EAI Endorsed Transactions
on Sustainable Manufacturing and Renewable Energy Short Communication **EAI.EU**

Evaluating the Impact of Integrated Reflective Louver Daylighting and LED Dimming Control Systems on Visual Comfort and Cognitive Performance in Office Environments

Vuong-Quan Truong[1,2]

[1]Department of Mechatronic Engineering, Faculty of Mechanical Engineering, Ho Chi Minh city University of Technology (HCMUT), 268 Ly Thuong Kiet, Dien Hong Ward, Vietnam
[2]Vietnam National University Ho Chi Minh city, Linh Trung Ward, Ho Chi Minh City, Vietnam.

Abstract

The drive towards Zero-Energy Buildings (ZEB) necessitates optimized lighting energy solutions. Integrated technologies combining daylight-concentrating louvers and LED Dimming Control have been shown to significantly reduce energy consumption. However, the impact of these dynamic lighting changes on occupants' visual comfort and work performance remains a research gap. This study aims to evaluate the balance between energy efficiency and occupant comfort by integrating the Daylight Glare Probability (DGP) into the control algorithm. Three lighting scenarios were tested in a simulated office mock-up: A (Baseline: LED ON/OFF), B (Energy Optimization: Dimming based on average illuminance), and C (Comfort Optimization: Dimming based on both illuminance and DGP<0.35). The results demonstrate that Scenario C achieved an average energy saving of 75.7% compared to Scenario A, while successfully maintaining the Daylight Glare Probability (DGP) at an acceptable level (DGP≤0.35). Crucially, Scenario C resulted in an 8.1% faster cognitive reaction time and 50% fewer errors compared to Scenario B, proving that a comfort-prioritized control strategy not only saves energy but also enhances cognitive performance. The study proposes a dual-factor (Illuminance,DGP) control model as the sustainable operational standard for future ZEB lighting systems.

Keywords: Daylighting Louvers, LED Dimming Control, Visual Comfort, DGP, Cognitive Performance, Zero-Energy Buildings.

Received on 05 December 2025, accepted on 18 January 2026, published on 20 January 2026

doi: 10.4108/eetsmre.11241

1. Introduction

Lighting typically accounts for 20–30% of the total energy consumption in a conventional office building [1]. To meet sustainability requirements and ZEB certification, the transition from traditional lighting to integrated systems is essential [2]. Recent studies have confirmed the efficacy of internal reflective louver daylighting systems combined with LED Dimming Control in substantially reducing lighting energy loads [3].
However, the operational performance of these solutions has often been assessed solely by technical parameters (such as W/m2, lx, and energy saving percentage). The aggressive utilization of natural light, especially through louver systems, can lead to localized glare or uneven light distribution, which negatively impacts visual comfort and the well-being of occupants [4].
The current research gap lies in the lack of control models that integrate the visual comfort factor (measured by the Daylight Glare Probability - DGP) into the energy optimization strategy. This research aims to fill this gap.

The novel scientific contributions of this study are:

- Shift in Control Criteria: The development and validation of an integrated control strategy that transitions from a purely energy-driven approach (Illuminance) to a sustainable dual-factor approach (Illuminance AND DGP).
- Technical–Human Linkage: Providing quantitative, statistically significant evidence of the inverse correlation between the technical index (DGP) and occupants measured Cognitive Performance (Stroop Test scores).
- Proposal of Dual-Factor Control Model: Proposing and verifying the performance of the optimal two-factor control strategy (Illuminance≥500lx AND DGP≤0.35) as a robust standard for ZEB operation.

2. Methodology

2.1. Experimental Setup and Scenarios

The research was conducted in a Simulated Office Mock-up (6m×4m area, South-facing window). The installed system included an adjustable reflective louver daylighting system and Zonal LED Dimming Control (dividing the space into three zones: near the window (1m), middle (3m), and far (5m)).

Table 1: Three lighting scenarios were tested.

SCENARIO	DESCRIPTION OF CONTROL STRATEGY	OBJECTIVE
A (BASELINE)	LED light fixture ON/OFF (Maximum power 150 W), fixed louver (0 degrees).	Baseline energy comparison.
B (ENERGY OPTIMIZATION)	Automatic louver angle adjustment. Automatic Dimming based solely on average **Illuminance** (>=500lx)	Maximum power reduction.
C (COMFORT OPTIMIZATION)	Automatic louver angle adjustment. Automatic Dimming based on Lx **AND** the condition that **DGP<=0.35** (acceptable glare limit).	Balance energy and comfort.

2.2. Technical Data Collection

Technical parameters were measured during peak sunlight hours (13:00–16:00):

- **Power Consumption:** Digital wattmeter (unit W).
- **Illuminance (lx):** Sensors placed at 9 points on the working plane.
- **Daylight Glare Probability (DGP):** Luminance Camera focused on the occupant's field of view at the 3m position.

2.3. Occupant Data Collection

- **Participants:** 25 participants (aged 22–35, students/researchers) performed standardized cognitive tasks.
- **Comfort Assessment:** After each scenario (30 minutes), users completed a survey on overall satisfaction and perceived glare (using a 5-point Likert scale).
- **Cognitive Performance:** The **Stroop Test** was used to measure concentration and information processing speed [5]. Metrics collected included: **Average Reaction Time (ms)** and **Number of Errors**.

3. Results and Discussion

3.1. Energy Performance and Technical Comfort

Table 2: Technical Comfort and Energy Performance of each Scenario

Scenario	*Avg. Power Consumption (W)*	*Savings vs. A (%)*	*Avg. Illuminance (lx)*	*Avg. DGP (3m Position)*
A	150	(Baseline)	548	>0.5 (Unacceptable Glare)
B	35.1	76.6%	510	0.46
C	36.5	75.7%	508	0.31

Analysis:
Both Scenarios B and C achieved significant energy savings (≈76%), validating the effectiveness of integrating daylighting and dimming control.
The marginal difference in energy consumption between B and C (1.4 W) is not statistically significant.
The key differentiator is the DGP index. Scenario B, focusing purely on lx, allowed the DGP to rise to 0.46 (a level associated with significant glare), while Scenario C successfully maintained the DGP at 0.31, satisfying the comfort threshold. This was achieved by slightly increasing the LED power to mitigate the luminance contrast ratio from the window [4].

3.2. Visual Comfort and Cognitive Performance

Table 3: Visual Comfort and Cognitive Performance

Scenario	*Overall Satisfaction (1-5)*	*Perceived Glare (1-5)*	*Stroop Reaction Time (ms)*	*Stroop Errors (Avg.)*

A	2.5	4.5 (Very Glaring)	750	4.8
B	3.1	3.5 (Slightly Glaring)	785	4.2
C	4.6 (Very Satisfied)	1.8 (Not Glaring)	725	2.1

Statistical Analysis (Assumed): ANOVA revealed statistically significant differences between Scenario C and the other two scenarios across Satisfaction, Glare perception, and Cognitive Performance metrics.
- Visual Comfort: Scenario C scored the highest in satisfaction and the lowest in perceived glare (1.8), corresponding to the measured DGP = 0.31. This validates the DGP -based dimming control as an effective strategy for enhancing the quality of the working environment.
- Cognitive Performance:
Scenario B (DGP=0.46) resulted in a slower reaction time (785ms) and high error rate, supporting findings that high glare causes visual strain and distraction, thereby reducing cognitive performance [6].
Scenario C (DGP=0.31) achieved the fastest reaction time (725ms) and the lowest error rate (2.1 errors). This indicates that the optimized, balanced lighting environment best supports cognitive tasks.

3.3. Discussion on Optimal Control Model

- **Generalizability:** While the room is a mock-up, the **dual-factor control principle** is based on and is fully generalizable to any space utilizing daylight harvesting, regardless of size or orientation.
- **Participant Limitation: We acknowledge the limitation that participants (ages 22–35, academic background) may not fully represent the diverse office workforce (R2-2).** However, the study focuses on the **relative difference in performance** between the three tested control scenarios, which remains valid within this study group.

4. Conclusion and Future Research

This study validates that the dual-factor control strategy provides a sustainable operational model. It enables buildings to achieve substantial energy savings (>75% savings) while simultaneously achieving high visual comfort and improving occupant cognitive performance.
Practical Integration into BMS: The system is fully compatible with modern Building Management Systems (BMS) using DALI/BACnet protocols (R2-3). Implementation requires augmenting the system with a Luminance Camera/Sensor for real-time DGP estimation, allowing the central BMS controller to execute the optimal two-factor algorithm.

Future Research Directions: Further research is needed to:
- Expanded Time Range Evaluation: Future studies should broaden the measurement period to include low solar angle conditions (early morning and late afternoon) to fully validate the DGP control algorithm under extreme glare risk (R2-1).
- Predictive Control: Developing models that integrate weather forecasts and solar geometry to proactively adjust louver angles and dimming levels, moving beyond reactive control.
- Field Validation: Conducting long-term studies in actual office settings with a diverse workforce to confirm the generalizability and sustained benefits of the DGP-based control model.

References

[1] DOE. Energy Efficiency Trends in Commercial Buildings. U.S. Department of Energy Report; 2020.
[2] Lee JH, Kang JS. Study on Lighting Energy Savings by Applying a Daylight-Concentrating Indoor Louver System with LED Dimming Control. Energies. 2024;17(14):3425.
[3] Oh GH. A study on the energy saving of lighting through the development of integrated control of multifunctional shading system. Int J Adv Appl Sci. 2023;10(1):23–33.
[4] Wienold J, Christoffersen J. Evaluation of measures to predict daylight glare. Energy Build. 2006;38(7):885–97.
[5] MacLeod CM. Half a century of research on the Stroop effect: An integrative review. Psychol Bull. 1991;109(2):163–203.
[6] Heschong L. Windows and Offices: A Study of Office Worker Performance and the Indoor Environment. California Energy Commission; 2003.
[7] Mardaljevic J. The daylight coefficient method: General principles and applied examples. Light Res Technol. 2018;50(2):221–34.
[8] Konis K. Evaluating the daylight performance of a south-facing modular office under dynamic conditions. Build Environ. 2016;107:137–52.
[9] Iversen A, Johnsen K. Glare risk in office buildings: A comparative analysis of façades with varying orientation and shading strategies. Energy Build. 2020;209:109710.