CHAPTER 4 Energy Efficient Lighting Design

4.1 Guidelines:

4.1.1 Interior lighting

For buildings with connected electrical load more than 100 kW (applicable for commercial buildings)

- The installed interior lighting power should not exceed the lighting power density (LPD) value as recommended by Energy Conservation Building Code (ECBC) 2007.
- Install lighting controls as recommended by ECBC 2007.
- Select lamps with high color rendering index (CRI).
- Lamps: Lamps used for the general lighting scheme should comply with the following:
  - **Point light source**: All the point light sources installed in the building for general lighting should be compact fluorescent lamp (CFL) based or light emitting diode (LED) based with minimum lamp efficacy of 50 lm/W
  - **Linear light source**: All the linear light sources installed in the building for general lighting should be T-5 or at least four-star BEE rated TFLs.
- Ballasts: All the ballasts installed (including those non-integrated ballasts in CFLs) should be electronic or low-loss copper ballasts.

For residential buildings

- The installed interior lighting power should not exceed the LPD value as recommended by ECBC 2007.
- Install lighting controls as recommended by ECBC 2007.
- Select lamps with higher CRI.
- Lamps: Lamps used for the general lighting scheme should comply with the following:
  - **Point light source**: All the point light sources installed in the building for general lighting should be CFL-based or LED-based with minimum lamp efficacy of 50 lm/W
• **Linear light source:** All the linear light sources installed in the building for general lighting should be T-5 or at least four-star BEE rated TFLs.

• Ballasts: All the ballasts installed (including those non-integrated ballasts in CFLs) should be electronic or low-loss copper ballasts.

### 4.1.2 Exterior lighting

**Commercial and multistorey residential complexes**

- The installed exterior lighting power density for the respective applications shall be in accordance with ECBC 2007.
- Lighting controls shall be installed as recommended by ECBC 2007 for external lighting.
- Lamps: External lighting sources shall have luminous efficacies as per the table given below.

<table>
<thead>
<tr>
<th>Light source</th>
<th>Minimum allowable luminous efficacy (lm/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFLs</td>
<td>50</td>
</tr>
<tr>
<td>LEDs</td>
<td>50</td>
</tr>
<tr>
<td>Fluorescent lamps</td>
<td>75</td>
</tr>
<tr>
<td>Metal halide lamps</td>
<td>75</td>
</tr>
<tr>
<td>High-pressure sodium vapor lamps</td>
<td>90</td>
</tr>
</tbody>
</table>

- Ballasts: All the ballasts installed (including those non-integrated ballasts in CFLs) shall be electronic or low-loss copper ballasts.
- Integration with renewable energy sources: 15% of the total external lighting load shall be met from renewable energy sources (solar, wind, biomass, fuel cells, etc.).
4.2 Mandatory clause

4.2.1 Interior lighting

For all types of buildings

- The installed interior lighting power shall not exceed the LPD value as recommended by ECBC 2007.

4.2.2 Exterior lighting

For commercial and multistorey residential complexes

- Lamps: External lighting sources shall have luminous efficacies as per Table 4.3.1

Table 4.3.1: Minimum allowable luminous efficacy for external lighting sources

<table>
<thead>
<tr>
<th>S No.</th>
<th>Light Source</th>
<th>Minimum allowable luminous efficacy (lm/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CFLs (compact fluorescent lamps)</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>LEDs (light emitting diodes)</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Fluorescent Lamps</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Metal Halide Lamps</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>High Pressure Sodium Vapour Lamps</td>
<td>90</td>
</tr>
</tbody>
</table>

- Integration with renewable energy sources: 15% of the total external lighting load shall be met from renewable energy sources (solar, wind, biomass, fuel cells, etc.).
4.3 Technical guidelines

4.3.1 Efficiency in the artificial lighting scheme

Any lighting scheme, interior or exterior, can be called an efficient scheme when it provides the required illuminance level for the application it has been designed for while utilizing least amount of energy.

Guidance notes for achieving efficiency in the lighting scheme for three categories, which include external lighting, internal lighting for commercial buildings, and internal lighting, for residential buildings have been elaborated below.

4.3.2 External lighting

Energy efficiency in external lighting
External lighting in and around a building is used for lighting pedestrian walks, landscaping, artifacts, parkways and parking, façade lighting, security, etc. To achieve the efficiency in the external lighting scheme designed for various applications, the following can be practiced:

Use of efficient lamps
Depending upon the kind of application, the following lamp types can be used in the external lighting scheme to improve the efficiency:

High pressure sodium vapor lamps
A high-pressure sodium vapor lamp (HPSV) is a gas discharge lamp, which uses sodium in an excited state to produce light. The efficacy of HPSVs varies from 50 to 140 lumens/W and lamp life is around 16000–24000 h.

Fig. 4.3.1: High-pressure sodium vapor lamps

Fig. 4.3.2: Metal Halide Lamps
The CRI of these lamps is quite low. These lamps can be primarily used for applications, where lighting from a height around 5 m is desired, such as for the driveways in a campus or car parking, etc.

**Metal halide lamps**

Metal halide lamps (MHs) are similar in construction and appearance to mercury vapor lamps. The addition of metal halide gases to mercury gas within the lamp results in higher light output, more lumens per watt (50–110 lm/W) and a higher CRI than from mercury gas alone. MHs have shorter lifetimes (5000–20000 h) compared to both mercury vapor and HPSVs. MHs in external lighting are used when a better CRI is required, such as façade lighting, etc.

**Fluorescent lamps**

A fluorescent lamp is a low-pressure mercury electric discharge lamp with a glass tube filled with a mixture of argon gas and mercury vapor at a low pressure. When current flows through the ionized gas between the electrodes, it emits ultraviolet (UV) radiation from the mercury arc, which is then converted to visible light by a fluorescent coating inside the tube. Fluorescent lamps are usually available in various colors, for example, warm white, normal white, cool white, etc. Fluorescent lamp efficacy is around 40–100 lm/W and the average life of the lamp varies from 10000 to 24000 h. The CRI of a fluorescent lamp is very good.

**Compact fluorescent lamps**

CFLs are fluorescent lamps, which are small in size and come in both types of ballast – integrated and non-integrated. Life of CFLs is almost nine to ten times to that of an incandescent lamp. CFLs can be extensively used in landscape lighting, security lighting fixtures, bollard lighting, etc.
Light emitting diode lamps
LEDs are semiconductor lighting sources. When a diode is forward-biased (switched on), electrons are able to recombine with holes within the device, releasing energy in the form of photons. LEDs consume very less power and have a very long life (50000–70000 h), as they are shock and vibration proof. LEDs, owing to their very small size, can be used for a variety of lighting applications in landscaping.

The exterior lighting power for the applications as mentioned in the table given below as per ECBC 2007 should be calculated and it should be in the limit of the recommended values in the table.

Fig.4.3.5: LED lamps

<table>
<thead>
<tr>
<th>Exterior lighting applications</th>
<th>Power limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building entrance (with canopy)</td>
<td>13 W/m² (1.3 W/ft²) of the canopied area</td>
</tr>
<tr>
<td>Building entrance (without canopy)</td>
<td>90 W/lin m (30 W/lin ft) of the door width</td>
</tr>
<tr>
<td>Building exit</td>
<td>60 W/lin m (20 W/lin ft) of the door width</td>
</tr>
<tr>
<td>Building façades</td>
<td>2 W/m² (0.2 W/ft²) of the vertical façade area</td>
</tr>
</tbody>
</table>

Use of lighting controls
Lighting controls, such as timer controls and astronomical switches, can be integrated with the exterior lighting fixtures in order to save energy when daylight is available outside.

These controls can be programmed to incorporate the seasonal time variation in sunrise and sunset.

Fig. 4.3.6: astronomical switch
Integration with renewable energy sources
Renewable energy, largely solar, has got a great potential of saving energy when integrated with the exterior lighting scheme.

The solar outdoor area lighting system operates by using the light energy available from the sun to provide lighting during night time. The Solar PV outdoor lighting is a reliable and an efficient stand-alone system. It consists of a solar PV module, a battery and a luminaire with very highly efficient electronics all mounted onto a pole with necessary hardware and cables.
Solar-based outdoor lighting can be used for various lighting applications, such as parking lots, landscape lighting, driveways, etc.

![Fig. 4.3.7: PV module integration with lighting fixture](image)

It is desirable that solar lights should be located on the south side of the building in order to receive solar radiation throughout the day for the entire year.

Care should be taken while selecting the solar PV module location with respect to a building. The solar PV module should not fall in the shadow zone of the building. In Bangalore, the shadow zone of a building on the south side is up to an angle of 30° from the top point of the building as shown in the figure below.

![Fig. 4.3.8: Landscape light integrated with solar PV](image)
4.3.3 Internal lighting for new commercial buildings

Efficiency of an internal lighting scheme depends on the following parameters:

- Interior lighting power density
- Lighting design
- Efficient lighting equipments e.g. lamps, luminaries, and control gears
- Use of appropriate lighting controls
- Explore possibilities of daylight integration
- Ensure effective maintenance

In addition to the above, the following parameters are also critical:

- Reflectance of various room surfaces
- Glare reduction
- Uniform light distribution

Lighting design
Lighting systems and equipments shall comply with the provisions of ECBC 2007 as outlined below. Lighting requirements are applicable to the following:

- Interior spaces of buildings
- Exterior building features, including façades, illuminated roofs, architectural features, entrances, exits, loading docks, illuminated canopies, and exterior building ground lighting that is provided through the building’s electrical service.

**Exceptions**
The following lighting equipments and applications shall not be considered when determining the interior lighting power allowance, nor shall the wattage for such lighting be included in the installed interior lighting power. However, any such lighting shall not be exempt, unless it is an addition to general lighting and is controlled by an independent control device.

- Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments
- Lighting that is integral to equipments or instrumentation and is installed by its manufacturer
- Lighting specifically designed for medical or dental procedures and lighting integral to medical equipments
- Lighting integral to food warming and food preparation equipments
- Lighting for plant growth or maintenance
- Lighting in spaces specifically designed for use by the visually impaired
- Lighting in retail display windows, provided the display area is enclosed by ceiling height partitions
- Lighting in interior spaces that have been specifically designated as a registered interior historic landmark
- Lighting that is an integral part of advertising or directional signages
- Exit signs
- Lighting that is for sale or lighting educational demonstration systems
- Lighting for theatrical purposes, including performance, stage, and film or video production
- Athletic playing areas with permanent facilities for television broadcasting

**Installed interior lighting power**
The installed interior lighting power should be calculated for all power used by the luminaires, including lamps, ballasts, current regulators, and control devices. If two or more independently operating lighting systems in a space are controlled to prevent simultaneous user operation, the installed interior lighting power shall be based solely on the lighting system with the highest power.

**Interior lighting power and design**

The installed interior lighting power for a building shall not exceed the interior lighting power allowance determined in accordance with the below-mentioned two methods. ECBC 2007 recommended the value for the lighting power density thus calculated by the methods for various spaces as given in Tables 4.3 and 4.4.

**Building area method**

Determination of the interior lighting power allowance (watts) by the building area method shall be in accordance with the following:

- Determine the allowed lighting power density from Table 4.3 for each appropriate building area type.
- Calculate the gross lighted floor area for each building area type.
- The interior lighting power allowance is the sum of the products of the gross lighted floor area of each building area times the allowed lighting power density for that building area type.

Space function method

Determination of the interior lighting power allowance (watts) by the space function method shall be in accordance with the following:

- Determine the appropriate building type as per the proposed use and the allowed lighting power density.
- For each space enclosed by partitions 80% or greater than the ceiling height, determine the gross interior floor area by measuring to the center of the partition wall. Include the floor area of balconies or other projections. Retail spaces do not have to comply with the 80% partition height requirements.
- The interior lighting power allowance is the sum of the lighting power allowances for all spaces. The lighting
power allowance for a space is the product of the gross lighted floor area of the space times the allowed lighting power density for that space.

Table 4.3.3: Interior lighting power – building area method

<table>
<thead>
<tr>
<th>Building area type</th>
<th>LPD (W/m²)</th>
<th>Building area type</th>
<th>LPD (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive facility</td>
<td>9.7</td>
<td>Multifamily residential</td>
<td>7.5</td>
</tr>
<tr>
<td>Convention center</td>
<td>12.9</td>
<td>Museum</td>
<td>11.8</td>
</tr>
<tr>
<td>Dining: bar lounge/leisure</td>
<td>14.0</td>
<td>Office</td>
<td>10.8</td>
</tr>
<tr>
<td>Dining: cafeteria/fast food</td>
<td>15.1</td>
<td>Parking garage</td>
<td>3.2</td>
</tr>
<tr>
<td>Dining: family</td>
<td>17.2</td>
<td>Performing arts theater</td>
<td>17.2</td>
</tr>
<tr>
<td>Dormitory/hostel</td>
<td>10.8</td>
<td>Police/fire station</td>
<td>10.8</td>
</tr>
<tr>
<td>Gymnasium</td>
<td>11.8</td>
<td>Post office/town hall</td>
<td>11.8</td>
</tr>
<tr>
<td>Healthcare clinic</td>
<td>10.8</td>
<td>Religious building</td>
<td>14.0</td>
</tr>
<tr>
<td>Hospital/health care</td>
<td>12.9</td>
<td>Retail/mall</td>
<td>16.1</td>
</tr>
<tr>
<td>Hotel</td>
<td>10.8</td>
<td>School/university</td>
<td>12.9</td>
</tr>
<tr>
<td>Library</td>
<td>14.0</td>
<td>Sports arena</td>
<td>11.8</td>
</tr>
<tr>
<td>Manufacturing facility</td>
<td>14.0</td>
<td>Transportation</td>
<td>10.8</td>
</tr>
<tr>
<td>Motel</td>
<td>10.8</td>
<td>Warehouse</td>
<td>8.6</td>
</tr>
<tr>
<td>Motion picture theater</td>
<td>12.9</td>
<td>Workshop</td>
<td>15.1</td>
</tr>
</tbody>
</table>

In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Table 4.3.4: Interior lighting power – space function method

<table>
<thead>
<tr>
<th>Space function</th>
<th>LPD (W/m²)</th>
<th>Space function</th>
<th>LPD (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office – enclosed</td>
<td>11.8</td>
<td>Library</td>
<td></td>
</tr>
<tr>
<td>Office – open plan</td>
<td>11.8</td>
<td>Card file and cataloging</td>
<td>11.8</td>
</tr>
<tr>
<td>Conference/meeting/multipurpose</td>
<td>14.0</td>
<td>Stacks</td>
<td>18.3</td>
</tr>
<tr>
<td>Classroom/lecture/training</td>
<td>15.1</td>
<td>Reading area</td>
<td>12.9</td>
</tr>
<tr>
<td>Lobby</td>
<td>14.0</td>
<td>Hospital</td>
<td></td>
</tr>
<tr>
<td>For hotel</td>
<td>11.8</td>
<td>Emergency</td>
<td>29.1</td>
</tr>
<tr>
<td>For performing arts theater</td>
<td>35.5</td>
<td>Recovery</td>
<td>8.6</td>
</tr>
<tr>
<td>For motion picture theater</td>
<td>11.8</td>
<td>Nurse station</td>
<td>10.8</td>
</tr>
<tr>
<td>Audience/seating area</td>
<td>9.7</td>
<td>Exam treatment</td>
<td>16.1</td>
</tr>
<tr>
<td>For gymnasium</td>
<td>4.3</td>
<td>Pharmacy</td>
<td>12.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Patient room</td>
<td>7.5</td>
</tr>
<tr>
<td>For convention center</td>
<td>7.5</td>
<td>Operating room</td>
<td>23.7</td>
</tr>
</tbody>
</table>

Luminaire wattage
Luminaire wattage incorporated into the installed interior lighting power shall be determined in accordance with the following:

a. The wattage of incandescent luminaires with medium base sockets and not containing permanently installed ballasts shall be the maximum labeled wattage of the luminaires.

b. The wattage of luminaires containing permanently installed ballasts shall be the operating input wattage of the specified lamp/ballast combination based on values from manufacturers’ catalogs or values from independent testing laboratory reports.

c. The wattage of all other miscellaneous luminaire types not described in a or b shall be the specified wattage of the luminaires.

d. The wattage of lighting track, plug-in busway, and flexible-lighting systems that allow the addition and/or relocation of luminaires without altering the wiring of the system shall be the larger of the specified wattage of the luminaires included in the system or 135 W/m (45 W/ft). Systems with integral overload protection, such as fuses or circuit breakers, shall be rated at 100% of the maximum rated load of the limiting device.

Fig. 4.3.10: A luminaire

**Luminaire efficiency**

The efficiency of a luminaire is the ratio of luminaire lumen output to the lamp lumen output. Mirror optics of a luminaire and louvers decides the luminaire efficiency along with the improved visual comfort and glare control. Lighting simulation tools can be used to choose which luminaire will suit best the required application by analysing the lighting distribution and glare index.

An efficient luminaire also plays an important role for energy conservation in lighting. The choice of a luminaire should be such that it is efficient not only initially but also throughout its life. The following luminaries are recommended by NBC 2005 for different locations:
- For offices, semidirect type of luminaries are recommended so that both the work plane illumination and surround luminance can be effectively enhanced.
- For corridors and staircases, direct type of luminaries with widespread light distribution are recommended.
- In residential buildings, bare fluorescent tubes are recommended. Wherever the incandescent lamps are employed, they should be provided with white enamelled conical reflectors at an inclination of about 45° from vertical.
**Ballasts**

All discharge lamps, including fluorescents, require ballasts for proper operation. Typical ballast losses are taken as approximately 15% of the lamp wattage. It is important to include calculation of ballast losses when comparing consumption and savings of different kinds of lamps.

![Fig. 4.3.11: Ballast](image)

New electronic or solid-state ballasts, now available in the market, save approximately 20–30% in energy consumption over standard ballasts. Electronic ballasts usually change the frequency of the power from the standard mains (e.g. 50 Hz in India) frequency to 20000 Hz or higher, substantially eliminating the stroboscopic effect of flicker associated with fluorescent lighting. In addition, because more gas remains ionized in the arc stream, the lamps actually operate at about 9% higher efficiency above approximately 10 kHz. Lamp efficiency increases sharply at about 10 kHz and continues to improve until approximately 20 kHz. Because of the higher efficiency of the ballast itself and the improvement of lamp efficiency by operating at a higher frequency, electronic ballasts offer higher system efficiency.

![Fig. 4.3.12: Lamps with high efficacy](image)

**High-efficacy lamps**

Lamp efficacy, in an interior lighting scheme, plays a very crucial role. A lighting scheme, which utilizes lamps with lower efficacies, will result in increased number of lamps and hence increases the lighting power density (LPD) of a space. The
increased LPD will not only increase the lighting power consumption, but also indirectly increase the heating load on the HVAC equipment and further add to energy consumption. The reduction in energy consumption is possible with a proper choice of lighting fixtures and the lamp types. The lighting output and wattage should be seen before choosing the lights. Given below are examples of high-efficacy lamps currently available in the market:

**T5 lamps**: These are fluorescent lamps with a diameter of 16 mm, which is 40% less than the diameter of existing slim fluorescent lamps. They are designed for higher efficacy and system miniaturization. The lifespan of T5 lamps is also very long, around 18000 h as compared to 8000 h for standard fluorescent lamps.

The Bureau of Energy Efficiency (BEE), India, in its appliance energy labeling program, has rated various tubular fluorescent lamps, by different manufacturers, on the basis of the energy consumption and light output. Given below is a table listing out the BEE-rated TFL lamps:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Product</th>
<th>Brand</th>
<th>Watt</th>
<th>Lamp type</th>
<th>Star rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TFL</td>
<td>OSRAM</td>
<td>36 W</td>
<td>HL tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>2</td>
<td>TFL</td>
<td>OSRAM</td>
<td>36 W</td>
<td>HL tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>3</td>
<td>TFL</td>
<td>OSRAM</td>
<td>36 W</td>
<td>HL tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>4</td>
<td>TFL</td>
<td>PHILIPS</td>
<td>36 W</td>
<td>Tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>5</td>
<td>TFL</td>
<td>PHILIPS</td>
<td>36 W</td>
<td>Tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>6</td>
<td>TFL</td>
<td>PHILIPS</td>
<td>36 W</td>
<td>Tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>7</td>
<td>TFL</td>
<td>WIPRO</td>
<td>36 W</td>
<td>Ultralite tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>8</td>
<td>TFL</td>
<td>WIPRO</td>
<td>36 W</td>
<td>Ultralite tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>9</td>
<td>TFL</td>
<td>WIPRO</td>
<td>36 W</td>
<td>Ultralite tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>10</td>
<td>TFL</td>
<td>CROMPTON</td>
<td>36 W</td>
<td>Power-lux tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>11</td>
<td>TFL</td>
<td>CROMPTON</td>
<td>36 W</td>
<td>Power-lux tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>12</td>
<td>TFL</td>
<td>Samsung</td>
<td>36 W</td>
<td>Tubular fluorescent lamp</td>
<td>5 Star</td>
</tr>
<tr>
<td>13</td>
<td>TFL</td>
<td>SURYA</td>
<td>36 W</td>
<td>SUPER BRIGHT tubular fluorescent lamp</td>
<td>4 Star</td>
</tr>
<tr>
<td>14</td>
<td>TFL</td>
<td>GALAXY</td>
<td>36 W</td>
<td>SUPER BRIGHT tubular fluorescent lamp</td>
<td>4 Star</td>
</tr>
<tr>
<td>15</td>
<td>TFL</td>
<td>MYNA</td>
<td>36 W</td>
<td>High lumen tubular fluorescent lamp</td>
<td>4 Star</td>
</tr>
<tr>
<td>16</td>
<td>TFL</td>
<td>SURYA</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
</tr>
<tr>
<td>17</td>
<td>TFL</td>
<td>SURYA</td>
<td>36 W</td>
<td>K SLIMLITE tubular fluorescent lamp</td>
<td>3 Star</td>
</tr>
</tbody>
</table>
### Energy Efficient Lighting Design

<table>
<thead>
<tr>
<th></th>
<th>Manufacturer</th>
<th>Model</th>
<th>Power (W)</th>
<th>Type</th>
<th>Efficiency (Star)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>TFL GALAXY</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>TFL GALAXY</td>
<td>36 W</td>
<td>SLIMLITE tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>TFL OSRAM</td>
<td>36 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>TFL OSRAM</td>
<td>40 W</td>
<td>OSRAM BASIC PLUS TFL</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>TFL OSRAM</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>TFL PHILIPS</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>TFL PHILIPS</td>
<td>36 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>TFL WIPRO</td>
<td>40 W</td>
<td>PREMIUM tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>TFL WIPRO</td>
<td>36 W</td>
<td>SAFELITE tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>TFL WIPRO</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>TFL ANCHOR</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>TFL ANCHOR</td>
<td>36 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>TFL CROMPTON</td>
<td>36 W</td>
<td>Supersaver tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>TFL CROMPTON</td>
<td>40 W</td>
<td>Bright-lux tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>TFL CROMPTON</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>TFL BAJAJ</td>
<td>40 W</td>
<td>Cool daylight tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>TFL BAJAJ</td>
<td>36 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>TFL HIND</td>
<td>40 W</td>
<td>Cool daylight tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>TFL HIND</td>
<td>36 W</td>
<td>Cool daylight tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>TFL MYNA</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>TFL MYNA</td>
<td>36 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>TFL GE</td>
<td>36 W</td>
<td>GE SLENDER TFL</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>TFL GE</td>
<td>40 W</td>
<td>GE Standard TFL</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>TFL CEMA</td>
<td>36 W</td>
<td>CEMA energy saver</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>TFL CEMA</td>
<td>40 W</td>
<td>CEMA TC 3</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>TFL Samsung</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>TFL ONIDA</td>
<td>36 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>TFL ONIDA</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>TFL ECOLITE</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>TFL ECOLITE</td>
<td>36 W</td>
<td>Tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>TFL JINDAL</td>
<td>40 W</td>
<td>Cool day light tubular fluorescent lamp</td>
<td>3 Star</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>TFL PHILIPS</td>
<td>40 W</td>
<td>Tubular fluorescent lamp</td>
<td>2 Star</td>
<td></td>
</tr>
</tbody>
</table>

### Compact fluorescent lamps

CFLs produce light in the same manner as linear fluorescent lamps. Their tube diameter is usually 5/8 inch (T5) or smaller. CFL power is 5–55 W.
Typical CFLs have been presented in the figure.

Fig. 4.3.13: Compact fluorescent lamps

**Light-emitting diodes**
LEDs are small in size but can be grouped together for higher intensity. The efficacy of a typical residential application LED is approximately 20–100 lumens/W have been created in laboratory conditions. LEDs are better for lighting in a single direction than incandescent or fluorescent bulbs. LED strip lights can be installed under counters, in hallways, and in staircases; concentrated arrays can be used for room lighting. Waterproof, outdoor fixtures are also available. Some manufacturers consider applications, such as gardens, walkways, and decorative fixtures outside garage doors, to be the most cost-efficient. LED lights are more rugged and damage-resistant than compact fluorescents and incandescent bulbs. LED lights do not flicker. They are very heat-sensitive; excessive heat or inappropriate applications dramatically reduce both light output and lifetime. Uses include:

- Task and reading lamps
- Linear strip lighting (under kitchen cabinets)
- Recessed lighting/ceiling cans
- Porch/outdoor/landscaping lighting
- Art lighting
- Night lights
- Staircase and walkway lighting
- Pendants and overhead
- Retrofit bulbs for lamps

LEDs last considerably longer than incandescent or fluorescent lighting. LEDs do not typically burn out like traditional lighting, but rather gradually decrease in light output.

*Controls in daylighted areas*
a. There should be use of appropriate controls, and it should be well integrated with internal lighting. Each space enclosed by ceiling-height partitions shall have at least one control device to independently control the general lighting within the space. Each control device shall be activated either manually by an occupant or automatically by sensing an occupant. Refer to the guidance note for the same. It is capable of reducing the light output of the luminaires in the daylit areas by at least 50%, and

b. Controls only the luminaires located entirely within the daylit area.

**Common types of controls: lighting controls**

Each control device shall:

a. Control a maximum of 250 m² (2500 ft²) for a space less than or equal to 1000 m² (10000 ft²), and a maximum of 1000 m² (10000 ft²) for a space greater than 1000 m² (10000 ft²);

b. Be capable of overriding the shutoff control required in (a) for no more than 2 h; and
c. Be readily accessible and located so the occupant can see the control.

**Exceptions**

The required control device may be remotely installed, if required, for reasons of safety or security. A remotely located device shall have a pilot light indicator as part of or next to the control device and shall be clearly labeled to identify the controlled lighting.

**Timers**

These represent the most basic type of automation, and are very popular for outdoor applications. Timers can be simple (responding to one setting all year round) or sophisticated enough to contain several settings that go into effect over time.

**Fig. 4.3.15: Occupancy sensors**
**Occupancy sensors**

These devices – also known as ‘motion detectors’ – turn lights off and on in response to human presence. Once the sensitivity and coverage area are established, sensors are selected from two predominant technology types.

**Passive infrared sensors**

These detect the motion or heat between vertical and horizontal detection zones. This technology requires a direct line of sight and is more sensitive to lateral motion, but it requires layer motion as the distance from the sensor increases. The coverage pattern and field of view can also be precisely controlled. It typically finds its best application in smaller spaces with a direct line of sight, such as restrooms.

*Fig. 4.3.16: Passive infrared sensors*
**Ultrasonic sensors**

These detect movement by sensing disturbances in high-frequency ultrasonic patterns. Because this technology emits ultrasonic waves that are reflected around the room surfaces, it does not require a direct line of sight. It is more sensitive to motion towards and away from the sensor and its sensitivity decreases relative to its distances from the sensor.

![Fig. 4.3.17: Ultrasonic sensors](image)

It also does not have a definable coverage pattern or field of view. These characteristics make it suitable for use in layer-enclosed areas that may have cabinets, shelving, partitions, or other obstructions. If necessary, these technologies can also be combined into one product to improve detection and reduce the likelihood of triggering a false on or off mode.

**Photocells**

These measure the amount of natural light available and suitable for both indoor and outdoor applications. When the available light falls below a specified level, a control unit switches the lights on (or adjusts a driver to provide more light). Photocells can be programmed so that lights do not flip on and off on partially cloudy days.

**Case Study – methodology to design an efficient lighting scheme for a new building**

In order to arrive at the optimum combination, the following options have been analysed:

1. Case 1: Analyse the proposed case (given by the architect)
2. Case 2: Modification in the proposed case to achieve visual comfort, if not met
3. Case 3: Select the luminaire with a twin fitting of a 28-W T-5 lamp with higher luminaire efficiency
4. Case 4: Use efficient low-glare fixture with twin 36-W CFL lamp mirror optic luminaries/lamps/ballasts

**Assumptions**

The following assumptions have been taken for the analysis:
Project maintenance factor = 0.8
Reflectance of the ceiling = 0.7
Walls = 0.5
Floor = 0.3

The existing lighting design incorporates luminaire, which is Philips TMC501 with 40-W fluorescent tube lights (2450 lumen is the output of a standard T12 40-W tubelight).

**Observation**
- In order to achieve the desired illuminance levels as recommended by the NBC, the number of fixtures has to be optimized so that the lighting power density should not exceed the ECBC 2007 guideline.
- The desired lux levels and uniformity can be achieved for lower lighting power density values with combination luminaires with better mirror optics and high-efficiency triphosphor tubelights and CFLs.

**Case 1 analysis: lighting scheme with a monophosphor lamp**

The general lighting scheme in case 1 uses the luminaire with the following specifications:

1. Manufacturer : Philips
2. Luminaire type : TMC501
3. Lamp type : 1x40 W TLD
4. Lumen output : 2450lm/lamp
5. Ballast power loss : 15W
6. Total power consumption of the lamp : 55W/lamp

**Observation**
- It has been observed from Table 4.3.6 below that the average lighting level for the office room is 84 and it is not conforming to the recommended NBC 2005 standards.
- From the energy efficiency point of view, the overall LPD achieved for the office room is 3.85 W/m², which is below the ECBC 2007 recommended value.
- Uniformity ratio achieved in this case is 0.49.

**Table 4.3.6:** Case 1 illumination level and LPD of the office room
Energy Efficient Lighting Design

Proposed Mandatory Clause

Technical Guidelines

Benefits

Table 4.3.18: Floor area, number of fixtures and average illumination level (lux)

<table>
<thead>
<tr>
<th>Floor</th>
<th>Area</th>
<th>Number of fixtures</th>
<th>Average illumination level (lux)</th>
<th>LPD (W/m²)</th>
<th>Uniformity ratio (min/avg)</th>
<th>NBC illumination level (lux)</th>
<th>ECBC recommended LPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground floor</td>
<td>Office Staff for seating</td>
<td>8</td>
<td>84</td>
<td>3.85</td>
<td>0.49</td>
<td>300–500</td>
<td>11.8</td>
</tr>
</tbody>
</table>

Case 2 analysis: modification in the proposed case to achieve visual comfort, if not met

The lighting scheme consists of the same monophosphor lamp, but the number of fixtures has been increased in order to meet the illuminance levels as recommended by the NBC. Given below are the luminaire specifications:

1. Manufacturer : Philips
2. Luminaire type : TMC501
3. Lamp type : 1 x 40 W TLD
4. Lumen output : 2450 lm/lamp
5. Ballast power loss : 15 W
6. Total power consumption of the lamp : 55 W/lamp

Observation

1. It has been observed from Table 4.3.7 given below that the average lighting level of the office room is 403 and it is not conforming to the recommended NBC 2005 standards.
2. From the energy efficiency point of view, the overall LPD achieved for the office room is 13.42 W/m², which is higher than the ECBC 2007 recommended value.

3. Uniformity ratio achieved in this case is 0.74.

Table 4.3.7: Case 2 illumination level and LPD of the office room

<table>
<thead>
<tr>
<th>Floor</th>
<th>Area</th>
<th>Number of fixtures</th>
<th>Average illumination level (lux)</th>
<th>LPD(W/m²)</th>
<th>Uniformity ratio (min/avg)</th>
<th>NBC illumination level (lux)</th>
<th>ECBC recommended LPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td>Office (Staff for</td>
<td>21</td>
<td>403</td>
<td>13.42</td>
<td>0.74</td>
<td>300–500</td>
<td>11.8</td>
</tr>
<tr>
<td>floor</td>
<td>seating)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.3.19: Rendered image and Iso-lux diagram of the office room

Case 3 analysis: select a luminaire with a twin fitting of a 28-W T-5 lamp with higher luminaire efficiency

The general lighting schemes in this case have been designed considering the 2 x 28 W advanced recessed luminaries with D8 micro-optics, with excellent glare control.

Given below are the luminaire specifications:
1. Manufacturer    : Philips
2. Luminaire type  : TBS 814
3. Lamp type       : 2 x 28 W TLD
4. Lumen output    : 2900 lm/lamp
5. Ballast power loss : 2 W
6. Total power consumption of the lamp : 30 W/lamp
Observation

a. It has been observed from Table 4.3.8 given below that the average lighting levels of the office room is 412 and it is conforming to the recommended NBC 2005 standards.

b. The overall LPD achieved for the office room is 6.7, which is below the ECBC 2007 recommended value.

c. Uniformity ratio achieved in this case is 0.48, the same as achieved in the previous case.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Area</th>
<th>Number of fixture</th>
<th>Average illumination level (lux)</th>
<th>LPD (W/m²)</th>
<th>Uniformity ratio (min/avg)</th>
<th>NBC illumination level (lux)</th>
<th>ECBC recommended LPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground floor</td>
<td>Office Staff for seating</td>
<td>18</td>
<td>412</td>
<td>6.7</td>
<td>0.48</td>
<td>300–500</td>
<td>11.8</td>
</tr>
</tbody>
</table>

Case 4 analysis: use an efficient low-glare fixture with twin 36-W CFL lamp mirror optic luminaries/lamps/ballasts

The general lighting schemes in this case have been designed considering a luminaire with 2 x 36 W CFLs, highly efficient with wide paralite P5 louvres to achieve low glare. An electronic ballast with a nominal power factor of 0.90–0.95 has been considered.

The luminaire specifications are given below:

Manufacturer : Wipro
Luminaire Typetype : WIP48236
Lamp type : 2 x 36 W CFLs
Lumen output : 2900 lm/lamp
Ballast power loss : 4 W
Total power consumption of the lamp : 40 W/lamp
Figure 4.3.20: Iso-lux diagram of the office room

**Observation:**
- It has been observed from Table 4.3.9 given below that the average lighting level of the office room is 464 and it is conforming to the recommended NBC 2005 standards.
- The overall LPD achieved for the office room is 11.8, which is exactly the same as recommended in ECBC 2007.
- Uniformity ratio achieved in this case is 0.53, which seems to be better than the rest.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Area</th>
<th>Number of fixtures</th>
<th>Average illumination level (lux)</th>
<th>LPD (W/m²)</th>
<th>Uniformity ratio (min/avg)</th>
<th>NBC illumination level (lux)</th>
<th>ECBC recommended LPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground floor</td>
<td>(Office) Staff for seating</td>
<td>20</td>
<td>464</td>
<td>11.8</td>
<td>0.53</td>
<td>300–500</td>
<td>11.8</td>
</tr>
</tbody>
</table>

**Summary of analysis**

Table 4.3.10: Summary of analysis and recommendation of the artificial lighting

<table>
<thead>
<tr>
<th>Typical area</th>
<th>Average illumination level achieved (lux)</th>
<th>Lighting power density achieved (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case 1</td>
<td>Case 2</td>
</tr>
<tr>
<td>Office room</td>
<td>84</td>
<td>403</td>
</tr>
</tbody>
</table>

**Recommendation**

It is clear from Figure 5 that the initial cost for Case 3 is slightly high, but at the end of the cycle time, it gives better savings. Hence, Case 3 i.e. TBS 814/228 D8 HF is the best option among all the other alternatives.
**Conclusion**

The main findings of this study are as follows:

- With a proposed design i.e. Case 1, the illumination levels are very low. No doubt, the lighting load will be less, but this may cause visual discomfort and is not advisable.
- An inefficient lighting luminaire (along with a lamp) may produce the required illumination, but at a higher lighting power density value, which will increase the lighting energy consumption,
- Use of efficient lighting fixtures along with efficient lamps will not only produce the required illumination, but also provide check on the increasing energy demand. Therefore, it is highly recommended to use such fixtures in place of inefficient ones in the existing lighting schemes.
- Using efficient lighting equipments will definitely increase the initial or first cost, but the total cost or the life cycle cost, which includes both the first cost and recurring cost (energy and maintenance cost) of such lighting schemes, if calculated for a period of 15 years, comes out to be less than the LCC of a system, which is designed with cheaper and inefficient equipments to produce the same illumination.

### 4.3.4 Retrofitting options in the existing commercial buildings

Given below is the methodology to check and improve the efficiency of the existing lighting scheme in commercial buildings:

1. Interior lighting power density: interior lighting power density for the existing lighting scheme should be calculated as per the methods explained above. If the LPD values are not in the limit of the ECBC recommended values, then to reduce it to the recommended values, the following can be practiced:
   a. *Replacement of lamps*: lamps in the existing lighting scheme can be replaced by the one having higher efficacy e.g. a 40-W TLD lamp can be replaced by a T-5, higher BEE star-rated lamp
or an Incandescent lamp can be replaced by a CFL or LED lamp, etc.

b. Replacement of ballasts: conventional magnetic ballasts can be replaced by more efficient electronic ballasts.

c. Replacement of luminaires: luminaires with better mirror optics, which enhances the light distribution and also the light output of a luminaire, can be opted.

2. Lighting controls: automatic lighting controls as recommended by ECBC 2007, mentioned above, can be integrated in the lighting scheme to reduce the wastage of lighting energy as and when not required. Daylighting controls can help in dimming or switching off the luminaire in the daylit zone during the availability of daylight.

4.3.5 Internal lighting for new residential buildings

Efficiency of an interior lighting scheme in a residential building depends on the following parameters:

1. Lighting power density: lighting power density in a residential building should comply with the ECBC recommended value given above in Table 4.3.2 & 4.3.3. The following can be applied in order to keep LPD in the recommended value:

a. Lamp selection: lamps with high efficacies, examples given in the above part, should be used for general lighting.

b. Ballasts: electronic ballasts or low-loss copper ballasts can result in higher system efficacies and reduce losses.

c. Luminaire efficiency: the decorative luminaires used in residential buildings, in general, have translucent surfaces, which reduce the luminaire efficiency of a fixture and results in installing more number of fixtures for the same illuminance level. While selecting the lamp, fixtures having high translucency should be selected.

2. Reflectance of surfaces: spaces, which have finishes dark in color, lead to installation of more number of lamps for the same illuminance level. The ceiling, wall, and other surfaces should be of light color so as to achieve better light distribution and illuminance levels.
3. Lighting design: lighting design in a residential area plays a key role in governing the efficiency of the design. The following factor should be kept in mind while designing a lighting scheme for residential buildings:
   - Lamps with a suitable wattage need to be selected for different spaces depending upon the space geometry. It is always desirable to have multiple fixtures instead of providing a single fixture of higher wattage.
   - Lamp placement should be such that:
     - One can achieve better light distribution in space
     - One can utilize the natural light available in daytime from the fenestration and do not have to switch on lamps unnecessarily

Case study
The case study described below for a 3-BHK apartment shows the importance of all the above-mentioned parameters, such as lamp selection, control gear selection, placement of fixtures, etc., in making an efficient lighting scheme:

Step 1: calculation of the lighting power density
For each of the spaces, first of all the area should be calculated. The area of each space should be multiplied by 7.5 (the recommended LPD value by the ECBC for residences) to get the upper limit of the lighting power density value as shown in the figure below.
Step 2: lighting design and lamp selection

Considering the living/dining area as an example for a lighting design, first of all, the location and source selection play an important role in the design. On longer façades, we can install linear lighting sources, while on the ceiling, recessed point sources can be installed.

After freezing the design, in terms of the location and type of sources, we can advance to the lamp and gear selection process. Considering Option 1, as shown in the figure, the linear lighting sources are 40-W T12 FTLs with magnetic ballasts and point sources are 60-W incandescent lamps. The lighting load in Option 1 for the space comes out to be 400 W, which is higher than the upper limit value of 390 W for the space; hence, the lighting scheme for Option 1 is an inefficient one.

Option 1

Now, for Option 2, as shown in the figure, the linear lighting sources are 28-W T5 FTLs with electronic ballasts and the point sources are 15-W CFLs with electronic ballasts. The lighting load in Option 2 for the space comes out to be 165 W only, which is quite lower than the upper limit value of 390 W; hence, the lighting scheme in Option 2 is an efficient one.

4.3.6 Retrofitting options in the existing residential buildings

Given below is the methodology to check and improve the efficiency of the existing lighting scheme in residential buildings:
1. Interior lighting power density: interior lighting power density for the existing lighting scheme should be calculated as per the methods explained above. If the LPD values are not in the limit of the ECBC recommended values, then to reduce it to the recommended values, the following can be practiced:
   a. *Replacement of lamps*: lamps in the existing lighting scheme can be replaced by the one having higher efficacy e.g. a 40-W TLD lamp can be replaced by a T-5, higher BEE star-rated lamp, or an incandescent lamp can be replaced by a CFL or LED lamp, etc.

   ![Diagram showing lighting design example](image)

   **Option 2**

   b. *Replacement of ballasts*: conventional magnetic ballasts can be replaced by more efficient electronic ballasts.

   c. *Replacement of luminaires*: decorative fixtures, which have surfaces with high translucency, can be selected in order to reduce the wattage of a lamp for the same lumen output.

2. Lighting design: an existing lighting design needs to be studied on factors mentioned below, and if possible, should be modified appropriately as given in the case study above:
   a. Light distribution in space
   b. Utilization of daylight during daytime from windows
   c. Placement of lighting fixtures
### Table 4.3.11: Lighting manufacturer contact details

<table>
<thead>
<tr>
<th>SN</th>
<th>Name</th>
<th>Address</th>
<th>Contact details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Asian Electronics</td>
<td>1799/430, 490, Sri Rangakavala, Magadi Main Road, Sunradan Kahle Vishsaneedam, Bangalore-560091</td>
<td>Ph: 080-3488974</td>
</tr>
<tr>
<td>2</td>
<td>Bajaj Electricals</td>
<td>Bajaj Bhavan, NO 16, Residency Rod, Bangalore - 560025</td>
<td>Ph: 080-2238984, Fax: 080-2214878</td>
</tr>
<tr>
<td>3</td>
<td>CERCO Lighting</td>
<td>CENTRAL ELECTRIC &amp; RADIO CO, 14-16, Lohar Chawl, Mumbai - 400 002. (India)</td>
<td>Ph: 022-22081125 / 2208 /1183, Fax: 022-22001693</td>
</tr>
<tr>
<td>4</td>
<td>Decon Lighting</td>
<td>5, Lok Nayak Bhawan, Khan Market New Delhi – 110003</td>
<td>Ph: 011-24617795, 24692863, Fax: 91-11-24633004</td>
</tr>
<tr>
<td>5</td>
<td>GE Lighting</td>
<td>Plot No. 42/1 &amp; 45/14, Electronic City - Phase II Bangalore – 560100</td>
<td>Ph: +91-80-26528355 / 375 to 380, Fax: +91-80-28528366</td>
</tr>
<tr>
<td>6</td>
<td>Halonix Lighting</td>
<td>No.6, &quot;Legacy&quot; 1st Floor, Convent Road, Richmond Town, Bangalore – 560025</td>
<td>Ph: 080-30527032</td>
</tr>
<tr>
<td>7</td>
<td>Havells India Limited</td>
<td>6th Floor, Emerald, Madras Bank Road (Lavelle Road) Bangalore – 560001</td>
<td>Ph: 080-39982100, 080-30515801, 080-30515802/3/4, Fax: 080-22112663</td>
</tr>
<tr>
<td>8</td>
<td>Lucifer Lights Ltd.</td>
<td>15, Shree Krishna CHS, Opp. Prince Mangal Karyalya Near Apsara Theatre, Pune - Maharashtra India – 411 037</td>
<td>Ph: 020-26455525, 26455526, Mobile: 9325510557, 9270052758</td>
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<tr>
<td>9</td>
<td>OSRAM India Pvt Ltd.</td>
<td>Unit No# 301 - 303, MADISON , 4th Floor, Airport Road (1/3 Kodihalli Main Road), Bangalore – 560008</td>
<td>Ph: 080-25210919, Fax: 080-25210920</td>
</tr>
<tr>
<td>10</td>
<td>Philips Electronics India Limited</td>
<td>The Estate, 4th floor (North Wing) (Next to Manipal Centre) , 121, Dickenson Road Bangalore - 560042, India.</td>
<td>Ph: 080-26751008/26751004/32973898</td>
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<tr>
<td>11</td>
<td>Surya Roshni</td>
<td>No.98, 1st Floor Main New timber Yard Layout Mysore Road Bangalore - 560026</td>
<td>Ph: 080-26751008/26751004/32973898</td>
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<tr>
<td>12</td>
<td>Wipro Lighting</td>
<td>Doddakannelli, Sarjapur Road, Bangalore - 560035</td>
<td>Ph.: 080-28440011, Fax: 080-28440057</td>
</tr>
</tbody>
</table>
4.4 Benefits

- Optimized lighting scheme enhances the effectiveness and efficiency of a lighting scheme.
- Lighting-connected load is minimized by utilization of high-efficacy lamps, luminaires, and efficient control gears.
- Installation of lighting controls reduces wastage of energy in lighting during non-operational hours. Also daylighting controls save energy during daytime, when natural light is available in abundance.
- Integration of renewable energy systems in exterior lighting applications helps in offsetting the conventional energy demand by renewable energy.
- A case study comparing a conventional lighting scheme with an ECBC-compliant lighting scheme for an office space:
  - Increment in the initial investment is around 5% if one switches over from a conventional lighting scheme to an ECBC-compliant lighting scheme for office spaces.
  - Annual lighting energy consumption decreases by around 35%.
  - Payback period for the ECBC-compliant lighting scheme is less than 1 yr compared to the conventionally designed lighting scheme for an office space.
Figure 4.4.1 Payback period graph