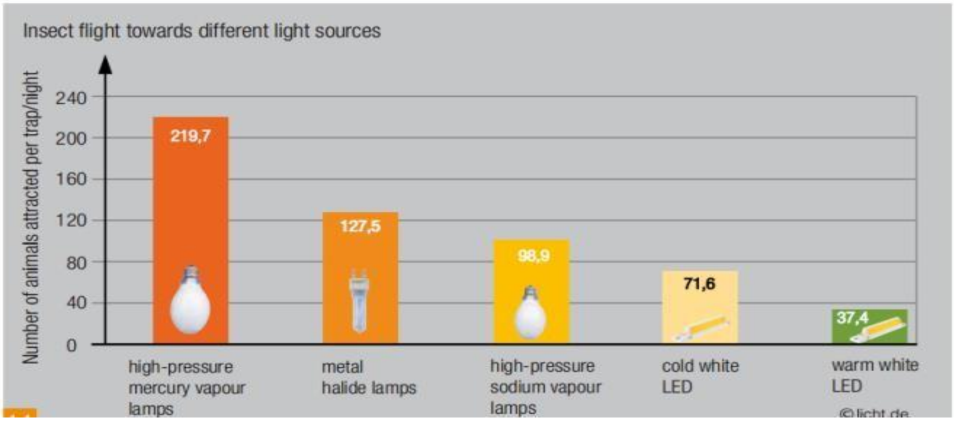

Fig. 11 Depicts the Light Souse Wise Insects Attraction