Improvement energy-efficiency for industrial applications: Analysing the fluorescent and LED illumination

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Abstract— This research paper presents a comparative study on the energy consumption and efficiency of fluorescent and LED lighting in an electronic workshop. The aim is to identify the most energy-efficient lighting solution for optimal energy consumption while ensuring adequate illumination for the workspace. The study involves a comprehensive analysis of both lighting technologies, including their energy consumption, lifespan, color rendering index (CRI), maintenance requirements, and overall cost-effectiveness. The results provide valuable insights into selecting the most suitable lighting option for electronic workshops, thereby promoting sustainable energy practices. Both scenarios have been modelled and simulated by using Dialux and photometric data for the luminaires have been gathered by using simulation software. The LED lighting system consumed approximately 68% less energy than the fluorescent lighting system, resulting in substantial energy savings over the long term.

Keywords: Energy consumption, Comparative study, fluorescent lighting, LED lighting, Energy Efficiency, Electronic workshop.

1 Introduction

The demands for energy-efficient lighting solutions has been growing rapidly in recent years due to the increasing focus on sustainability and cost savings.

The industrial sector is a significant consumer of energy, and with increasing concerns about environmental sustainability and energy costs, the need for energy-efficient lighting solutions in industrial applications becomes crucial. Among the various energy-efficient lighting technologies, fluorescent and light-emitting diode (LED) lighting are two widely adopted options. This research aims to analyse the energy consumption and efficiency of these lighting technologies in electronic workshops are an essential part of various industries, where adequate lighting is crucial for efficient operations and worker productivity. This study aims to compare the energy consumption and efficiency of two commonly used lighting technologies, fluorescent and LED lighting, in an electronic workshop setting. This paper also presents an energy-efficient lighting design using DIALux software for the electronic industry, complying with the lighting standards. Illumination levels achieved and energy consumption are studied to assure the quality of the optimized one-on-one solution.

Section II briefly review about the different light source, different areas and their lighting requirement in industry. Methodology adopted in this paper including DIALux modelling, recommendation for better lighting quality is discussed in section III. Results of the study are discussed in section IV followed by the conclusion in section V.

2 LITERATURE REVIEW

A lighting system's basic function is to provide appropriate light while minimizing energy use. Lighting control strategies like occupancy and daylight adaptation have proven to be effective in reducing energy consumption. Advancements in technology, such as LEDs and smart systems, have enabled lighting controls to become more sophisticated and integrated with other applications. The article discusses different control strategies, emerging smart lighting systems, their role in the building ecosystem, challenges to market adoption, and opportunities for researchers and practitioners [1]. A simulation environment and control strategy for achieving energy-efficient lighting with desired illuminance levels. The strategy utilizes a self-tuning multivariable controller to maintain illuminance at user-defined set-points while reducing energy consumption. The simulation environment employs a layered lighting design to evaluate different control strategies and assess potential energy savings. This approach is unique and has not been explored in prior literature, making it relevant for energy-aware automated lighting systems. The paper includes a case study of an open-plan office space with variable natural light through windows and individually addressable LED luminaires [2]. Comparing different lighting technologies to improve energy efficiency and reduce electricity consumption in the building. The electricity consumption of lighting plays a crucial role in modern human activities. The illumination industry has made advancements in energy-efficient lighting, increasing lamp lifespan and reducing power usage. The study concludes that LED lighting is more efficient than fluorescent lamps for the building. However, the payback period for fluorescent lighting is better compared to LED lamps. This research provides valuable insights for optimizing energy efficiency in the building's lighting system while considering cost-effectiveness [3].

3 METHODOLOGY

The research was conducted in an actual electronic workshop, with carefully controlled variables to ensure accurate comparisons between fluorescent and LED lighting systems. The parameters studied includes energy consumption for the power usage of both lighting technologies was measured under various operational conditions. Lifespan is the longevity of each lighting system was evaluated based on manufacturer specifications and real-time observations. Color rendering index (CRI) values were measured to assess how accurately each lighting technology renders colors, which is essential in electronic assembly and repair tasks. Maintenance requirement to the frequency and complexity of maintenance tasks for each lighting system were recorded and Cost-effectiveness of the initial installation costs, energy expenses, and maintenance costs were considered to evaluate the overall economic viability of both options.

This experimental Setup A controlled experiment was conducted in a representative electronic workshop to evaluate the performance of fluorescent TL5 and LED lighting. Both lighting systems were installed in separated of the workshop, with identical layout and fixtures. The Electronic workshop model recommended lux values according to European Standard (EN 12464-1). To achieve target lux value after that calculating various parameter, such as energy consumption, luminous intensity, energy saving by LED lights, Luminaire Luminous efficiency, and CRI, were measured and compared. Table 1 and Figures (Fig 1 and 2) shows the location and parameters and 3D-2D view of an Electronic Workshop model.

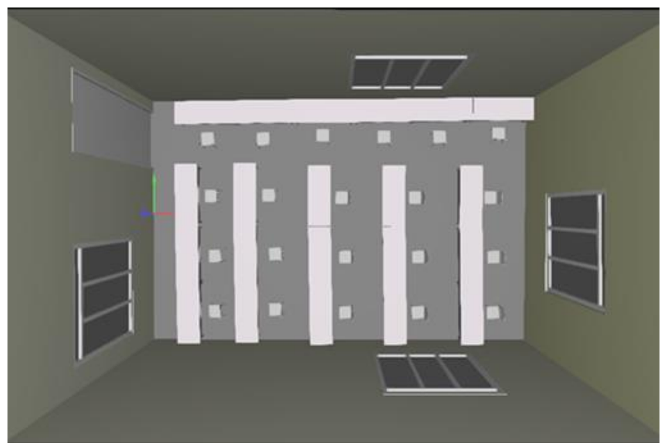

Fig1. 3D Top view of Electronic Workshop in DIALux

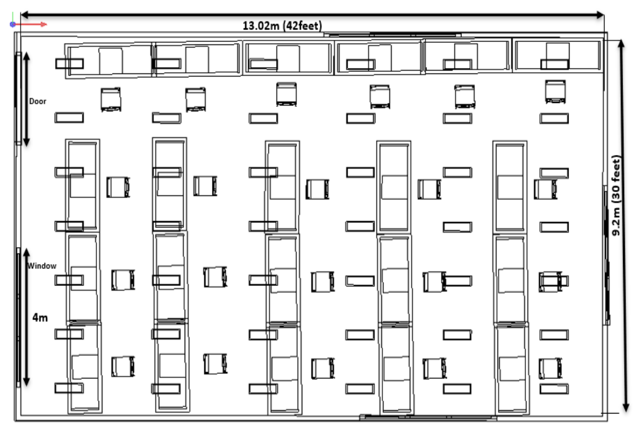

Fig2. 2D representation of an Electronic Workshop in DIALux

The following figure shows (Fig3 and 4) A polar diagram and photometric data are two critical pieces of information when evaluating the performance of lighting fixtures, including fluorescent and LED fixtures. A polar diagram, as an intensity distribution diagram or light distribution curve, provides a visual representation of how light is distributed in all directions from a lighting fixture. It helps users understand where the light is concentrated and how it spreads out.

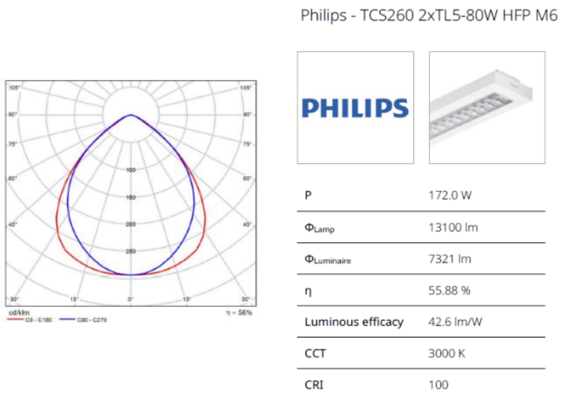

Fig3. Polar diagram and photometric data for Fluorescent Fixture

Parameters	Values
Longitude	73.85o
Latitude	18.50o
North alignment	360o
Electronic Workshop dimension in meters	13.0×8.3×9.3 (L×W×H)
Window dimension	2m × 3m × 4m (4W)
Target Value	1000 lux
Reflection factor	Celling=70%, Wall=50%, Floor= 20%
Uniformity	0.5
Maintenance Value (MF)	0.8
Area (L×W)	107.9 m2

Table 1. Location and parameters of an Electronic Workshop model.

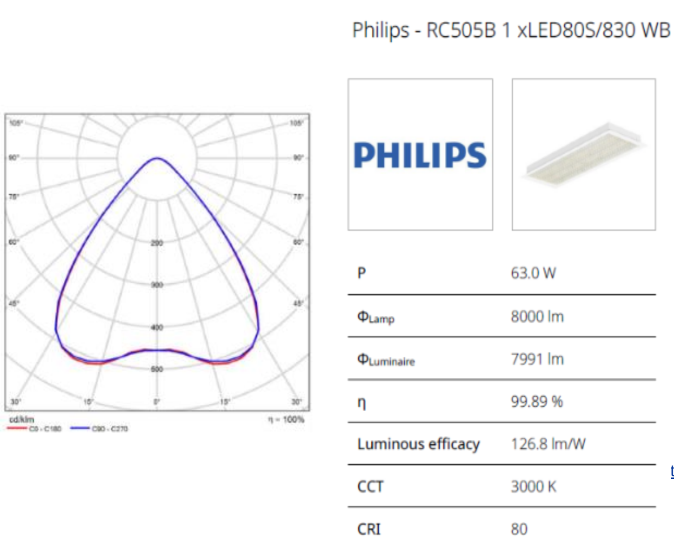

Fig4. Polar diagram and photometric data for LED Fixture

The Photometric data provides detailed information about the characteristics of light emitted by a fixture. This data is crucial for understanding how a fixture performs in different applications. The key parameters found in photometric data include Luminous Flux, Candela Distribution, CRI, Color Temperature and beam angle.

4 RESULTS AND ANALYSIS

The energy consumption of the fluorescent lighting system was found to be significantly higher compared to the LED lighting system.

Parameters	Fluorescent	LED
Light output ratio (%)	55.88	99.89
Connected load (W)	172.0	63
Color Rendering Index (CRI)	100	80
No of Luminaire required	48	42
Average illuminance (Lux)	1053	1045
Luminaire Luminous efficiency (lm/W)	42.6	126.8

Table 2. Analysis of Fluorescent and LED lights

Parameters / Luminaries	TL5 lights	LED lights	Total energy saved by LED lights
Total energy consumption for 24 hrs or per day (kWhr)	192.14	63.50	134
Total energy consumption for 365 days or Per Year (kWhr)	72,322	23,17	49,143

Table 3. The energy consumption of the fluorescent and LED lights.

The energy consumption of the fluorescent and LED lighting results calculated from software values and total energy saved by using LED lights are shown in Table 3 and Fig3. The comparison of the energy consumption of the fluorescent and LED lighting indicates that the results of the DIALux software.

The following figures (Fig4 and 5) show the DIALux results for graphical output of the calculated illumination by lighting design software using fluorescent luminaires and LED luminaires.

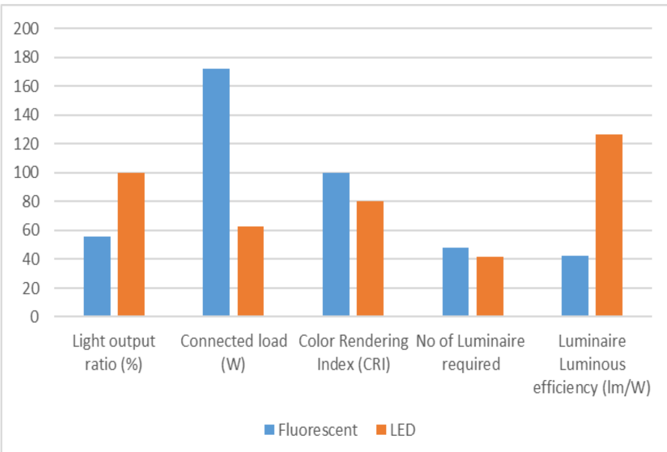

Fig4. Comparison of lighting parameters of fluorescent and LED light

The results show an improvement in the LED luminaires lighting and in the visual task areas. The figures (Fig6,7, 8, 9) show the 3D color rending and False color rending for Fluorescent and LED Fixtures respectively.

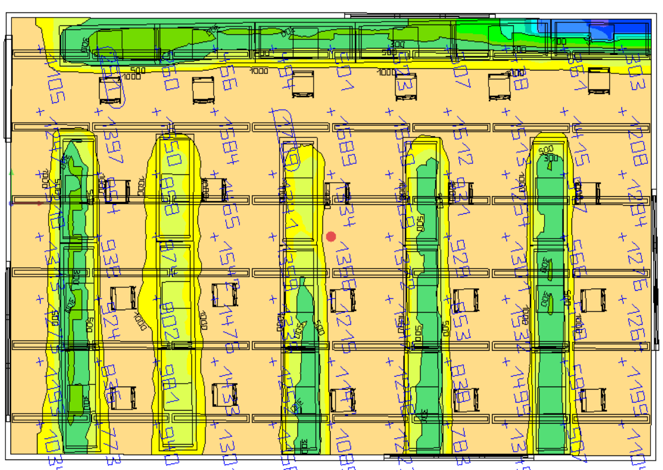

Fig4. DIALux results for Fluorescent Fixture

The LED lighting system consumed approximately 68% less energy than the fluorescent lighting system, resulting in substantial energy savings over the long term. Luminous Efficiency LED lighting demonstrated higher luminous efficiency compared to fluorescent lighting. LEDs convert a larger percentage of energy into visible light, providing brighter illumination while consuming less power.

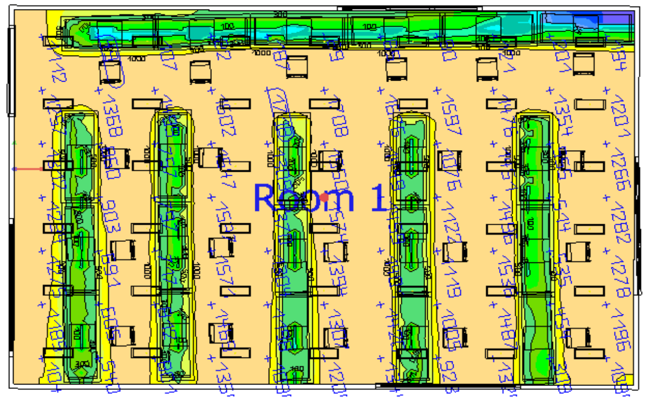

Fig5. DIALux results for LED Fixture

False color rendering refers to a method used to represent the distribution and intensity of light in a visual display. It involves assigning artificial colors to different light intensities or wavelengths to make variations more discernible to the human eye.

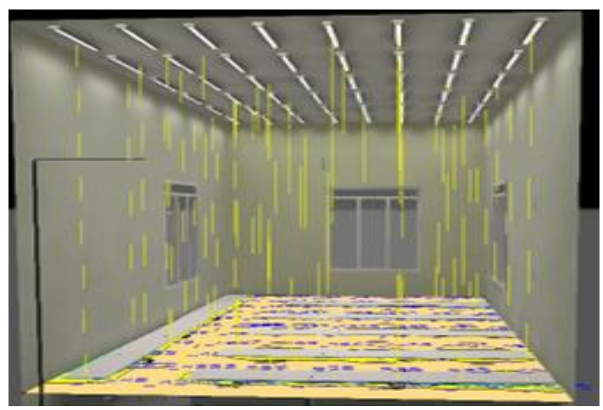

Fig6. 3D color rending for Fluorescent Fixture

In interior lighting design, false color rendering can be used to simulate how different light sources will illuminate a space. This helps designers make informed decisions about the placement and type of lighting fixtures to achieve the desired functionality.

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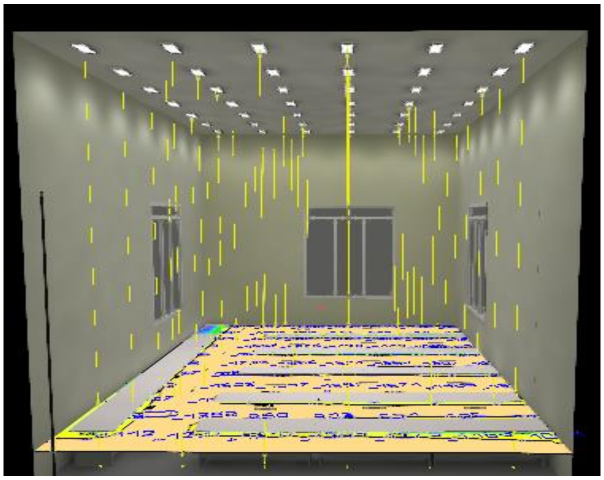

Fig7. 3D color rending for LED Fixture

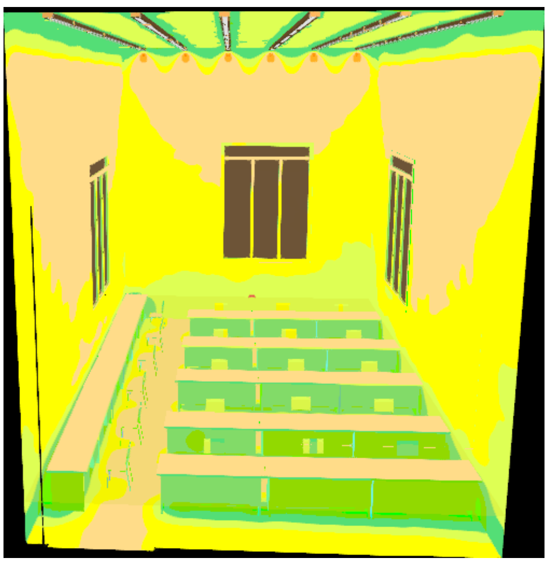

Fig8. False color rending for Fluorescent Fixture

Color Rendering Index (CRI) LED lighting exhibited superior color rendering capabilities compared to fluorescent lighting. The higher CRI of LEDs ensured accurate color representation, which is crucial in an electronic workshop where accurate color differentiation is necessary.

Lifespan and Maintenance LED lighting outperformed fluorescent lighting in terms of lifespan and maintenance requirements. LEDs have a significantly longer lifespan, reducing the frequency of replacement and associated maintenance costs.

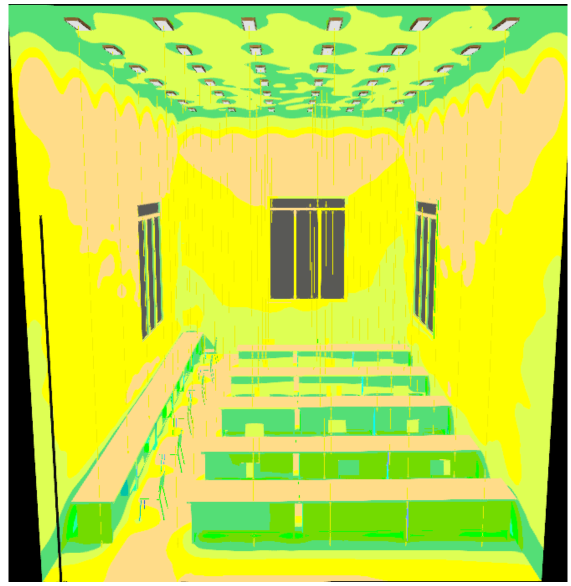

Fig9. False color rending for LED Fixture

5 Conclusion and Discussion

Based on the results obtained, it is evident that LED lighting offers substantial advantages over fluorescent lighting in terms of energy consumption, luminous efficiency, color rendering, and maintenance. LED lighting systems provide higher energy savings, improved lighting quality, and longer lifespan, making them the optimal choice for electronic workshops aiming to optimize energy consumption.

This research paper provides a comprehensive comparative analysis of fluorescent and LED lighting systems in an electronic workshop. The LED lighting system consumed approximately 68% less energy than the fluorescent lighting system. The study highlights the superior energy efficiency, luminous efficiency, and longer lifespan of LED lighting. By adopting LED lighting, electronic workshops can significantly reduce energy consumption, minimize maintenance costs, and enhance overall productivity. The findings of this study contribute to sustainable energy practices and encourage the adoption of energy-efficient lighting solutions in similar work environments.

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