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ENERGY EFFICIENT LIGHTING DESIGN - A CASE STUDY OF JIGME NAMGYEL ENGINEERING COLLEGE

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***Abstract*—** This study focuses on efficient lighting design in Jigme Namgyel Engineering College (JNEC), under the Royal University of Bhutan (RUB). To carry out the detailed study and review of the existing lighting scheme, Relux simulation software was used and it is one of the high-performance software to simulate electric and daylight for illumination design and study.

The study was based on the existing lighting scheme and a comparative study employing different luminaires (fluorescent lamp and LED) was performed succeeded by designing an efficient illumination lighting scheme. Further to increase energy saving during the daytime, daylight has been integrated with all the lighting schemes studied. The simulation result exhibits that the average illuminance for the existing lighting scheme is 161lx which does not meet the standard lx level for given infrastructures. Two new lighting schemes using fluorescent lamps and LED lamps were suggested following the standard lx level recommended at the workplace. The comparative life cycle cost analysis of the proposed lighting scheme resulted in 59.9% energy saving potential and accounted for a payback period of 2years when employing LED lamps instead of existing illumination fixtures.

Keywords— *Illumination, Fluorescent, LED, Energy Efficiency and Relux*

I. INTRODUCTION

Due to the importance of energy and its relationship to economic development, there are multiple initiatives for advancing energy efficiency and conservation approaches in the operation of buildings. An educational institute provides complete infrastructure such as classrooms, offices, laboratories, library hall and many which are necessary to be equipped with advanced equipment to ensure maximum quality of education. It is impossible to create a pleasing environment without proper lighting which in addition plays a critical role in supporting high-quality learning addressing issues of visual quality, comfort and related performances [1][2][3][4][5]. As lighting design integrates fundamental factors to create a desirable environment [2], Relux software has been employed for this purpose. Relux software has helped to evaluate the performance of the existing lighting scheme and propose a new lighting scheme following the required quantity of lx level [6][7]. Since lighting contributes to around 20-30% of electricity consumption in an academic institute [1], an energy-efficient illumination design that does not compromise the user comfort needs to be adapted [8][9]. Significant opportunities exist to advance the inherent efficacy of lighting systems as well as achieve energy saving by limiting the amount of electrical energy use. For this purpose, integrated artificial and daylight harvesting schemes were also simulated [10][11]. The energy-saving derived through the use of daylight facilitates the sparing use of electric lighting and reduces peak electrical demands [6].

II. METHODOLOGY

For this research three different buildings namely;

i) Department of Electrical Engineering
ii) Administration building and
iii) Library & IT building were selected.

The above three buildings were chosen as it covers the major infrastructures provided in an educational institution. Detailed illumination studies for the existing lighting scheme were carried out using Relux simulation software, then an efficient lighting design was suggested.

2.1. Measurement of room geometries

For this case study, to evaluate the illumination of various designated rooms, the dimensions, height, working-plane height, ceiling type, luminaire maintenance factor, orientation and distance from the floor/ceiling [3] were considered. Placement and distance between luminaires were also measured by projecting it on the floor using a plumb bob.

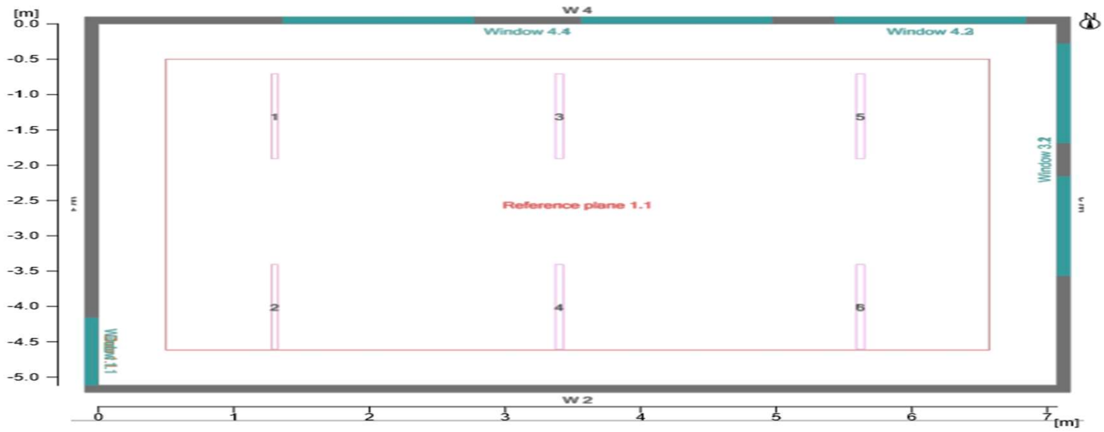
2.2. 2D and 3D Modelling

The measured geometrical parameters were used for 2D modelling in AutoCAD, which is then imported into Relux software for designing lighting schemes in a 3D model. A brief study on existing luminaires including wattage, lumen, and color rendering temperature was carried out. The lighting performance is known to be affected by many factors such as paint colors, reflection factor, utilization factor and maintenance factor which are also considered in simulation [6].

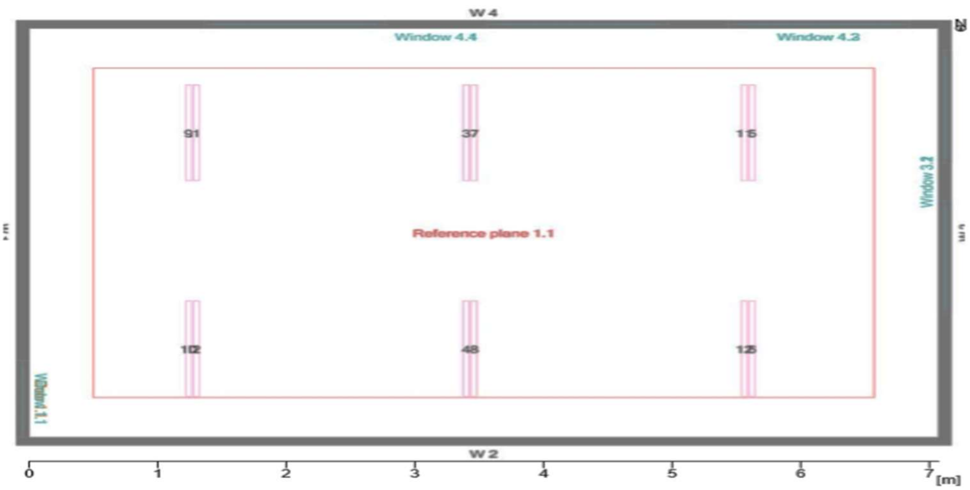
The 3D modelling of different buildings was used to recommend a new lighting scheme with both fluorescent and LEDs. The illumination level obtained were compared with the standard target illumination 300lx inside a classroom as per the Bhutan Standards Bureau [12]. Afterward, daylight was integrated with artificial lighting for providing energy-efficient lighting and analyze the energy-saving potential [13][14].

2.3. Pilot Project

To validate the results and findings obtained from the simulation for artificial lighting using Relux, a pilot project in classroom 1 of DEE was carried out. Lighting simulation depends on the geometry of space, its objects, the materials of existing surfaces, lighting and the objectives to be achieved [7]. It includes a detailed simulation of existing and suggested luminaires taking into account all the room's dimensions and luminaire parameters. The suggested one was implemented in classroom 1 utilizing the materials available in the maintenance sector of DEE. The results obtained from the simulation were then verified using a lux meter (a lux meter is measuring equipment that measures the lumen per square meter). The figure below shows the arrangement of the existing 40W fluorescent lamp and the suggested 36W fluorescent lamp in classroom 1.



(a) Existing scheme

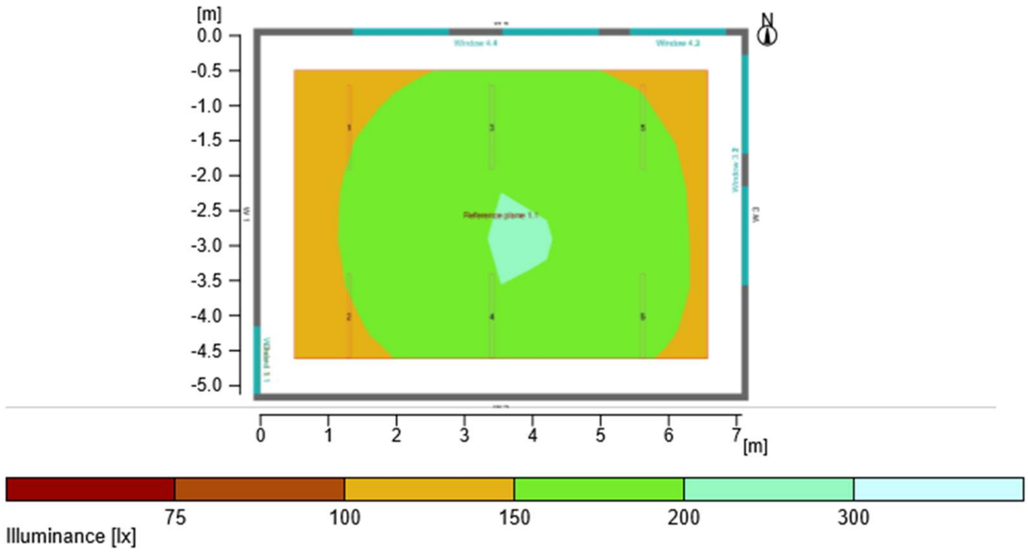


(b) Suggested scheme

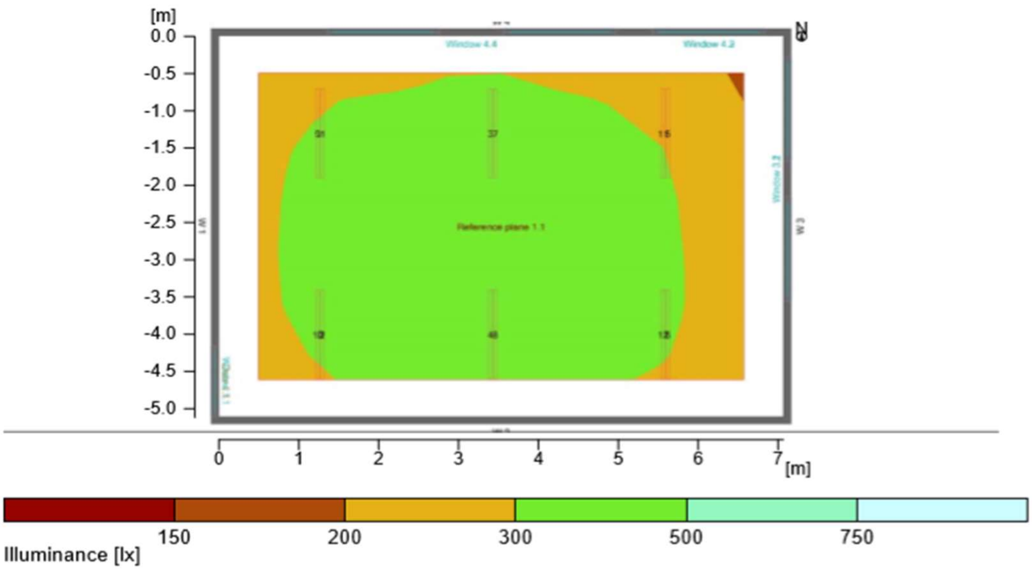
Fig. 1. Arrangement of luminaires in classroom 1

During simulation with existing luminaires, the lx level obtained were not efficient. EasyLux tool in RELUX was then used to design an energy efficient room. The illumination levels and power consumed by the lighting fixtures are analyzed for both the cases, which is sufficient to justify the saving in energy consumption.

The figure below shows the illuminance distribution on the working/reference plane in the class after taking into consideration the reflectance of all the room materials and maintenance factor of the luminaire.



(a) Existing scheme



(b) Suggested scheme

Fig. 2. Obtained illuminance level in classroom 1

The average illuminance required in the classroom for the visual task is 300 lx as per the BSB. The above figure (a) clearly shows that the average illuminance of the existing lighting scheme of classroom 1 is 161lx which does not meet the required illumination level. The reasons for poor illumination are improper lighting arrangement, lack of maintenance and depreciation of the luminaire.

An improved lighting layout was proposed and analyzed using the Relux software, that achieved appropriate illuminance levels and uniformity throughout the space. This was achieved by using an appropriate fixture layout and spacing in conjunction with improved distribution characteristics from the fixtures.

TABLE 4. Luminaires employed for simulation

SL.No	Luminaire	Wattage	Lumen
1	Fluorescent TL	40W	2600lm
2	Fluorescent TL	36W	2500lm
3	LED TL	16.4W	2300lm

III. RESULT

3.1. Illumination Analysis

The illuminance of existing luminaires is below 200 lx for classroom 1 in DEE as shown in figure 2. Thus, existing luminaires alone cannot provide necessary interior illuminance. This is since the existing luminaires are old lamps, mostly covered with dust which in turn reduces their lumen rendering per wattage. Similarly, the existing lighting scheme of other working areas in DEE, administration building and library & IT building does not meet the required illuminance. Therefore, a simulation involving the integration of existing artificial luminaires with daylight was carried out to examine the illuminance level.

Since the existing luminaires cannot meet the required illumination level, the same existing luminaires were used with increased numbers and different orientations until the required illumination level was met. This scheme was then integrated with daylight to determine the energy-saving potential.

Furthermore, to have an energy-efficient lighting scheme, LED is suggested. Though the initial cost of an LED luminaire is very high, it has a longer life span of 50,000 hours compared to a fluorescent luminaire of 20,000 hours of life span [15].

3.2. Lighting Audit

Energy saving is determined through reviewing the existing lighting, by calculating the difference between the installed lumens and the required lumens level [4]. After scheming the required lumen level for the suggested artificial lighting design using the fluorescent lamp and LED, an energy audit was carried out to check the energy-saving potential. In doing so, it was found that LEDs have huge energy-saving potential besides meeting the required lumen.
To further study the energy-saving potential during the daytime, integration of artificial and day light harvesting was simulated.
The graphs below summarize the energy consumption under various schemes in different buildings.

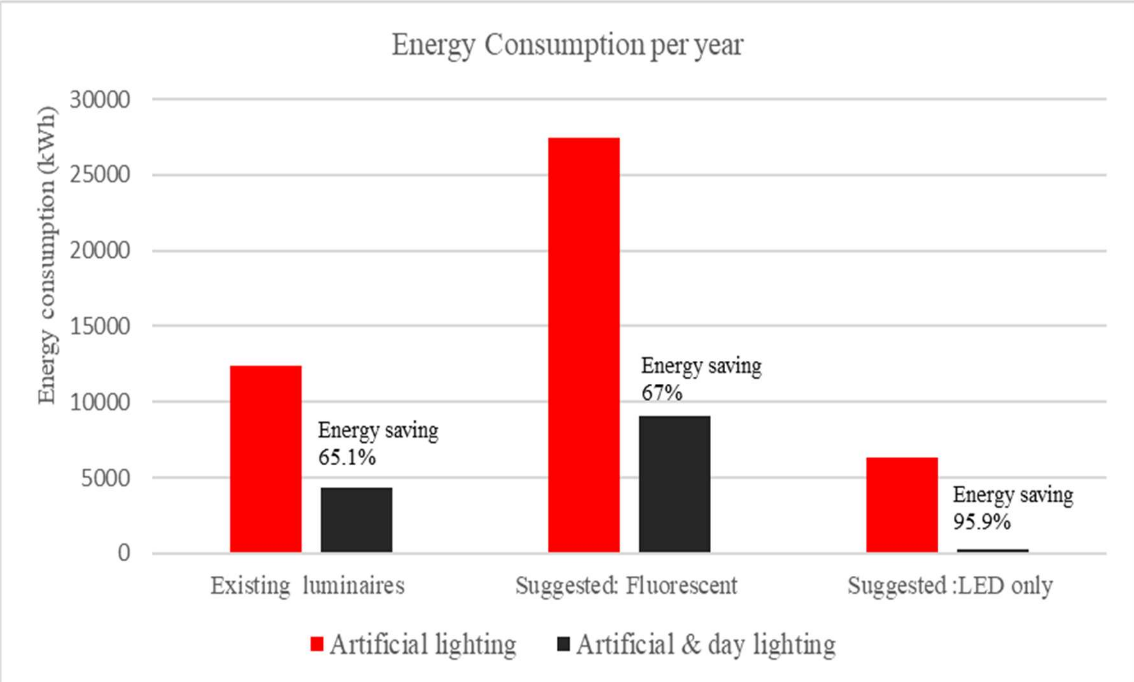


Fig. 3. Energy consumed by luminaires in DEE

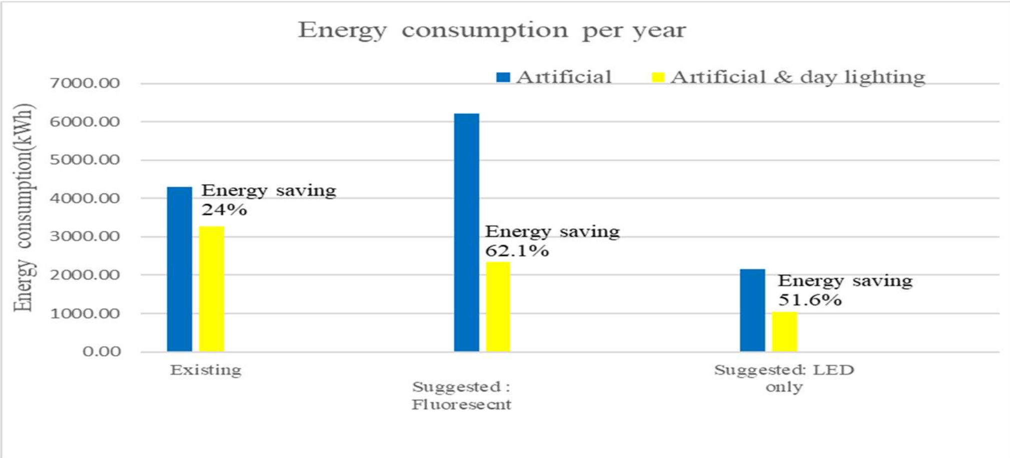


Fig. 4. Energy consumed by luminaires in Administration building

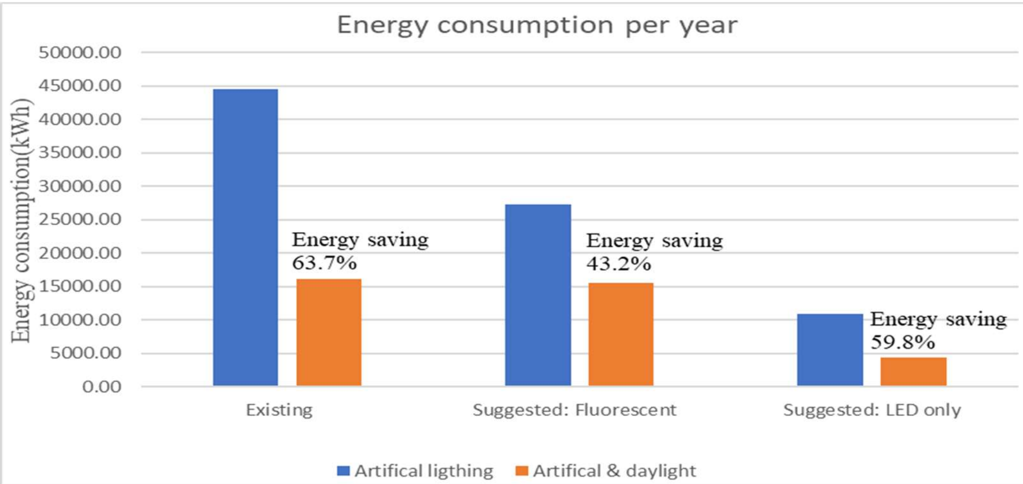


Fig. 5. Energy consumed by luminaires in Library & IT building

The above figures show a comparison between the energy consumed by three different lighting schemes with and without harvesting daylight in DEE, administration block and Library & IT building. A minimum energy saving of 24% on the existing lighting scheme and a maximum of 95.9% on the suggested LED lighting scheme was observed on integrating natural daylight. The least electrical energy consumption was achieved when using LED lamps, maximizing the energy-saving goal.

3.3. Life Cycle Cost Analysis

To evaluate the economic impacts of the suggested LED and Fluorescent lighting, an analysis was done for 25 years. In this analysis, the LED cost was compared with the cost of fluorescent lamps. The total cost of proposed LEDs and fluorescent lamps suggested for three buildings is Nu. 248,140 and Nu. 70,534 respectively.

The life of an LED lamp is 50,000 hours equivalent to 25 years and a fluorescent lamp is 20,000 hours equivalent to 10 years. Considering 8 working hours-a-day excluding all the holidays for both the cases, the life cycle cost of both the proposed lamps i.e., fluorescent lamp and LED was calculated. The comparison was carried out basically to see which suggested lighting scheme would be efficient not only in the field of illumination but also in energy saving. Fluorescent lamps consume significantly more energy than the LED lamps.
As per the classified life of both the lamps, for a life cycle analysis of 25years fluorescent lamps need to be replaced twice. Though LED has a high installation cost compared to a fluorescent lamp, for an educational sector where bulk energy consumption is through lighting, it can be seen that the rate of return is faster.

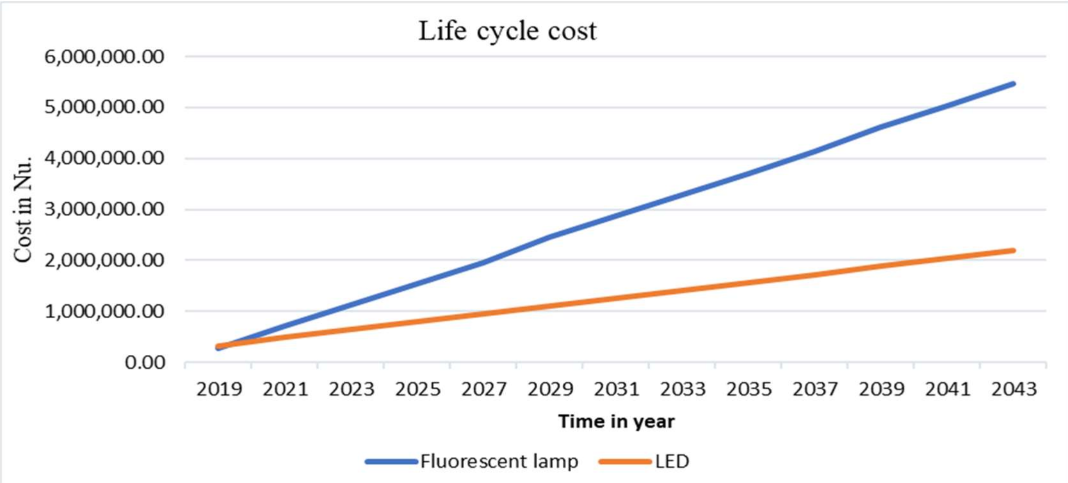


Fig. 6. Life cycle cost analysis

IV. CONCLUSION

The illumination from the existing luminaires in DEE and Administration building does not meet the standard level whereas, for some rooms in IT & library building the illumination exceeds the standard level. Therefore, to meet the required illuminance level and to see the energy-saving scope, the integration of existing artificial luminaires with daylight was simulated in Relux. According to the results obtained from the simulation, the integration of existing luminaires with day light meets the required illumination but, in few cases, it exceeds the requirement. It is seen that the benefit from daylighting can be penalized by glare and over-illumination causes fatigue, headache and eye strain, whereas low illumination makes one's eyes tried easily. So as for artificial light, there is the scope of both dynamic switching and dimming approaches and for daylight integration, proper lighting control is required utilizing appropriate sensors and or scheduling controls that support energy saving as well as occupant comfort.

It is known that during the night the daylight cannot be harvested, thus, considering such a case, a luminaires arrangement that fulfills the required lumen of artificial lighting with different luminaire was used and simulated to do the comparison of the existing fluorescent lamps with the suggested LED. Through life cycle cost analysis, it was found that 59.9% of energy-saving potential was accounted for with a payback period of 2 years when using LED lamps.

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