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[Please use A4 size sheet of paper only and type within fields indicated. Comments on each clause/sub-clause/ table/figure, etc, be stated on a fresh row. Information/comments should include reasons for comments, technical references and suggestions for modified wordings of the clause. **Comments through e-mail in MS WORD format to eetd@bis.gov.in shall be appreciated.**]

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Title: Draft National Lighting Code of India: Part 7 Energy-Effective Lighting Systems/Section 1 and Section 2 [First Revision of SP 72 (Part 7/Section 1 and Section 2)]

Name of the Commentator/ Organization: ______________________________________

Part 7 /Section 1 Energy Efficiency in Lighting		
Clause No. with Para No. or Table No. or Figure No. commented (as applicable)	**Comments / Modified Wordings**	**Justification of Proposed Change**
Part 7/Section 2 Sustainability		
Clause No. with Para No. or Table No. or Figure No. commented (as applicable)	**Comments / Modified Wordings**	**Justification of Proposed Change**

BUREAU OF INDIAN STANDARDS

DRAFT FOR COMMENTS ONLY

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	**Last Date for Comments: 30-June-2024**

FOREWORD

Across India, Energy Management was a talked subject since 1970s since when then whole universe became very serious energy utilization & energy saving.

For India, it has been considered to be even more important, as demand for electricity was going up every year with the need for rapid industrialization and all-round growth. In early 80s when energy saving approach started in India -" 1w ENERY SAVED = 2w Energy Generated" was the slogan. With the rise in demand and depleting natural resources, the 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, lead time plus CO_2 gas emission etc.

The history of energy management efforts in lighting with the introduction of high pressure sodium vapour lamp HPSV to replace high pressure mercury vapour HPMV lamps in beginning of 1980s, Those days HPMV lamps used in street lighting & industrial lighting. Thereafter FTL 36 watt replacing the FTL40 Watt tube light was a big activity. These two energy management activity based on pay pack, thereafter in 1990 introduction of electronics ballast for tube light replacing the electromagnetic and thereafter the number of efficient luminaries optics like BAT-WING distribution aluminum reflector for interior commercial applications and POT-OPTICS for street lighting payed a great role in energy saving drive.

Introduction of T5 lamps saw marked improvement in tube light replacement schemes in a big way. T5 retrofit solution was big game changer in this area of energy saving, that is the time India saw lot of big projects for energy saving drive introduced in all India level in public and private sector. This drives leads to come up few ESCO companies. Beginning of good quality CFL retrofit and non-retrofit solution won the confident of Indian market and accelerated the energy saving drive in many fold.

Finally, 7th generation of lighting and transition of lighting got its peak with the introduction of Solid state lighting i.e LED. LED's quick acceptance & adaptation made the dream of energy saving in lighting come true.

1 SCOPE

Lighting energy management calculations process & the snap short of different characteristic of lamps, drivers, controllers, luminaires covered as a guide line for understanding and applying to achieve the energy effectiveness and quality lighting.

While some energy-efficient lighting solutions may have a higher initial cost, they often yield substantial savings over time. For instance, advanced lighting controls, such as IoT-based systems, can reduce energy consumption by up to 80%. Although these installations might require the expertise of lighting professionals, the savings achieved typically offset the initial investment within one to three years. When considering the total cost of ownership (TCO) — encompassing initial, operating, and maintenance costs — energy-efficient lighting proves to be a profitable investment with an excellent return on investment.

A lighting system comprises several components, including light sources, drivers, ballasts, controllers, modules, and luminaires, which work together to ensure the system operates efficiently and effectively.

Energy efficiency in lighting is referred to as efficacy. Conducting a comprehensive survey of each component in the system can provide valuable insights for application guidelines to enhance overall system efficiency. In lighting design, it's crucial to consider both efficiency and quality parameters such as color rendition, color temperature, uniformity, glare, and modeling, as they are equally important for achieving optimal lighting performance.

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 (Part 16/Sec 1) shall apply

4 ENERGY CONSERVATION MEASURES

4.1 Thought Process

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 distinct options, with a fourth option being a combination of the three. These options are:

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.

Daylighting presents a significant opportunity in countries like India, where its potential is yet to be fully explored. This topic is extensive and is covered in detail in a dedicated chapter.

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

Besides many computer apps are now available and also being supplied by companies for doing this calculation for the whole buildings / premieres. But basic though 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 system audit.
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 and daylight 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, luminaire and advanced controls devises (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 of light distribution by providing finishes that give proper ceiling, wall and task reflectance values.
i) All lighting components must be compatible to operate properly.
j) All applicable safety requirements and regulations should be strictly adhered to when any work is done on an electrical system.
k) Consider a planned lighting maintenance programme and opening retrofit opportunities that reduce light output and energy consumption.
l) 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.
m) Be sure to include provisions for legal compliance in disposing of any lighting waste
n) 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.
o) Ensure compliance with Energy Conservation Act and other statutory Regulations for the country.

5 METRICS

All lighting equipment requires electric power, measured in watts (W). As the lighting system operates over time, it consumes energy, which is calculated as power multiplied by time, expressed in kilowatt-hours (kWh). One kWh equals 1,000 watts used for one hour. Electric utilities charge for two main metrics: the total electrical load of the building in kilowatts (kW) and the amount of energy consumed in kilowatt-hours (kWh). Therefore, in any lighting upgrade, our goal is to reduce both the power the lighting system requires and, whenever possible, its hours of operation.

5.1 Demand Charge

The monthly cost of electricity is based on the connected electrical load of the building. Actual demand is metered by the utility, and the charge is determined by the peak demand for the month. With this in mind, it's beneficial not only to reduce wattage but also to minimize consumption during peak load periods, typically around midday. Additionally, utilities may impose a ratchet clause based on demand, locking in the demand charge at the maximum demand recorded in the recent past.

5.2 Energy Use Charge

5.2.1 It is the monthly charge by the kWh for electrical energy consumed by the building's electrical systems. Our lighting energy management goals therefore can be clearly stated as:

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

5.2.2 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.

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

5.2.4 KWh per square metre - This metric, called the energy utilization index, is determined by dividing the total kWh of energy consumed by the lighting system in a space by the interior space's total area in square metre. The advantage of using the energy utilization index is that it includes the factor of time, and encourages the use of lighting controls that reduce the amount of time the lighting system operates when it is not needed.

5.3 Relevant Formula

Using local environmental data and system performance data from manufacturers' literature, we can use the formulas below to determine the energy characteristics of an application:

Demand for Power (kW) = System Input Wattage (W) ÷ 1.000
Energy Consumption (kWh) = System Input Wattage (kW) x Hours of Operation/Year
Hours of Operation/Year = Operating Hours/Day x Operating Days/Week x Operating Weeks/Year
Lighting System Efficacy (Lumen per Watt or LPW) = System Lumen Output ÷ Input Wattage
Light Power Density (W/m 2) = Total System Input Wattage (W) ÷ Total Area (Square metre)
Watts (W) = Volts (V) x Current in Amperes (A) x Power Factor (pf)
Voltage (V) = Current in Amperes (A) x Impedance (Ohms) [this is called Ohm's Law]

6 COMPARING SYSTEMS

6.1 It is always recommended that more number of solutions/recommendations for energy saving solutions should be worked based on many factors to make decision very rational and best for the user /customer/ 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 achieve these goals at the lowest wattage possible. From this we can also compare LPD, or watts per square metre. 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 new installation
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 any new 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 produces energy savings, which deliver a payback and return on the investment. There are several ways of using economics to compare lighting systems. The most popular for screening purposes are simple payback and return on investment.

a) First determine the initial cost of the new lighting system, and then compare energy usage to the existing system to determine energy savings.

Initial Cost (Rs) = Equipment Cost + (Installation Hours x Labour Rate)
Annual Energy Savings = (A - B) x energy rate charged by utility
where,
A = [Existing System Wattage (kW) x Annual operating hours (h)]
B = [New System Wattage (kW) x Annual operating hours (h)]

b) Next step to determine simple payback, 3 to 5 year cash flow and simple return on investment. Less than 3yrs payback is always the best proposition. Even 7 years warranty /guarantee base pay back by ESCO system is being operating in India very successful in India for street lighting retrofit solution. Even for LED retrofit lamps payback is less 12 months.

Different project specific models even standards programme as well as calculators amiable and used by energy auditors or lighting designers/professionals. Simple process is mentioned below as guide line calculations.

Simple Payback on an Investment (Years) = Initial Cost (Rs) ÷ Annual Energy Savings (Rs). 5-Year Cash Flow (Rs) = 5 Years – Payback (Years) x Annual Energy Savings (Rs) and simple Return on Investment (%) = [Annual Energy Cost Savings (Rs) ÷ Net Installation Cost (Rs)] x 100.

c) Another method of comparing lighting systems is to look at the cost efficacy of the system, expressed as Rupees per lumen-hour, and the total cost of ownership for the system over its life.

Cost of Light/Lumen-Hour = (Initial Cost + Total Operating Cost) ÷ (Total Lumen Delivered x Hours of Operation). Total Operating Cost and Hour of Operation are set for any period of time that the specifier or owner wishes to consider.

Simple Life-Cycle Cost = Initial Cost + (Annual Operating Cost x Life of System in Years). Annual Operating Cost is Annual Energy Cost + Annual Maintenance Cost, with the annual maintenance cost assuming all labour costs, replacement components, etc. The life of the system in years must be estimated. The owner can participate in determining this figure, but otherwise one could assume 20 years.

Once simple values are achieved, one can determine which lighting system makes the most economic sense to replace the existing system with. Then one can conduct a full economic analysis, including life-cycle costing and return on investment. that takes into account many economic factors such as the future value of money etc.

7 COMPARISON OF DIFFERENT LIIGHTING SYSTEM COMPONENETS

This section provides a guideline for the main components of a lighting system, considering their properties related to energy savings, quality, and usage. There are numerous innovative approaches that experts can apply. As technology evolves rapidly, these guidelines represent the best current practices but remain open to improvement with future advancements in technology and systems.

7.1 Light Sources

7.1.1 *Absolute efficacy of light sources* - The theoretical maximum luminous efficacy of a perfect lamp, producing light from electromagnetic radiation without any energy losses, is 683 lumens per watt (lm/W). This ideal lamp would emit light at a single wavelength for which the human eye has maximum sensitivity during photopic vision, around 555nm.

In practical cases, monochromatic light approaches this maximum efficacy. For white light, which consists of a mixture of wavelengths, the theoretical maximum efficacy without any energy loss was calculated by Ohno in 2004 to be between 350 and 450 lm/W. It's also observed that white discharge lamps typically do not exceed 105 lm/W.

Regarding white LEDs, the U.S. Department of Energy (DOE) projected in a 2017 report that efficacies of up to 250 lm/W could be achieved by 2025, for both cool and warm colors, with a color rendering index (CRI) greater than 80. As of today, white LED efficacy has reached approximately 200 lm/W.

With this back ground, following table will give clear picture for light sources guideline.

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 are
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 activity is not important
i) Metal Halide Lamps (HPMH) -Improvement in generation from quartz to Ceramic on efficiency & quality - sports lighting, shop lighting
j) Light Emitting Diode LED - Applications in all areas and superseding & replacing all lamps.

Today in India, 2020 where LED penetration for new installation and new refurbishment market is almost 100% there by traditional lamps in energy management lost its importance and hence out of scope here.

7.1.3 *Technical Data sheet on comparison for commonly available light sources (as a guide line)*

Table 1
Technical Data Sheet on Comparison for Commonly Available Light Sources

Sl. No.	Light Source	Wattage Range (W)	Efficacy (lm/W)	Life (h)	Lumen. Maintenance %	Starting Time in Second	Colour Rendition Ra	Dimming Capability	Colour Temp K
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1.	Incandescent	15 to 150w	8-to 12	500 to 1,000	50 to 65%	Instant	100 Excellent	Excellent	2700
2.	Low Voltage Halogen	1to 30	12 to 20	1000 to 2,000	50 to 75%	Instant	100 Excellent	Excellent	2700 to 3000
3.	Mains voltage Halogen	300 to 1500	20 to 27	200 to 2,000	50 to 60%	Instant	100 Excellent	Excellent	3000
4.	Fluorescent T8 & T8 Tri-Phosphor	18 to 80	60 to 90	5,000 to 15,000	60 to 85%	3 to 10	60 to 88	Possible	2700 to 65000
5.	Fluorescent T5	14 to 58	80 to 105	10,000 to 20,000	80 to 90%	3 to 10	80 to 98	Possible	2300 to 6500
6.	Compact Fluorescent Integral (retrofit)	5 to 180	60 to 85	5,000 to 15,000	65 to 85%	2 to 5	65 to 85	Very Low	2300 to 6500
7.	Compact Fluorescent Non-Integral (2pin & 4 pin)	5 to 120	60 to 85	5,000 to 20,000	65 to 85%	2 to 5	70 to 90	Possible	2300 to 6500
8.	Blended Light	160 to 250	20 to 30	3,000 to 5,000	55 to 65%	Instant	85 to 95	Very Low	3500 to 5000
9.	Metal Halide	35 to 2000	80 to 95	4,000 to 12,000	60 to 85%	240 to 480	70 to 95	Up to 40%	2700 to 4500
10.	High Pressure Sodium	50 to 1000	90 to 125	10,000 to 32,000	70 to 88%	120 to 360	20 to 28	Up to 40%	2000 to 3000

11.	Low pressure Sodium Sox	10 to 180	65- 100 to 220	8,000 to 15,000	80 to 90	120 to 240	Negative Mono-chromatic	Not recommended	2400 to 3500
12.	Induction lamp	10 to 160	66- To 80	8,000 to 15,0000	60 to 75%	Instant	75 to 85	Not commended	32000 to 5500
13.	Single LED white	0.5 to 5	60 to 180	10,000 to 1,00,000	60 to 95%	Instant	60 to 95	Excellent	2700- to 10000
14.	LED system white	2 to 8,000	70 to 160	10,000 to 75,000	60 to 95%	Instant	60 to 95	Excellent	2701- 2700 to 10000
15.	OLED	0.5 to 60	40 to 80	10,000 to 40,000	85 to 95%	Instant	60to 95	Excellence	2702- 2700 to 6500

When working on energy management lighting, it's crucial to grasp the specific tasks and requirements of both the people and the space targeted for energy-saving efforts. Every area has prescribed norms for lighting levels, color temperature, and color rendition. Often overlooked, the unified glare control index is especially important, particularly in retrofit solutions for street lighting. Additionally, lumen maintenance and sustained lighting levels are essential considerations, alongside cost comparisons over the lifespan of the solution. With a wide array of product variations available, selecting the right one is paramount for effective energy management design.

In the Indian context, it's crucial to provide guidance or cautionary notes in energy-saving initiatives where lamp wattage is often used as a reference for replacements, such as replacing a 100W GLS bulb with a 9W LED lamp. The term 'watt' is ingrained in purchase decisions, both domestically and in national energy-saving schemes. However, it's important to avoid using 'watt' as the primary metric in public discourse about energy efficiency. This is particularly vital for solid-state LED technology, which continually improves in efficacy each year and holds significant untapped potential. True replacement should not only enhance energy efficiency but also elevate the quality of life.

This watt terminology in retrofit replacement process for commercial and street lighting applications is misleading and need to be corrected.

7.2 Control Gear (Ballast, Driver), Sensor Dimer, Dim-Able Ballast & Controller

7.2.1 *Control Gear* - This regulates the operation of the light source, typically through electromagnetic or electronic ballasts. In the case of LEDs, this device is referred to as a Driver. Achieving desired lighting levels at various points of activity doesn't always require constant lighting. Dimmable drivers are widely utilized for this purpose. Operational specifics are detailed in relevant chapters of the national lighting code. In terms of energy efficiency, low-loss magnetic ballasts are available, consuming only 4 to 8% of the lamp power, depending on construction and cost, compared to conventional electromagnetic ballasts, which can consume over 12%.

Electronics High Frequency ballasts are best option for low pressure discharge lamp and lower wattage up to 150w metal Halide lamps. Electronics driver/ transformer for halogen are always recommend for energy saving scheme.

Considerations such as compatibility, power factor (PF), inrush current, immunity, electromagnetic compatibility (EMC), and temperature declaration, tailored to the specific application area, are crucial in energy-saving schemes. Additionally, factors like reliability and safety should be carefully assessed. In the Indian context, features like wide voltage operation and surge protection devices hold significant importance.

In lighting Driver used to call as "Heart of the lighting system" therefore performance and reliability factor are of equal important not only energy saving.

7.2.2 *Sensor* - Various types of sensors, such as time sensors, occupancy sensors, and astronomical sensors, play a crucial role in reducing energy consumption by activating lighting only when and where it's needed. Depending on specific needs, a range of sensors can be deployed, 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 controlled remotely through IoT-based systems.

7.2.3 *Dimmable drivers* - Next, we consider the applications of dimmable drivers, offering the flexibility to adjust lighting levels according to specific requirements. Regardless of the light source, though LED is currently in the spotlight, all dimming controllers/devices are now electronic, making their applications seamless. Dimmable drivers play a significant role in energy-saving applications. Daylight linking and automatic lighting control have been effectively utilized by energy managers over the past two decades.

There are two methods of dimming: mains dimming and regulation. Mains dimming involves reducing input power to the compatible driver by using a phase-cut dimmer before the driver. Regulation, on the other hand, achieves dimming effects by electronically adjusting the output power of the driver to the LED lamp or array of lamps, either through analog (1-10V) or digital (DSI, DALI) means. These devices are connected separately to the driver and regulate power output while the power input to the driver remains constant 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, WiFi, 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 energy efficiency. Sensors and dimmable systems are chosen according to the project's scale and specific requirements.

The question of whether to implement dimming control is frequently raised due to concerns about additional investment, maintenance, and the need for operational knowledge. However, controlling systems have evolved into invaluable tools for energy management projects in lighting. Costs have reduced, a wide variety of products are available, and knowledge is expanding, thanks in part to the contributions of new-generation IT professionals. Moreover, the direct impact of dimming control on energy savings is now measurable and evident. Operations have become automatic and programmable, with remote access and the ability to gather and analyze data, including feedback on fault conditions. Data is stored centrally and provides on-site information as well as operation feedback. From simple on/off switching and dimming to presence and daylight-dependent activation, and fully integrated building control systems where all devices exchange information, lighting and building control systems today offer solutions to meet every need.

In addition to LED technology with various dimmable drivers, the ability to create millions of colors for dynamic effects and ambiance has a positive impact on health and performance. This aspect is an integral part of the sustainability effect on society.

Today, sophisticated building controls are often taken for granted, particularly in Europeanized and North American countries where standards and legislation, such as ISO 18599, provide comprehensive guidelines. However, in many cases, controllers are still utilized for various reasons, such as the ongoing discussion surrounding street lighting lamp lumen control in India. Therefore, decisions must be made on a case-by-case basis. The following points can serve as guidelines for decision-making:

The scale of the building project is a key consideration. For smaller projects or a limited number of rooms, a room-based control solution may suffice. Assessing whether the property is large enough to warrant a building-based control system is crucial, along with evaluating the feasibility of integrating the old system. Other factors include the challenge of integrating emergency lighting, the demand for energy-saving measures to benefit renting schemes, such as in shopping malls and shared office buildings, and the need for flexibility in individual workspaces. Additionally, considering whether luminaires should simultaneously collect data on presence/absence, duration/intensity of room use, oxygen/CO2 content of the room air, temperature, etc., underscores the importance of 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.

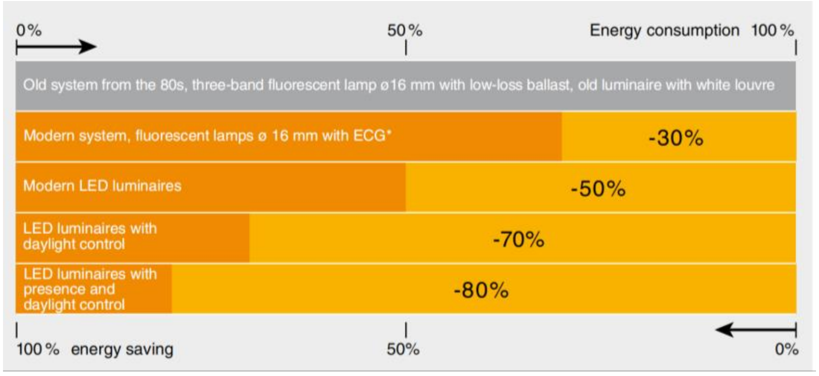


Fig 1 Potential Savings in Interior Lighting

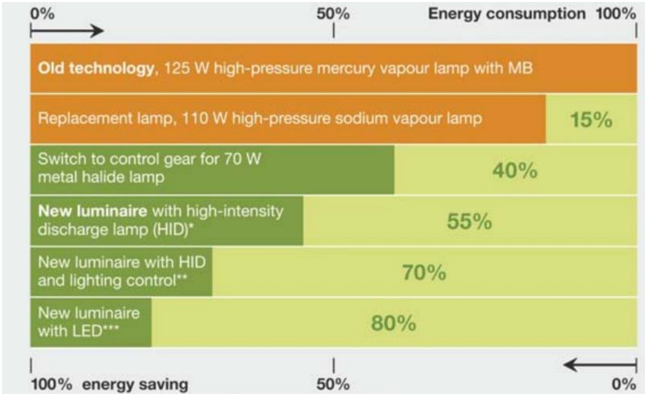


Fig 2 Savings Potential of Exterior Lighting

To add with Lamp level control dimming another 10%energy saving plus smart applications pole benefit

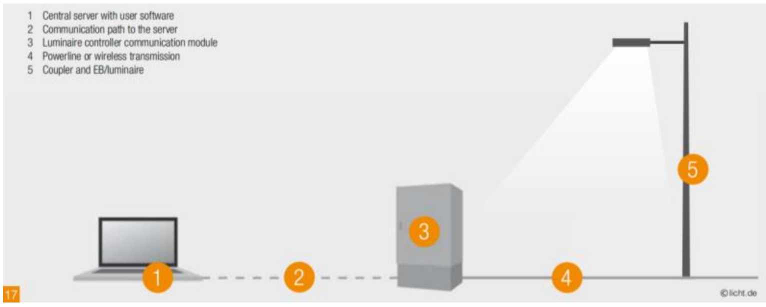


Fig 3 Examples of Components of a Powerline or Wireless Lighting Management System

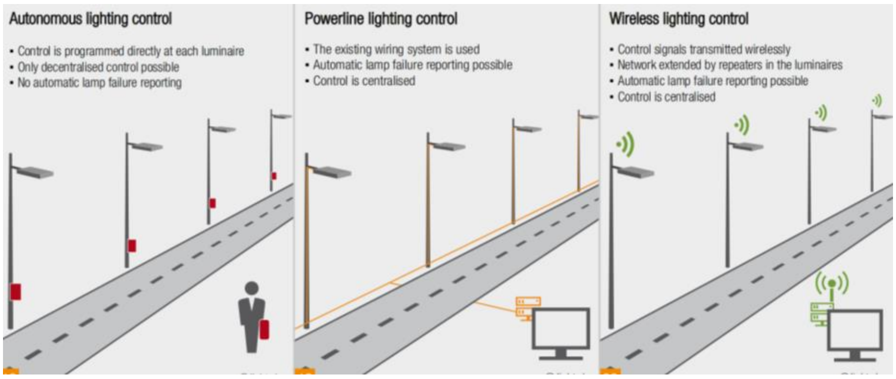


Fig 4 Examples of Lighting Controls

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, 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*

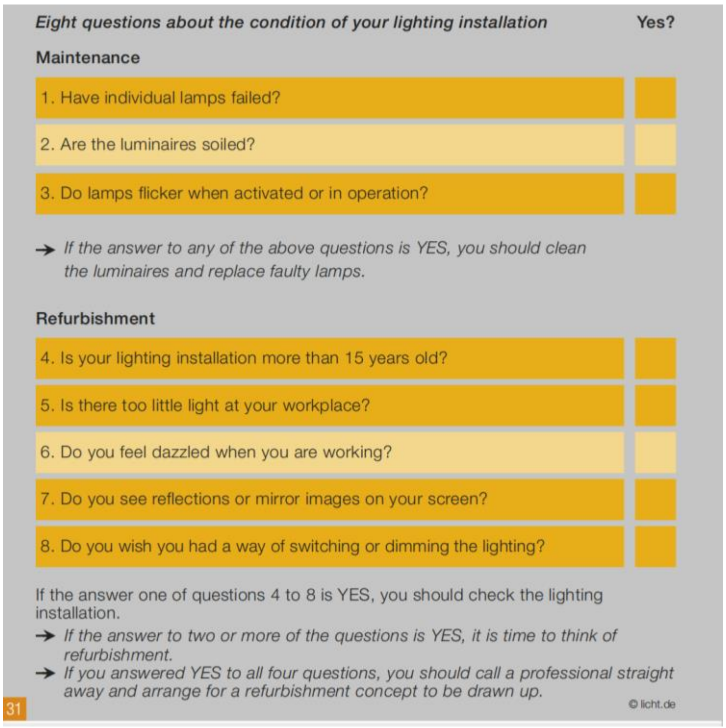
There are presently no universally recognized standards for evaluating the performance and efficiency of luminaire systems. One method gaining traction is the NEEMA system, which employs metrics like Luminaire Efficiency Ratio (LER). Alternatively, the Target Efficiency Rating (TER) can be considered. 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.

The energy-saving approach in lighting for an installation survey, as outlined in the Lich handbook, involves identifying potential savings by assessing old luminaires based on their design and components. However, quantifying power consumption and maintenance costs caused by obsolete technology can be challenging. The decision to modernize or replace a lighting system hinges on maintenance schedules, systematic recording, documentation, and analysis of all components. In the project, the first step is to evaluate the quantity and quality of the existing luminaires. Next, assess whether the lighting system effectively serves its intended purpose, including visual tasks. Lastly, determine if the project meets acceptable energy and maintenance levels, while ensuring costs remain competitive. This requires both quantitative and qualitative technical evaluations, culminating in a professional presentation of facts, figures, and economic implications. Such an approach provides a clear direction and prioritizes steps for initiating an energy-saving project.

A standardize check lists & data collection survey are the effective tools for analysis and its documentation support all stake holders to decide and take action. High quality measurement device to be used by trained professionals so no deviation and errors comes in measurements data before and end of the project. Below simple formatted questioner to guide whether the project has potential to start the energy management for nay old installation. Even, one area is yes then it is good enough to start the project, if more then more potential for energy saving

a) Is the installation older than a 10 years ?

b) Is annual operating time more than 2,500 hours or the daily operating time is more 8 hours.
c) Does large number of lamps are traditional and first generation old model?
d) Are the luminaire still operative with old electromagnetic devices be it ballast or transformer?
e) Is the diffuser is used in the luminaire?
f) Is the power consumed by lighting is more than 18%
g) Is the uneven uniformity in lighting level causing the efficiency or user feeling unhappy with lighting environment
h) Is luminaire using retrofit 2 pin CFL or G12 CFLi?
i) Is indirect lighting with tube light or CFL
j) Is day light provision not used properly but scope is there to include.



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 you 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.*

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Fig. 5 Refurbishment Checklist

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 lighting has 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. For more information on solar lighting, refer to the NLC chapter.

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. They 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, there may 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 during the 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 (CO2) 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.

The planner checklist requires specialist lighting technology knowledge. The purpose is to rate relevant aspects from the *ZVEI "Reliable Planning with LED lighting" guide* for individual applications. Decision-makers can use this to obtain answers to questions relating to product quality, and to calculate costs.

Data sheet specifications	Office	Industry	Retail outlet	Public lighting	Home / Hotel	Museum
Luminaire output: W	Relatively important	Extremely important	Very important	Relatively important	Minor importance	Relatively important
Luminaire luminous flux lm	Relatively important	Very important	Relatively important	Relatively important	Not important	Minor importance
Luminaire luminous efficacy: lm/W	Very important	Extremely important	Minor importance	Extremely important	Minor importance	Minor importance
Colour rendering index: CRI or R_a	Very important	Relatively important	Very important	Minor importance	Very important	Extremely important
Correlated colour temperature / CCT or TCP: K	Very important	Relatively important	Extremely important	Minor importance	Extremely important	Extremely important
Colour tolerance (initial, MacAdam): [Number]	Very important	Minor importance	Very important	Minor importance	Very important	Extremely important
Median useful life: L_x	Very important	Extremely important	Relatively important	Extremely important	Minor importance	Relatively important

Fig. 6 for Planners: Product and System Criteria for Quality Assessment

10 LIGHTING SERVICE COMPANY

With the introduction of LED technology, energy savings of 50 to 80% over traditional lighting products are achievable, and with the application of controlling devices, savings can be further improved to more than 70 to 80%. Additionally, the advent of CCMS (Centralized Control and Monitoring Systems) or built-in energy meters enables precise measurement of these savings. These advancements have catalyzed the emergence of 'lighting as a service' projects. In this model, companies invest in the initial setup and operation of the project, leading to a significant increase in the adoption of this business/service model. These service providers are often referred to as Energy Service Companies (ESCOs).

ESCO companies invest the initial capital and operate the project until the end of the contract period, after which they hand over the system to the owner at no cost. This arrangement creates a win-win situation, as ESCOs generate revenue from energy savings achieved by the installed lighting system. In the Indian context, this approach has been highly successful, largely due to initiatives by the Government of India through entities like Energy Efficiency Services Limited (EESL). EESL has undertaken commendable work nationwide, particularly in retrofitting LED lamps and street lighting, as well as in industrial and commercial lighting. Despite these achievements, there is still a significant amount of work to be done.

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 projects or 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 the success 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 of utmost importance and should be an integral part of project tenders and contracts to ensure that the agreed-upon specifications are met. This process is essential for building confidence in the users' minds and should be incorporated into every energy management project.

12 TIME CONSTRAIN

Unfortunately, many logistical decisions are made under significant time pressure, making it challenging to consider superior quality alternatives. These alternatives often offer greater sustainable value for the environment, possess individual product profiles, and boast long service lives. Although initially seeming more expensive, they ultimately yield higher returns compared to seemingly cheaper options.

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 cost of installation, deployment, operation, upgrading, building, and maintaining the asset, and includes the interest cost of the investment.

14 INDIRECT COSTS

These costs are less visible and are usually dispersed across the business operations organizations a. End user operation, such as anyone going end user support within the organization. End user costs incurred when individually gradually evolve to become part of the supportive structure facility & product and field inspection personnel. C) Down time or when the process is interrupted from regular work.

TCO analysis focused on

a) Managing asset life cycle
b) Prioritizing capital acquisition proposal
c) Budgeting & planning
d) Selection of vendor

After the feasibility survey, the Total Cost of Ownership (TCO) analysis provides insight into the economic viability of the project. TCO includes managing the asset life cycle, prioritizing capital acquisition proposals, budgeting and planning, repayment plans, and selecting vendors. It factors in all accumulated costs, presenting a comprehensive view of the economic impact that plays a crucial role in determining the project's viability.

For traditional lighting, the primary cost components are energy consumption (over 42%), maintenance (around 10%), purchase (23%), and revamping (15%). Emphasized repeatedly throughout this chapter and to be further explored in the sustainability section, focusing solely on TCO—considering economic factors such as efficacy, initial costs, and maintenance costs—while neglecting quality and social aspects, can lead to catastrophic effects in the future. Maintaining a balance between these factors is crucial, though it often gets overlooked. Owners tend to prioritize minimum design requirements or compromise solutions, emphasizing energy savings and cost reduction while ignoring human factors. Local codes, standards, legislation, norms, and their implementation play a vital role in the overall success of such projects.

Another issue in this model is the involvement of multiple entities, such as consultants, investors, contractors, project authorities, and vendors, who often work in isolation, focusing on their own interests rather than the overall project's interest. For retrofit solutions, criteria like glare and uniformity are critical, especially in street lighting and outdoor lighting, whether for environmental and security purposes or area lighting, which is a concern in Indian conditions. The TCO of a lighting control system is best understood by reviewing the system architecture, its scale of operation, and its cost.

Key benefit of lighting control in TCO calculations- a) low initial cost b) Failure based reporting, reduced light pollution, c) most & simply Plug & play d) increased Lamp life e) Maintenance and Repair saving f) Power saving g) Easy expansion h) no Photocell required.

15 TOOLS FOR CALCULATING TCO

Several TCO tools are available from various software companies, such as Source Age, CISCO, and Solution Matrix. Additionally, many lighting companies offer their own TCO software, and some Energy Service Companies (ESCOs) are developing their own business models to provide tailored TCO analysis.

Few example for TCO for LED in Industrial applications.

Decision-makers need guidance on the relevance of the different quality criteria for their project.

	Office	Industry	Retail outlet	Public lighting	Home / Hotel	Museum
Life cycle costs	Very important	Very important	Minor importance	Extremely important	Relatively important	Minor importance
Lighting design	Very important	Minor importance	Extremely important	Relatively important	Very important	Extremely important
Product / System	Relatively important	Extremely important	Very important	Very important	Relatively important	Relatively important
Aesthetics	Very important	Minor importance	Very important	Very important Minor importance	Very important	Very important

Supplier criteria should also be taken into account when awarding contracts.

Fig.7 for Decision-Makers: Quality Criteria for Lighting Systems

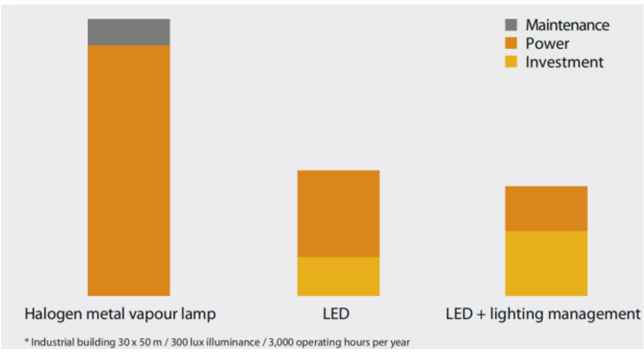

Fig. 8 Sample Analysis of Lighting Costs of an Industrial Building* Over 10 Years

Recent development of Residential and commercial building

BUREAU OF INDIAN STANDARDS

DRAFT FOR COMMENTS ONLY

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Draft NATIONAL LIGHTING CODE OF INDIA

PART 7 Energy-Effective Lighting Systems

Section 2 Sustainability

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

Illumination Engineering and Luminaries Sectional Committee, ETD 49	**Last Date for Comments: 30-June-2024**

FOREWORD

"Secure the future for our next generation" is the theme of sustainability. The role of lighting in sustainability has become a prime focus for the lighting community, especially as LED technology has significantly improved energy efficiency. The successful G20 summit in India prioritized zero emissions, leading to discussions and commitments from member nations worldwide.

1 SCOPE

This section covers the concept of sustainability, the analysis and methodology of sustainable practices, and recommendations being followed worldwide. It aims to help users and government agencies understand the requirements and actions needed to make India's environment sustainable. The lighting community should adopt lighting sustainability as a self-imposed goal.

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*)

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 first understand the three-pillar concept for sustainability.

First one is the economics of the installation which has already been covered in detail in part 7 section1. For sustainability in lighting, attention must be given to energy efficiency and the entire life cycle cost, from product selection to disposal. The concept of energy-saving green systems, driven by LED and modern lighting technologies, has led to the popularity of 'Green Buildings.' However, a more advanced concept, the 'Blue Building' system, is emerging. This system better balances sustainability principles. The materials used and the disposal of products must also meet environmental criteria.

The second pillar is environmental conservation, which encompasses nature preservation, climate protection, resource utilization and conservation, avoidance of light pollution, emission control, and recycling.

The third pillar involves social aspects, including health, safety, improved quality of life, and a greater sense of well-being.

Sustainability in lighting means not only saving energy but also protecting and securing the planet and its inhabitants. The initial concept of kilowatt savings stems from the need to reduce CO_2 emissions, which strain the environment. The Kyoto Protocol and G20 have agreed on specific energy reduction targets to mitigate climate change. The roadmap for low carbon emissions aims for an 80 to 95 percent reduction in greenhouse gas emissions by 2050.

Currently, sustainability extends beyond the traditional three-pillar concept. Every occupant, user, and owner must participate in sustainability programs. Lighting system design should consider functional, technological, process-related, and locational factors. Both natural and artificial light are crucial, and the effective use of the intangible qualities of light presents a challenge for designers. Architects and lighting specialists should collaborate to achieve this integration. A truly sustainable lighting concept encompasses more than energy savings or efficiency; it combines environmental protection, cost-effectiveness, and comfort.

5 COMPONENTS OF SUSTAINABILITY LIGHTING

The main Focus areas include:

a) Energy-efficient, long-life light sources with low maintenance requirements and economically viable payback periods.
b) High interchangeability, replaceability, 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 friendly disposal at the end of the product's life.

6 VALUE CREATION IN LIGHTING

Sustainability in lighting is a continuous process, requiring each stakeholder to add value to build an ecosystem design. Sustainable lighting systems must be maintained throughout the entire value chain. A total cost of ownership (TCO) based project design, from raw material selection to distribution, cannot guarantee sustainability unless the process is established and followed at every step.

6.1 Process

In project management, various processes must be followed. Generally, it starts with the concept stage, including initiation and survey, project design, planning and proposal, project approval, tender preparation, contract preparation, contract award, and purchase of goods. This is followed by installation, commissioning, project closing and handover, and finally, the operation and maintenance of the project.

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 project initiation to completion. Relevant standards and certifications include ISO 14001, ISO 50001, BEE star rebelling for lamps, tubes & residential flats, notifications from Ministry for disposal and hazardous materials, different BIS standards for product quality for safety and performance, and LEED certification.

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 and environmental 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 these challenges, 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,. Environmental guideline is given in ISO 14000 for company and its ancillary additionally, 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 in India. The government should support projects like Energy Service Companies (ESCO) to create dedicated disposal companies responsible for handling lighting system waste. In India, informal waste collectors, like "raddiwalas" who collect newspapers, could be organized into a formal disposal process, as done in the USA and EU countries with established norms and legislation.

The full energy balance for a lighting system includes raw material preparation, production, transport, use, and recycling. Although modern lighting already saves a lot of energy, focusing on disposal and recycling addresses only a fraction of the energy cost and should be managed efficiently. See Fig. 1

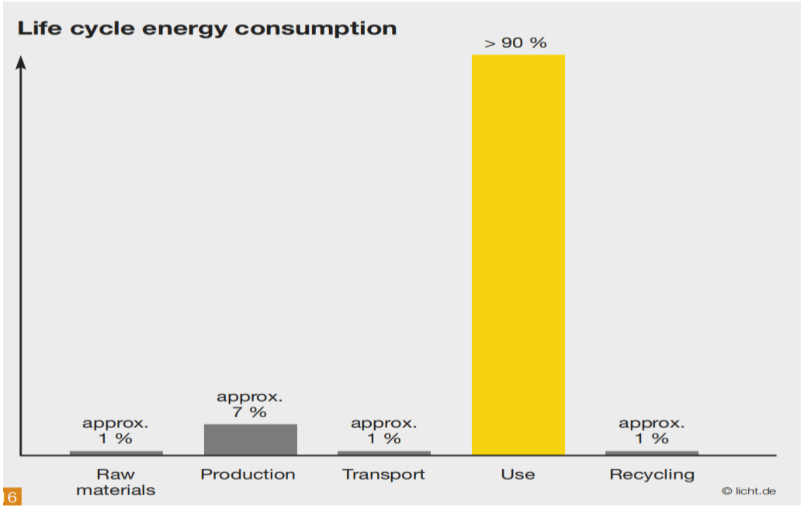

Fig. 1 Life Cycle Energy Cost of the Total Lighting

6.3 Environmental Product Declaration (EPD) for a Lighting System

This statement from the product company describes the environmental impact of their product/system. For sustainability projects, this data is crucial for selection during the initial design stage. The Environmental Product Declaration (EPD) is given in Fig.2

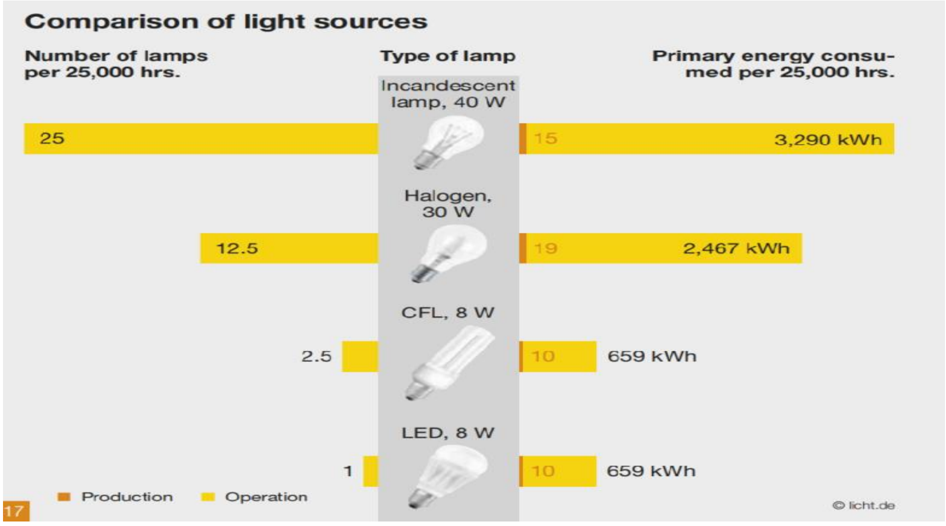

Fig.2 Light Source Declaration

One 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, led system and with Controlling the light .This is for interior calculations.

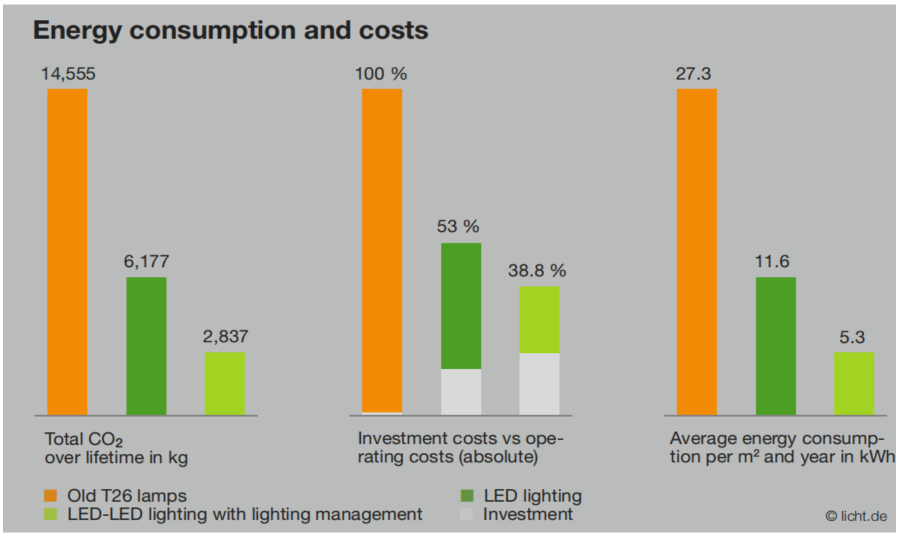

Fig. 3 Energy Consumption Chart Courtesy

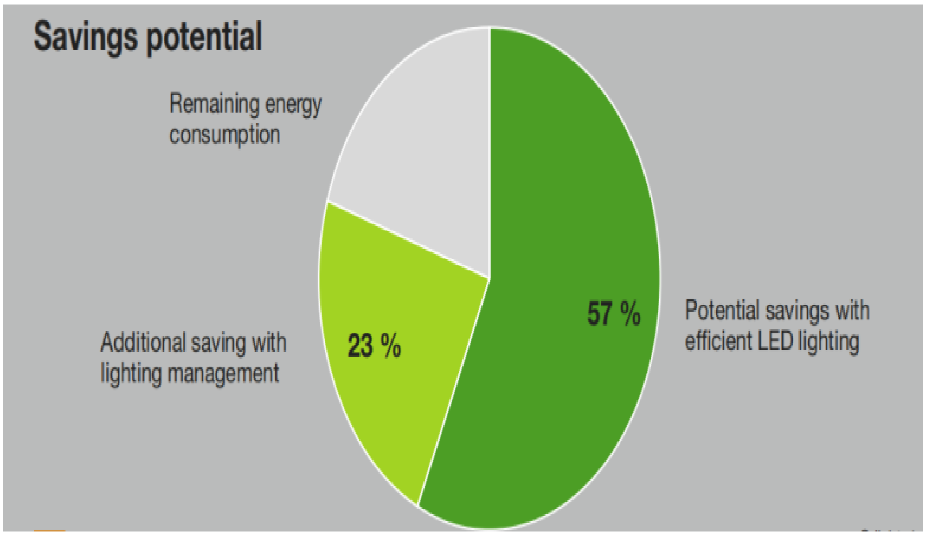

Fig. 4 Saving Potential

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, paste etc.
c) Production - Place of manufacturing, process and paint /solder materials used etc.
d) Delivery-Area and transport conditions, any precaution required, packaging materials, dimension and 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 presents a comprehensive overview of the environmental impacts associated with the entire life cycle of the product. This Environmental Product Declaration (EPD) assessment provides a clear understanding of the product's environmental contributions in addition to its inherent benefits. The product's impact is analysed against defined standards, legislation, and various certification criteria to provide precise insights.

6.4 Lighting Comfort

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

In 60% of economic lighting criteria**,** the different components like price, energy, maintenance and others components can as given in Table 1.

Table 1 Lighting Cost component

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

In the case of 40% 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

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. It's worth noting that in India, there are currently no specific regulations, but these guidelines will assist professionals in approaching the subject in a structured manner. Thanks to modern lighting systems, managing both the economic and quality aspects has become easier. A German court ruling has emphasized that both aspects should be given equal weight, each accounting for 50%. Fig. 5 illustrates the Holistic installation model.

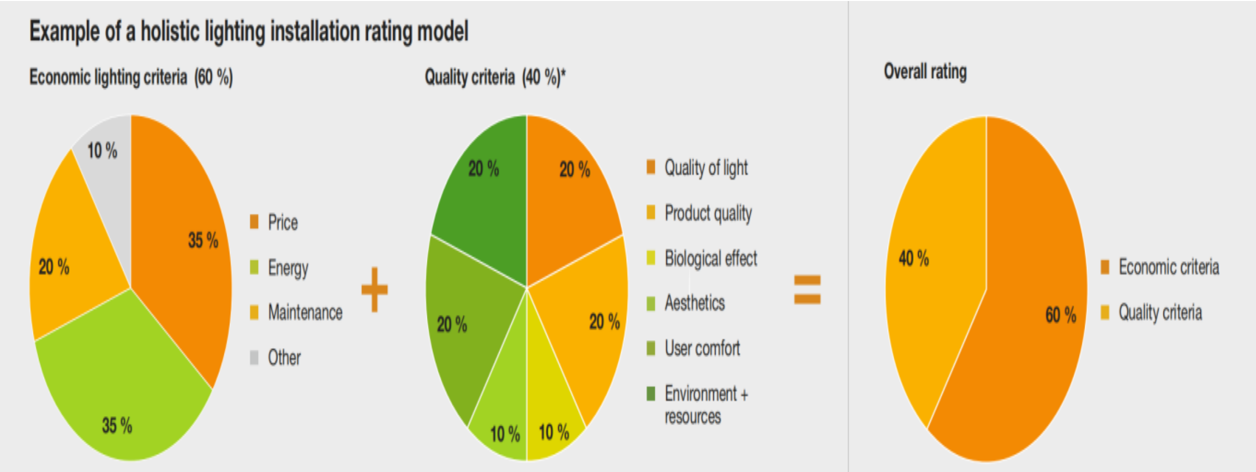

Fig. 5 Holistic Installation Model

6.5 Light Pollution

This topic garners much discussion within the lighting community but often sees limited implementation in practical settings. Particularly in developing countries like India, this aspect is frequently overlooked, with attention primarily focused on energy savings and lighting quantity, occasionally meeting certain quality parameters. This tendency persists even in new installations, and for retrofit projects aimed at one-to-one energy management replacements, the focus on holistic lighting design is nearly absent.

This issue has been addressed in various sections of this code and serves to raise awareness and draw attention to the matter. A basic understanding of the causes of lighting pollution is reiterated in this section, as light pollution remains integral to the sustainability context in India.

Many of us experience light pollution firsthand from our bedrooms, often caused by streetlights, garden lights, or security area lighting. While light enhances life, its improper use, installation, or maintenance can lead to irritation and environmental hazards. All three stages – product design, selection, installation, and maintenance – are equally important in mitigating light pollution. The roles of designers and maintenance personnel are particularly critical.
The terms "light pollution" or "light smog" are commonly used to describe light that is emitted upwards, brightening the night sky over large urban areas. These stray lights not only disrupt our sleep but also wreak

havoc on the nocturnal habitats of birds, animals, and plants. Artificial lighting, whether for sports, decorative city features, gardens, advertisements, yards, or areas, can have adverse effects on both humans and nature if not carefully implemented.

The contemporary movement towards safeguarding the night sky is evident in the adoption of legislation across various EU and North American nations. The Illuminating Engineering Society (IES) has initiated efforts to establish standards in this regard. Notably, the German Lighting Society has already published measurement and assessment methods, which outline maximum permissible limits.

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

Fig. 6 Street Lighting Glare

Fig. 7 Glare from Post of Lantern

Fig. 8 Road- Junction Streetlighting Effect

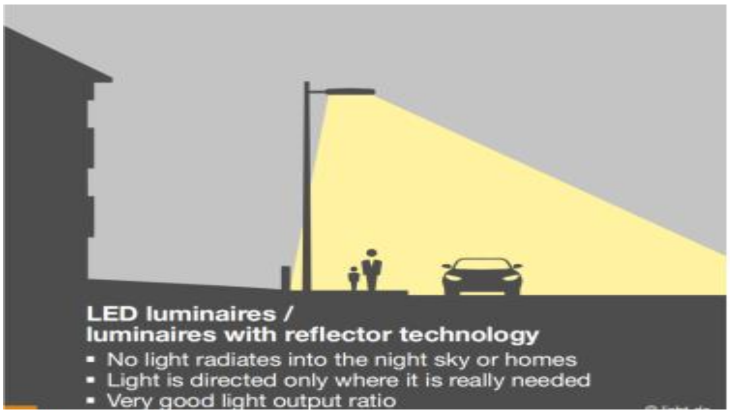

Fig. 9 Right Reflector for Glare Control

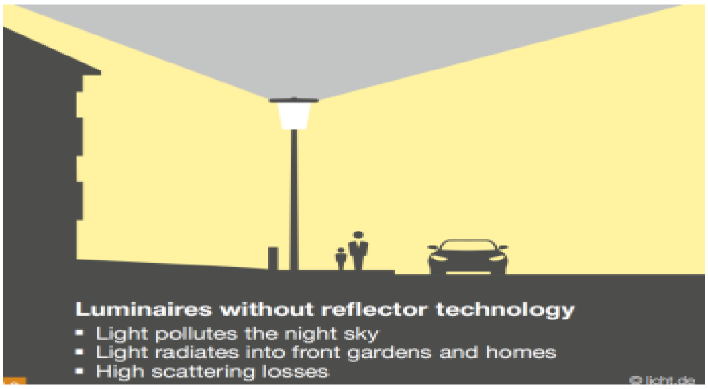

Fig. 10 Luminaire without Light Control

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

a) *Use the Right Light in the Right Place* – Choose application-specific products. For instance, retrofit solutions like street and flood lights are often used for garden and area lighting, but this isn't always appropriate. 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 everywhere, as inventory and logistic issues often dictate. This can disturb ecological balance. The right selection is usually more economical. 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, and birds. 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 the luminaire without light control.

c) *Use Standard Lighting Levels* – Over-illumination is common but unnecessary. Excessive light not only consumes more energy but also disrupts the harmony between nature and humans, as reflected light highlights the sky. Lighting should adhere to established standards to avoid these issues.

d) *Color Temperature* – Research shows that nighttime is a resting period for plants, birds, and animals also. 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 attracted to artificial light, often leading to their deaths and creating disturbances for people around the lighting system. This is detrimental to natural habitats as many insects perish in this process.

Most nocturnal insects are significantly more sensitive than humans to brightness and spectral composition, particularly ultraviolet (UV) light. Fluorescent, mercury vapor, and metal halide lights, which emit UV light, attract insects by mimicking the pale moonlight they use for orientation. Consequently, insects gather in large numbers around these lights.

However, high-pressure sodium vapor lamps, which emit light in the orange and red spectrum, are less attractive and almost invisible to insects. LED lights, which lack UV content, are also less appealing to insects, making them more "insect-friendly." Fig. 11 depicts the light souse wise insects attraction.

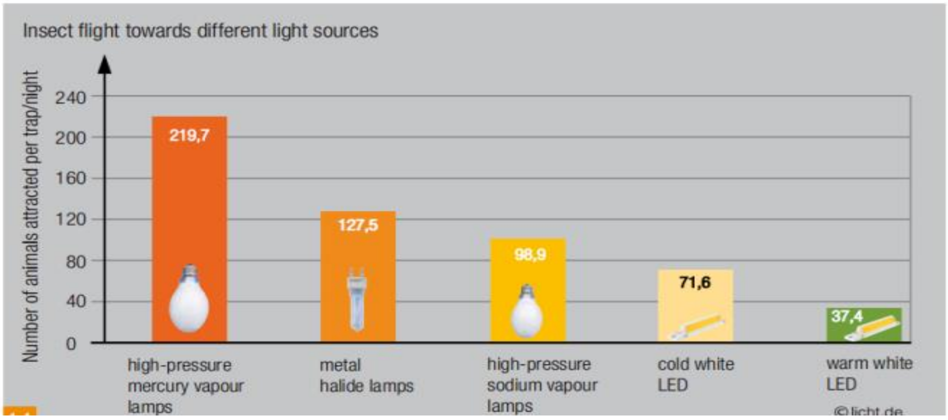

Fig. 11 Depicts the Light Souse Wise Insects Attraction