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# Impact of window to walls ratios on thermal comfort and energy consumption in tropical zone

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## Abstract

**This paper investigated the impact of Window to Wall Ratios (WWR) an the thermal comfort and energy lighting demand of a building in tropical zone. Simulations were carried out for a reference office proposed by Task 27 of IEA using three Window to Wall Ratios (WWR). Results were analyzed both in terms of operative temperature and energy lighting consumption. Simulations results showed that for increasing WWR, the operative temperature increases and energy lighting demand decreases.**

***Keywords:*** *Window to Wall Ratios, Thermal comfort, energy lighting demand, Tropical zone*

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## 1. Introduction

Energy production and its use account for about two-thirds of greenhouse gas (GHG) emissions. The energy sector must be at the center of priorities to fight climate change [1]. Limiting the consumption of fossil fuels is considered as the best solution to address the issue of increasing the concentration of carbon dioxide (CO2) in the atmosphere.

Buildings account for more than 40% of worldwide energy use and contribute for more than 30% of greenhouse gas emissions [2]. This sector offers significant potential for energy savings and mitigation of greenhouse gas emissions. The building sector can play an important role in achieving the COP 21 target of limiting global warming to 2 ° C below pre-industrial levels by the end of this century.

The majority of energy consumption in buildings is used to provide thermal and visual comfort, air conditioning systems (30-60%) and artificial lighting (20-35%) [3].

The daylight received by the windows of a building can contribute to the reduction of the lighting energy demand by reducing the number of hours that the artificial lighting *is* used [4]. In addition, it is considered a strategy

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to improve human performance (psychological well-being, productivity at work, etc.) without cost or expensive installation [5]. Several authors have analyzed the effect of construction parameters on lighting energy consumption. Fasi et al. [6] studied the impact of the type of glazing on the energy performance of a building. Several authors have shown that the increase in window opening size leads to a reduction of the lighting energy consumption. Ignacio Acosta analyzed the effect of the shape and position of window openings and the reflectance of interior surfaces on the lighting energy consumption. Hoa et al. [7] have shown that the use of shading reduce indoor natural lighting, which can lead to an increase in lighting energy consumption. Daylight has many advantages for the building. However, the excessive penetration of daylight contributes negatively to the energy consumption [8].

In a hot climate, air conditioning accounts for the largest share of energy consumption in office buildings. The internal heat gain and the heat gain through the building envelope are the main contributors to the air conditioning load. The heat gain through the windows due to incident solar radiation represents in particular an important component of this air conditioning load, and therefore a major contributor to energy consumption. Incidental solar radiation can also cause visual discomfort, which can lead to an increase in energy consumption when occupants decide to intervene to improve their comfort [9].

The literature review shows that in the design phase of buildings in a hot climate, contradictions may arise when attempting to increase interior natural lighting. Indeed, a large window opening reduces lighting energy consumption but increases the energy consumption of air conditioning. The study of the optimal window opening size and its impact on the energy performance and quality of lighting in the building has been led by many researchers. Chirarattananon et al. [10] determined the optimal window opening size that leads to minimal energy consumption in the tropics. The authors have shown the influence of the type of glazing on the optimal opening size. Mangkuto et al. [11] studied the influence of several variables: window opening size, reflectance factor of the wall and orientation of the window openings on the level of illumination, uniformity of the lighting, visual comfort and demand lighting energy in buildings in tropical climate. A multi-objective optimization approach was used to find the optimal combination of variables. Kazanasmaz et al. [12] studied the optimal size of window opening that leads to maximum daylighting. The presence of a film on the glazing was taken into account.

In all these studies, the authors do not take into account the thermal comfort of the occupants. The objective of this study is to determine the impact of daylight in the building on thermal comfort and energy consumption for lighting in tropical areas.

## 2. Building and simulation

In this study, the reference office proposed by Task 27 of the IEA (International Energy Agency) [13] is considered. The office perimeter space are (5.4 m x l3.5 m x 2.7 m high). The office is located in Dakar (latitude 14.73 °N, longitude -17.26 °W). Design Day file used in our simulation is from EnergyPlus. The summer design day for Dakar is the 21 September.

The ceiling and floor reflectance values are 0.85 and 0.20 respectively. The wall reflectance factor is 0.6. The window a single glazing with a light transmittance of 0.85. The window is square and is located to the south. No shading, furniture and other accessories are present in the office. Three Window to Wall Ratios (WWR) are studied: 10%, 20%, and 30%. The objective of our simulation is to determine the impact of WWR on thermal comfort and energy consumption. Indeed, lighting energy demand and operating temperature were determined. The operating temperature is a summer comfort index and is fixed at 26 ° C.

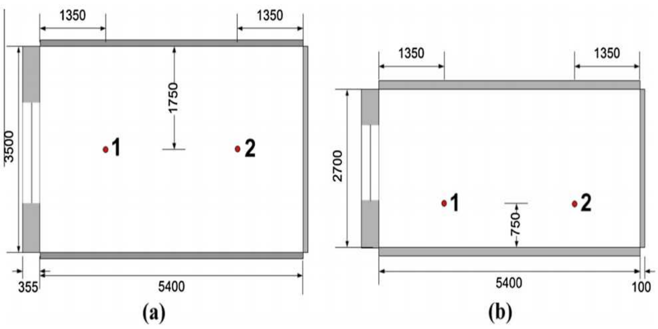


**Figure 1.** Representation of the office on two dimensions.

## 3. Results

Fig. 2. shows the evolution of the operative temperature as a function of time for three WWR: 10%, 20%, and 30%. The operative temperature is less than 26 ° C between 8 am and 12 am. Beyond 12 hours, there is a thermal discomfort in the office. Fig. 2. shows that the operating temperature increases while the WWR increase. This trend is observed throughout the day.

Fig. 3. shows that energy consumption is a function of time for different WWR values. Between 8 am and 9 am, energy consumption decreases to zero for all WWR. Between 9 am and 18 pm, natural lighting is sufficient. So there is no energy consumption for light. From 18 pm, there is an increase in lighting energy demand reach the appropriate value. Fig. 3. shows that energy consumption decreases while the WWR increases.

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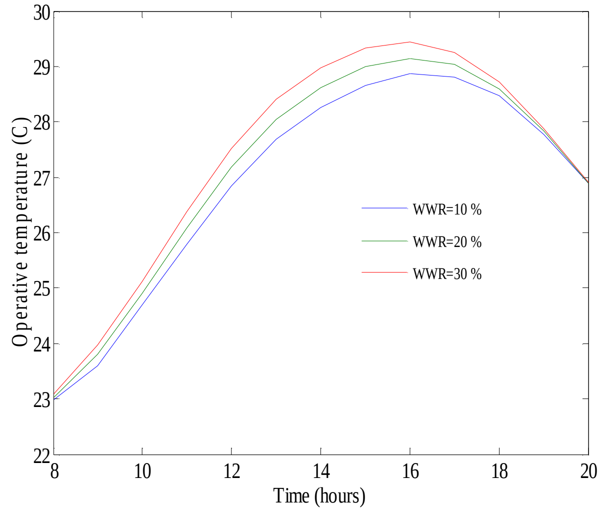


**Figure 2.** . Evolution of operative temperature during a day.

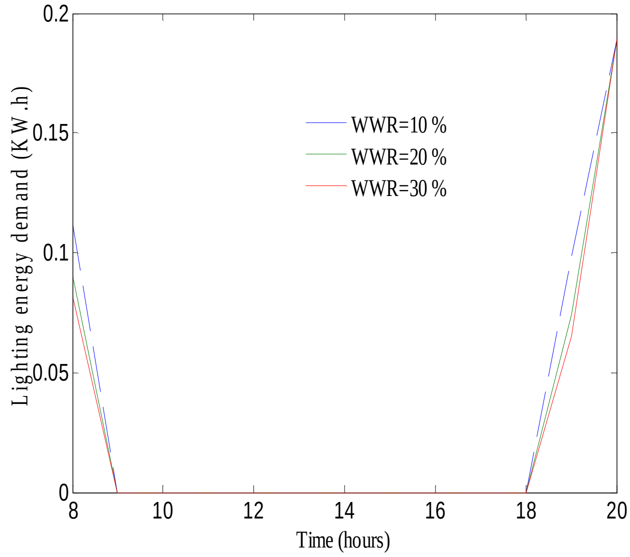


**Figure 3.** Lighting energy demand during a day.

## 4. Conclusion and perspectives

This paper presents a daylighting simulation of a reference office proposed by Task 27 of the IEA. The office has a window located to the south. The objective of this study was to determine the impact of the daylight on thermal comfort and energy consumption of a building in tropical zone. Simulation results show that the operative temperature increases while the WWR increases. The energy lighting demand decreases while the WWR increases. The results show also that between 9 am to 18 pm, the WWR do not impact the lighting energy demand.

Our simulation show that, in tropical zone, the increase of daylighting in buildings decreases the energy lighting demand but increases the thermal discomfort.
As a perspective, we plan to do a multi-objective optimization to find the optimal WWR of a building in tropical zone.

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