Development of energy efficient lighting (EEL) design and savings calculator for commercial application

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ABSTRACT

The Energy Efficient Lighting (EEL) Design and Savings Calculator (DSC) for Commercial Application is a handy tool intended for project engineers to have a quick reference in the illumination design. This project is specifically focused on selecting energy efficient lamps used notwithstanding its illumination requirement in the given area/task.

The EEL-DSC comprises of the rotary disk (inner and outer) and disk jacket. The inner rotary disk shows the various lamps type, lamp wattage, lamp light output, color temperature, color appearance, and color rendering group. Side A of the outer rotary disk displays the Lumen Method formula while side B shows the notations for Color Rendering Group (CRG), Correlated Color Temperature (CCT), and the Lamps type legend.

The disk jacket has two parts: the inner disk jacket and the outer disk jacket. The inner disk jacket (IDJ) illustrates the instruction manual and steps in calculation.

Table 1 indicates the recommended level of illumination and Table 2 the color rendering index (CRI) with lamp efficacy. The outer disk jacket (ODJ) illustrates the picture from DOE while Table 3 displays the Coefficient of Utilization (CU), the Maintenance Factor (MU) and Terminologies.

These parameters were simplified to help the engineers quickly estimate the design of energy efficient lighting system by selecting the lamps type, categories e.g. High-bay, low-bay and 2-Lamps, coefficient of utilization, and maintenance factors. The reflectance for ceiling, walls, and floor cavity were also simplified at 70%, 50% and 30% respectively. Finally, the total number of luminaires was determined.

Moreover, EEL-DSC for Commercial Application is one of the contributions of the Technological University of the Philippines (TUP) in the advocacy of the Department of Energy to address the barrier to use energy efficient lighting system in the Philippines and its goal to reduce Greenhouse Gas (GHG) emission in the energy sector. Furthermore, this project was funded by the United Nation Development Programme (UNDP) through the Philippine Efficient Lighting Market Transformation Project (PELMATP) – Department of Energy.

Keywords
Energy Efficiency, Lighting Design Calculator
Introduction

The world’s lighting issues according to Carbon Trust, states that “Commercial and industrial lighting consumes an estimated 20% of all electricity generated in the UK alone. In most organizations, lighting accounts for up to 40% of total electricity costs.” It is also supported by the Green Business Light Association which states “Electric lighting burns up to 25% of the average home energy budget.” Further, the Light Research Center hold that “Energy Efficient Lighting (EEL) demands less electricity, which reduces polluting power plant emissions.”

In this account, the Philippines was among the first country to prepare a National Action Plan to mitigate the polluting emission that leads to Climate Change. The Department of Energy (DOE) as one of the implementing agencies that moderate, monitor, and evaluate the Greenhouse Gas (GHG) effect in the country. DOE has also received the climate change project with a total funding of US$ 15M through the Philippine Efficient Lighting Market Transformation Project (PELMATP) under the Global Environmental Facility - United Nation Development Programme (GEF-UNDP-DOE).

The PELMATP seeks to address the barriers to widespread use of energy efficient lighting system (EELs) in the Philippines. Also it aims to promote the use and benefits of EEL with simplified tools to calculate savings for new commercial and industrial establishments.

This project Energy Efficient Lighting Design and Savings Calculator (EEL-DSC) was developed to provide designers (e.g. engineers, architects, etc.) of lighting system for commercial application a handy tool for a quick comparative estimate on energy consumptions and savings.

It is focused on determining a number of luminaires and the type of lamp to be used in the particular area or task within a recommended illumination and energy efficiency.

Objectives

The objectives of the project follow:

1. To develop simplified tools that can quickly estimate and calculate of energy consumption using the energy efficient lighting (EEL) products.

2. To provide EEL products of comparative parameters as light sources commonly used for commercial applications lighting systems.

3. To prepare an instruction manual for the Energy Efficient Lighting Design & Savings Calculator (EEL-DSC) as guideline of designers (e.g. engineers, architects, practitioners, etc).

4. To determine the level of accuracy of the estimated lighting systems using EEL-Design & Savings Calculator.

Method

The energy efficient lighting design and savings calculator (EEL-DSC) was created in reference to several calculators in rectangular, triangular and circular format. The initial pattern used was the rectangular form, however, after deliberation with colleagues the circular form was decided to use to give optimum space that carries more information than any other forms.

The light sources were taken from the catalogues of several known manufacturers producing EEL commercially available products. They were arranged according to types, lamp wattage, lamp light output, color temperature, color appearance, and color rendering group. The light sources were arranged according to ascending values of the watts, lumens and Kelvin units. These parameters were printed in the inner rotary disk.

The design calculation used to determine the number of luminaires is the Lumen method from the journal published by the latest edition of the Illumination
Engineering Society of North America (IESNA), the most widely used designing lighting systems by practitioner. Tables were selected, simplified, and adhered to the most frequently used specifications.

The instruction manual was printed to guide the designer-engineer to facilitate calculation. The calculation method was taken from IESNA and all the needed parameters in the formula marked in the disk.

Results

After several trials and configurations of the calculators, these results were obtained:

The selected form of the EEL DSC was a circular form that carries more information than others. Figure 1 below shows the inner rotary disk:

![EEL Saving Calculator for Commercial Use](image_url)

Figure 1. The Inner Rotating Disk that contains specifications of lighting source e.g. Lamp type, Lamp wattage, Lamp light output, Color temperature, Color appearance, Color rendering group. A single lamp specification is arranged in one column of different levels.
Figure 1 shows the inner rotary disk of the EEL DSC calculator and the specifications of various light sources. These light sources are commercially available in the market with lighting catalogues of different known lamp manufacturers.

Figure 2a shows the construction layout of the outer disk. The lumen method formula and lighting parameters are printed in faces of the outer disk Side A and Side B respectively.

Figure 2b illustrates the assembly format of the outer disk. Side A is not visible as it is at the back of side B. The selection of lamp types can be changed by moving the inner rotating disk upward or downward to see the different lamp types and their specification. These will provide the designer flexibility in choosing the appropriate lamp type according to specifications/design, as found in the window at the upper part of the disk.
Table 1: Recommended level of Illumination

<table>
<thead>
<tr>
<th>Type of interior, task or activity</th>
<th>Maintained illumination level, lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>Electric equipment manufacturing</td>
</tr>
<tr>
<td>Dining room</td>
<td>Insulating, cool/warmand wintering</td>
</tr>
<tr>
<td>Rough layout drafting, accounting offices</td>
<td>Dairy products</td>
</tr>
<tr>
<td>Reading, handwriting, informal social</td>
<td>Boiler room, bottle storage, paradox, and storage/Refrigerator</td>
</tr>
<tr>
<td>Conference room (conferencing and meeting)</td>
<td>Textile mills</td>
</tr>
<tr>
<td>Corridor</td>
<td>Cleaning, cleaning, polishing, wearing, weaving</td>
</tr>
<tr>
<td>Hotels</td>
<td>Storage room or warehouses</td>
</tr>
<tr>
<td>Bathrooms, bedrooms, lobby/glory lighting</td>
<td>Active and passive</td>
</tr>
<tr>
<td>Stores (Merchandising areas)</td>
<td>Show manufacturing</td>
</tr>
<tr>
<td>Self-service, showrooms, and work areas</td>
<td>Varnishing, staining, upper and side cutting</td>
</tr>
</tbody>
</table>

For other level of illumination please see Manual of Practice of Interior Lighting, 2017 edition

Table 2: Color Rendering Index and Lamp Efficacy for Typical Light Source

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Lamp Watts</th>
<th>Mean Lamp Efficacy</th>
<th>Mean Lamp Lumens</th>
<th>CRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent</td>
<td>100</td>
<td>15</td>
<td>1575</td>
<td>100</td>
</tr>
<tr>
<td>Compact Fluorescent</td>
<td>60</td>
<td>53</td>
<td>1370</td>
<td>82</td>
</tr>
<tr>
<td>Fluorescent (41 - Standard Phosphor)</td>
<td>66</td>
<td>63</td>
<td>2300</td>
<td>62</td>
</tr>
<tr>
<td>Mercury Vapor</td>
<td>250</td>
<td>63</td>
<td>1200</td>
<td>20</td>
</tr>
<tr>
<td>Color Improved</td>
<td>250</td>
<td>63</td>
<td>1200</td>
<td>40</td>
</tr>
<tr>
<td>Metal Halide</td>
<td>60</td>
<td>67</td>
<td>11000</td>
<td>65</td>
</tr>
<tr>
<td>Color Improved</td>
<td>250</td>
<td>64</td>
<td>16000</td>
<td>70</td>
</tr>
<tr>
<td>Pulse Start</td>
<td>250</td>
<td>65</td>
<td>21040</td>
<td>65</td>
</tr>
<tr>
<td>High Pressure Sodium</td>
<td>250</td>
<td>102</td>
<td>26000</td>
<td>21</td>
</tr>
<tr>
<td>Cold Improved</td>
<td>250</td>
<td>58</td>
<td>25000</td>
<td>66</td>
</tr>
</tbody>
</table>

Figure 3 reveals the inner cover jacket (ICJ) where the outer disk is inserted for protection like the common compact disk (CD) with cover. The printed instruction manual gives direction and steps by step calculation of lighting system to the designer while Table 1 refers to the recommended level of illumination. Table 2 indicates the Color rendering index and Lamp Efficacy of different lamp types.

Figure 3. The inner disk jacket (IDJ) shows the instruction manual calculation on page 2 while page 3 displays Table 1 Recommended level of illumination and Table 2 Coloring rendering index and lamp efficacy.
Table 2 on Color rendering index and Lamp efficacy refers to the lamp type and its parameters considered such as incandescent, CFL, fluorescent, mercury vapor, and metal halide.

<table>
<thead>
<tr>
<th>Types of Luminaires</th>
<th>Reflectance for ceiling (70% wall) (90%) and Room area (90%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R&lt;sub&gt;red&lt;/sub&gt;/R&lt;sub&gt;blue&lt;/sub&gt;/R&lt;sub&gt;green&lt;/sub&gt; (%)</td>
</tr>
<tr>
<td></td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>High bay*</td>
<td>0.97 0.98 0.92 0.75 0.64 0.58 0.52 0.47 0.43 0.39 0.36</td>
</tr>
<tr>
<td>Low bay*</td>
<td>0.94 0.78 0.67 0.58 0.51 0.44 0.40 0.39 0.32 0.31 0.27</td>
</tr>
<tr>
<td>2-Lamp†</td>
<td>0.76 0.72 0.62 0.56 0.49 0.44 0.40 0.36 0.33 0.31 0.29</td>
</tr>
</tbody>
</table>

* Nominal values are based on ISO 896:2012/EN 60607:2001
† Based on EN 62957:2012/IEC 60086-2001
‡ With wide-open metal reflector
§ With narrow dropout lens
¶ With two lamp fixture with A12 lens

Note: For different reflectance types of luminaires and values for room area, please refer to lighting handbooks and manufacturers supplied catalog.

The outer cover jacket (OCJ) shows the initial design of the front page “Palit-ilaw” project of the Department of Energy and was later revised. The back page of the OCJ shows Table 3 on Coefficient of Utilization (CU) including the Maintenance Factor and Terminologies.

**Figure 4.** The outer cover jacket (OCJ) composed of front page and back page. The front page is the picture from DOE while the back page shows Table 3 on Coefficient of Utilization (CU) including the Maintenance Factor and Terminologies.

The outer cover jacket (OCJ) shows the initial design of the front page “Palit-ilaw” project of the Department of Energy and was later revised. The back page of the OCJ shows Table 3 on Coefficient of Utilization of different type of luminaires. The researcher simplified the table by considering only the high bay, low bay and the 2-lamps types of luminaires. Furthermore, the researcher assumed the percentage of reflectance as follows: 70% of ceiling, 50% walls, and 30% floor cavity reflectance due to its frequent practice combination in the design.
Maintenance factor was considered to be of four types such as, 0.85 air-conditioned interior, 0.80 non air-conditioned interior, 0.75 normal industrial areas, and 0.70 dusty industrial areas.

The terminologies were also included on the last portion of the OCJ.
Figure 5a shows the final layout of the front page of the Cover Jacket of the EEL DSC while Figure 5b the final layout of the Cover Jacket in one piece for printing and mass production. The Department of Energy through the Philippines Efficient Lighting Market Transformation Project under the United Nation Development Programme (DOE-PELMATP-UNDP-GEF), mass produced the EEL DSC.

Discussion

The EEL DSC were tested through the simulation of the three (3) different problems from the samples on the Manual of Practice on Efficient Lighting and three (3) actual design problems given by a design practitioner. The six problems were calculated using both the computer software and the EEL-DSC.

Comparing the results of the computer software simulation against EEL DSC calculation, EEL DSC gave an average of 80% level of accuracy. This result can be attributed to the lack of available lamp types of the software that tend to give lower accuracy. However, the results from the estimated calculation of the practitioner against the use of EEL DSC calculation, EEL DSC gave an average of 90% level of accuracy, as attributed to the actual assumption of the practitioner in the lighting system design.

The result also provides an average percent accuracy for the EEL DSC that ranges from +/- 10% minimum to +/- 15% maximum of the estimated value. This can be attributed to the assumption made by the design engineer on the flexibility of the coefficient of utilization and the lamp type used in the design.

Finally, the result indicates that EEL DSC can be used as alternative tool to quickly estimate EEL products to attain energy efficient in lighting system.

Conclusion

In light of the findings, these conclusions can be drawn:

1. Circular format was used for the EEL-DSC. The spaces for printing information in circular form were strategically designed to give more lamps specification. Also the used cover jacket provides useful information such as:
   a. Twelve (13) most common types of interior and activities were considered in Table 1 with recommended level of illumination.
   b. Ten (10) lamps types were considered in the Table 2 with the most common mean lamp lumen used for commercial application.
   c. Only three (3) types of percent reflectance were considered in Table 3. Coefficient of Utilization: ceiling - 70%, walls - 50% and floor cavity - 30%

2. More than 70 luminaires were considered in EEL DSC Calculator Disc with complete specifications.

3. The instruction manual as guide for the designer to facilitate calculation can easily be followed.

4. The EEL-DSC can be used as an alternative tool to readily estimate EEL products with accuracy of about +/- 10% minimum and +/- 15% maximum.

Recommendations

1. Update the luminaires with the most recent technology of lighting source with LEDs from the different manufacturers' catalog.

2. Reduce the parts of material and cost of EEL-DSC by combining the print of the inner disc and calculator disc back to back.
3. Validate the accuracy of the EEL-DSC calculator by conducting more surveys to engineers and lighting design practitioners.

4. Determine the level of satisfaction as perceived by engineers and lighting design practitioners using EEL-DSC.

References

ISO 8995:2002(E) CIE S 008/E-2001

IESNA Lighting Ready Reference RR-04


GE Catalogs for lamps and luminaires, 2006.


http://www.lrc.rpi.edu/programs/designWorks/index.asp retrieved (10/20/2014)