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ARTICLE

Evaluation of Daylight Parameters on the Basis Simulation Model for the Tropical Climate

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ABSTRACT

Use of natural daylight in the building is energy saving with respect to illumination levels and health benefits. However in, the hot and dry climatic zone increase in daylight availability may result into thermal ingress. This might lead to excess energy conservation. The aim of this paper is to evolve the methodology which could be used as a pre design tool for assessing the lighting provisions and thermal performance of spaces within buildings adopted by designers during the design process. The field measurements were conducted on the liveable spaces of a dwelling unit of the Nagpur region. Simulation studies using Ecotect Analysis 2011 was conducted for both illumination and thermal energy. The field measurements were compared with the simulated results. It has been found that the percentage difference (PD) between the Ecotect measurements (EM) and field measurements (FM) for both thermal loads and an illuminance level was less than 15%, the simulated model was considered precise for further study. The result imply that the simulated model would be ample for designers to evaluate the parameters associated to wall to window ratio, shading devices with respect to orientation of the building which helps to achieve the optimum useful daylight index.

1. Introduction

Daylight is a readily available natural resource. It has a very special characteristic of having ability to illuminate the interior spaces and makes them very interesting for occupants. Due to this reason, the Architects and Designers try to make provisions for day light come into the interiors of building whenever it is possible practically. For a building designer it is not an easy task to provide good daylight in architectural spaces. It requires that the illuminance level of the space be kept within the adequate range that does not critically affect occupant's heath. There are many factors affecting the illuminance level in spaces. The main task of building designers is to deal with these factors. The amount of indoor daylight illuminance depends upon the size and position of a window and the sky luminance distributions. Integrating daylight with architectural design is of great interest to those who are with the issues of energy and environment and visual comfort and health [1,2] .

India is one of the developed countries, broadly divided into two area urban area and rural area. In urban area overall, electricity consumption seems to be growing exponentially. Urban and rural homes are distinguished due to their difference in energy requirement. The number of urban and rural households is used as drivers for residential en-

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ergy consumption [3]. The Energy Statistics 2013 of India's National Statistical Organisation (SO) shows electricity accounted for more than 57 per cent of the total energy consumption during 2011-12 in India, and building sector is already consuming close to 40 per cent of the electricity. This is expected to increase to 76 per cent by 2040. A large quantity of incremental electricity demand will come from the residential sector in India [4]. One of the major reasons behind the increased cooling load in new buildings in the subcontinent is the growing use of big windows to the external wall made of glass in buildings. Glass traps heat from the sun and warms up the interiors of the building. Window glazing tends to reduce lighting demand by using daylight. However, along with light, the rate of heat exchange of the building with the outside environment also goes up. Thus, size of window should be optimised on the basis of minimum specific energy demand for both air conditioning and lighting inside a building. In other words, ratio of wall to window in a building should be balanced in a way to improve day lighting without compromising the building's thermal performance. In the tropics, buildings are subject to significant cooling requirements due to the high intensity of solar radiation penetration through fenestration [5,6] .

The aim of this study is to achieve the optimum daylight and indoor temperature by evolving the methodology, which helps to evaluate the daylight parameters related to the windows. This research helps as a "Design Tool" to the Architects and Designer to achieve the optimum daylight and indoor temperature in the interior spaces of residential buildings. The finding of this study is the application of the evolved Methodology in this study.

In this study, Autodesk Ecotect has used for analysis of thermal loads, lighting design, shadows and reflections, shading devices, and solar radiation [6]. Architects with its application in architecture and the design process in mind develop Ecotect. Engineers, local authorities, environmental consultants, building designers, owners, builders, and environmental specialists can also use Ecotect. Ecotect uses the CIBSE Admittance Method to calculate heating and cooling loads and daylight factor method to calculate illuminance levels [7].

2. Case Study Area for Research Work

The rapid growth in the residential sectors and its energy demands in developed cities of India, the typology used for this study was multi storied residential building at Nagpur city (Latitude 21.1 N, Longitude 79.1 E). The annual climate of the city is hot and dry. In Nagpur city, the maximum electricity consumption is from Residential Sector, which consumes about 42.96% of the total electricity consumption in the city. The Sectorial Growth in last 5 years for residential, commercial, industrial sectors is 51.48%, 33.47% and 24.14% respectively and 19.20% for municipal sector for the last four years. Overall, the electricity consumption has increased by 40.17% in 5 years span [8].

Figure 1. Residential development in Nagpur city

Table 1. Electricity consumption in Nagpur city by Residential sector

	Electricity Consumption (MU)					No. of
Year	2003-04	2004-05	2005-06	2006-07	2007-08	Consumers
Residential	362.4	415.2	439.9	481.0	549.0	412253
Commercial	106.6	115.8	120.9	132.2	142.3	55063
Industrial	385.8	479.7	468.8	473.7	479.0	6248
Municipal	-	33.5	63.2	106.0	107.6	-
Total	**855**	**1044**	**1093**	**1193**	**1278**	**473564**

During last five years, the residential and commercial sectors have shown higher growth in electricity consumption as compared to the municipal and industrial sectors.

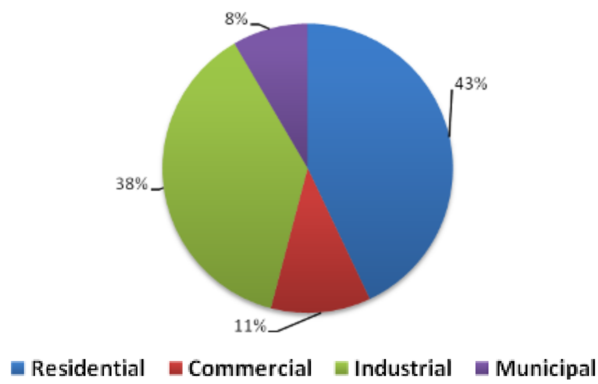

Figure 2. Pattern of electricity consumption in Nagpur city

Therefore, it is essential to reduce the energy consumption of residential sector of city. To overcome these challenges, the architect must use tools that are precise and, at

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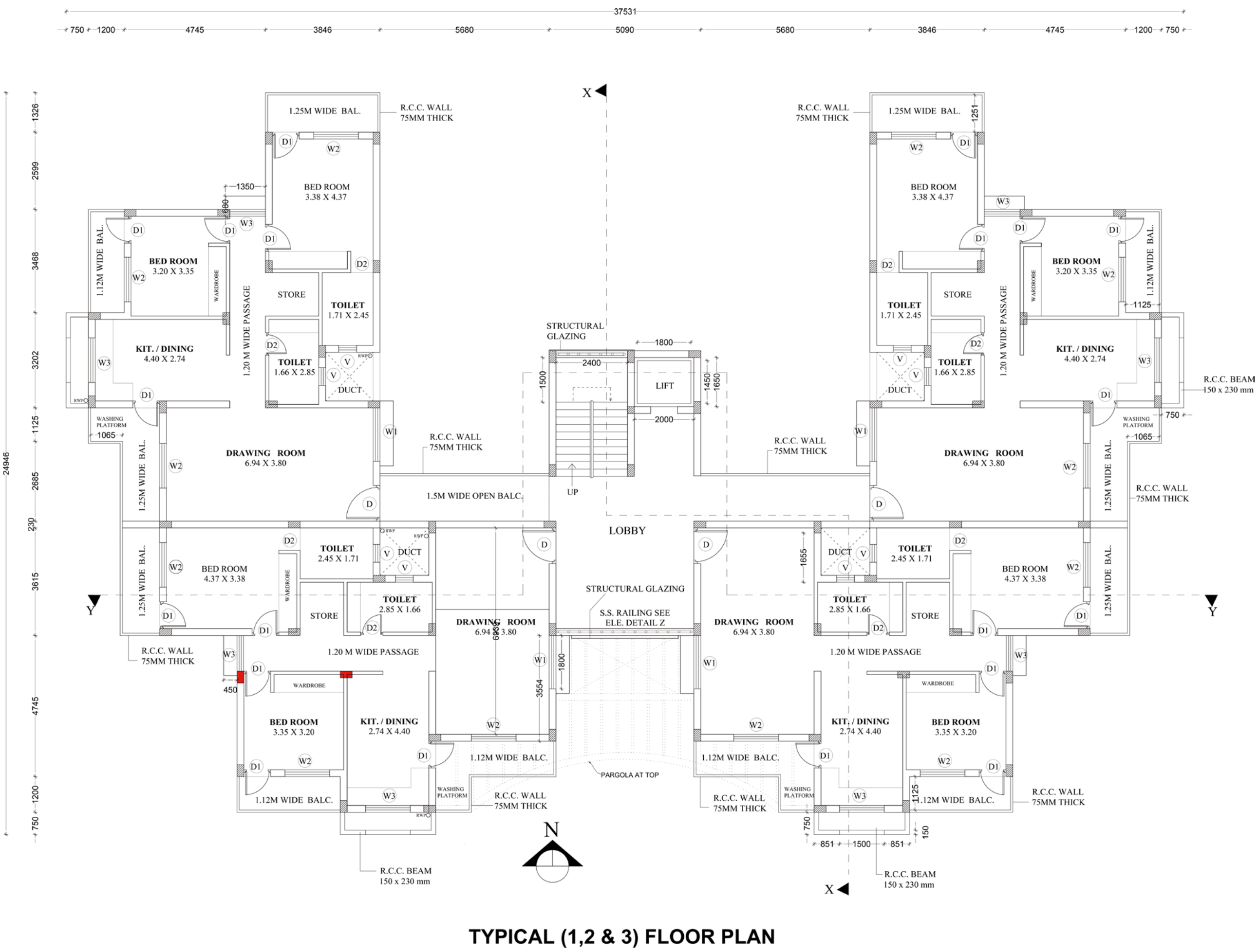

Figure 3. Shows the plan of the selected residential building

the same time, interactive, to evaluate the lighting choices or solutions throughout the architectural design process [6]. Hence, the typology selected for this study was the residential building. The residential building of Associate Professor, which is designed and constructed by Architect Dr. V.S. Adane, is selected, as a case for this research is located in an educational campus of VNIT, Nagpur. The total built up area of residential building is 1652.50 sq m. & built up area of selected dwelling unit is 120.12sq.m. This residential building facilitates common services area, lifts, staircase, and four flats on each floor.

3. Methodological Procedure

To achieve the aim and objectives of this study, the procedure adopted was to compare the values of daylight level generated from simulated results with those of measured values and calibrated the simulated model of Ecotect for evaluating the parameters including wall to window ratio and shading devices with respect to orientation of building for good indoor daylighting environmental performance.

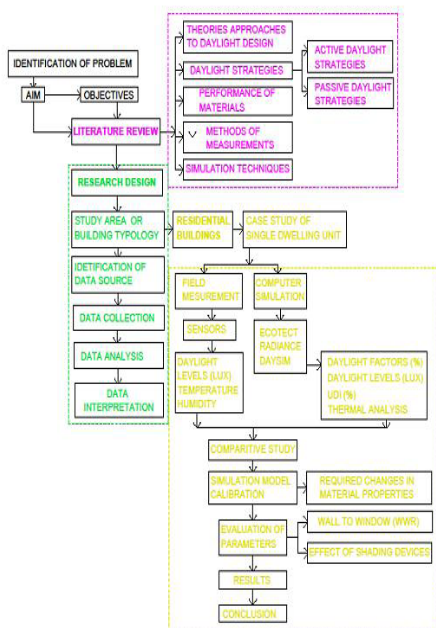

Figure 4. Methodology workflow

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Figure 5. Plan and interior views of selected liveable spaces of dwelling units with sensors position

4. Criterions for Dynamic Simulation Process

Parameters have been considered for the Ecotect programs that allow an optimum accuracy of the results obtained. The criterions were considered for calculation for simulation as per shown below

Table 2. Parameters considered for simulation measurements

INPUT FOR SIMULATION	PARAMETERS
Sky Conditions	CIE Intermediate Sky 8500lx
Type of Calculation	Natural Light Levels
Calculation	Over daylight Analysis Grid
Ray-Tracing	Precision Full
Window cleanliness	Clear x1.00
Calculate Room Averaged	Yes
Window Areas	
Grid Data & Scale	Minimum 0.20
	Maximum 0.40
	Contours 0.15

To obtain the same status of existing day light level into simulation model, it needs to take the same sample of hours and same day, which were taken in field measurement [9]. To get actual and accurate results it is required to enter the accurate materials properties of walls, ceiling, and floor into the simulation model. In this simulation model to identify the internal colours, its reflection and colour rates of wall, ceiling and floor, colour analyser was used. To get the actual and accurate result of simulation model the reflectivity values of Red, Green, and Blue components were modified [10].

5. Calibration method of simulation model

5.1 Analysis of Field Measurements of Living Room

The field measurements of daylight levels obtained in 2014 were used in this study. Thus, the Ecotect simulation measurements of daylight levels were also simulated for the same. The field measurements of the daylight levels of living room show that the highest total daylight level 1219 lux was recorded by sensor (S1)placed near window while the lowest total daylight level 347 lux was recorded by sensor (S3) near wall.

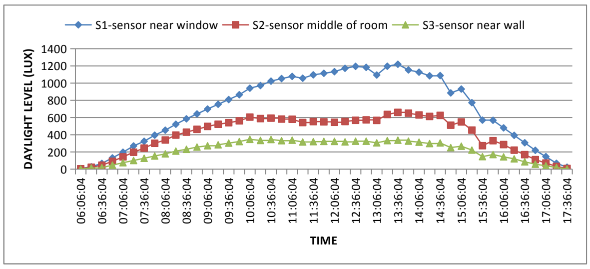


Figure 6. Field measurements of living room

5.2 Analysis of Simulation Measurements of Living Room

The Ecotect simulation measurements of daylight levels were also simulated in 2014. The simulation measurements of the daylight levels of living room show that the highest total daylight level 1117.5 lux was recorded by sensor (SO1) placed near window while the lowest total daylight level 455.32 lux was recorded by sensor (SO3) near wall.

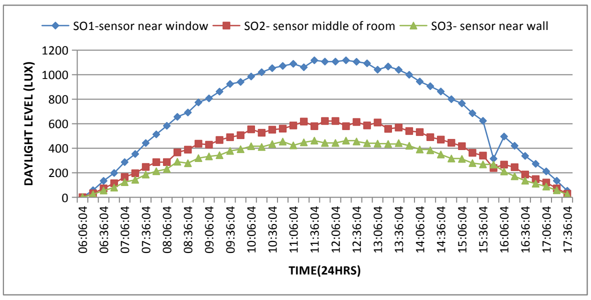


Figure 7. Simulation measurements of living room

5.3 Comparative Analysis of Field Measurements and Simulation Measurements of Living Room

The comparison between the Ecotect simulation measurements and field measurements of daylight level showed the daylight level simulated by Ecotect had frequently lower values than the daylight level obtained by the field measurements.

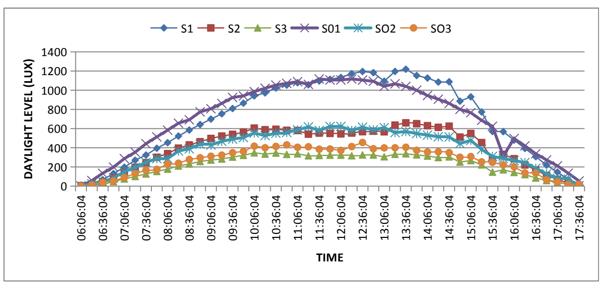


Figure 8. Comparison of simulation measurements and field measurements

5.4 Percentage Difference between the Ecotect Simulation Measurements and Field Measurements

To validate the accuracy of study, the results obtained by Ecotect simulations and by field measurements were compared by analyzing the percentage difference between the measurements. The percentage difference (PD) between the Ecotect simulation measurements (EM) and field measurements (FM) for illuminance levels was calculated by using the equation:

$$PD = ((EM-FM)/FM)/100$$

Based on the literature, the acceptable percentage difference between computer simulation results and field measurements is maximum 15% (Maamari et al. 2006). In this research, the percentage difference was found to be 1-15% which is less than 15%, and thus the simulation model was calibrated and now can be used for further experimentation.

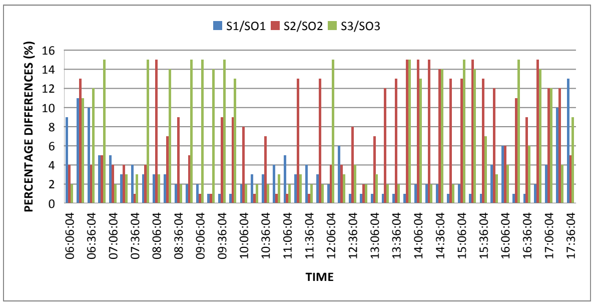


Figure 9. Percentage difference between simulation measurements and field measurements of daylight levels

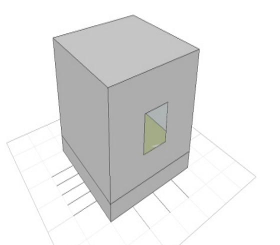
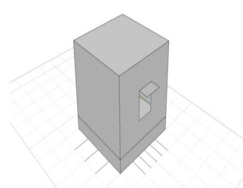
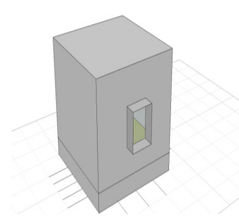
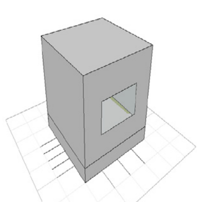
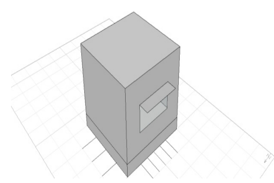
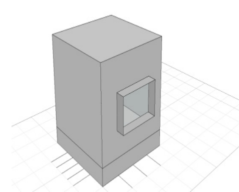
Figure 9 shows the percentage difference between the simulation measurements and field measurements of the daylight level. The percentage difference was less than 15% (acceptable) for all the sensors of living room. For sensor near to window S1/SO1 the largest percentage difference 13% was observed at 17:36:04 while the lowest percentage difference 1% was observed at 06:06:04. For sensor middle of room S2/SO2 the largest percentage difference 15% was observed at 17:36:04 while the lowest percentage difference 1% was observed at 06:06:04. For sensor near to wall S3/SO3 the largest percentage difference 15% was observed at 17:36:04 while the lowest percentage difference 2% was observed at 06:06:04. Therefore, these results show that the simulated model can be considered as an accurate tool for further evaluation study of the parameters.

6. Parameters for Evaluation

Further this research has done the evaluation of parameters to judge the calibrated simulated model of living room was used which helps to predict the optimum daylight level into interior space of room. There were several parameters for evaluation including wall to window ratio, types of shading devices, depth of room from external window wall, types of glazing, sill level of window, head height of window (lintel level), orientation of window/building, internal surface reflection. This study was conducted considering only two parameters wall to window ratio and type of shading device for evaluation of performance of day lighting into interior of building.

Simulation results for different WWRs show that a

Table 3. Configuration of parameters

Wall to Windo Ratio (%)	Window Without Shading Device	Window With 0.60M Projected Shading Device	Window With 0.45M Projected Box Type Shading Device
10			
20			

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comprehensive and integrated analysis of daylight availability, occupant's comfort and energy use may offer new insight into long standing assumptions such as those large WWRs necessarily constitute an environmental liability [11].

This model will be studied over several considerations, as described below:

(1) Direction: North, East, South, West
(2) Wall to window ratio (WWR): 10%, 20%
(3) Size of room:6.97m x3.80m
(4) Height of room: 3.20m
(5) Window sill level: 0.9m (from floor level)
(6) Head height of window: 2.1m(from floor level)
(7) Shading device: Two types of shading devices
(a) 0.6m externally projected
(b) 0.45m projected box type

6.1 Evaluation of Parameters

For this study, parameters were taken with different combination as mentioned in Table-3 for living room space. Living room had two windows one with balcony and second with projected shading device. The selected residential building was facing towards south shown in Figure-1. The simulated model of living room was evaluated under four possible direction i.e. the cardinal directions and for each considered 10 and 20 percent wall to window ratio. The second window evaluate with three conditions of shading devices including ; window without shading device, window with 0.60m externally projected and 0.45m projected box type shading device..

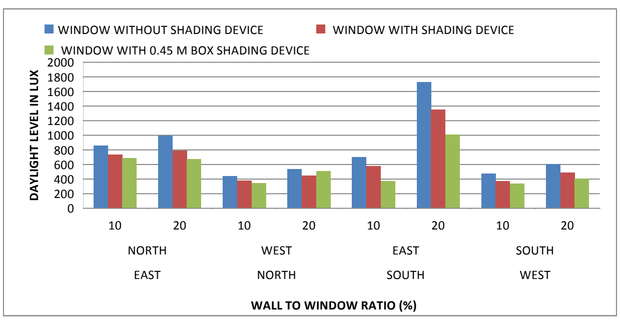

Figure 10. Comparison between daylight level (lux) and wall to window ratio (%) and shading devices

6.2 Analysis of Evaluation of Parameters

Figure-10 shows the impact of wall to window ratio on daylight level of interior spaces of building. In order to achieve optimum daylight level ECOTECH simulation investigation was carried out with different values of two parameters namely window to wall ratio (WWR) and shading device. The main inferences of the simulation investigation may be summarised as follows:

For the first configuration, daylight level were observed when values of the studied parameters kept as - 0.9 m sill level, 10% WWR for both the windows and without providing projecting shading device to second window facing towards East. Whereas, in this configuration of same values of parameters, daylight levels were observed to be decreased by 167.22 lux after providing 0.45m projected box to second window as a shading device. Similarly, for North, West and South direction (of second window) the daylight levels were decreased by 326.05 lux, 101.05 lux and 135.87 lux respectively. For the second configuration, the daylight levels were observed when the values of the studied parameters kept as - 0.9 m sill level, 20 percent WWR and without providing projecting shading device to second window facing towards East. Whereas, in this configuration of same values of parameters, daylight levels were observed to be decreased by 316.89 lux after providing 0.45m projected box to second window as a shading device. . Similarly for North, West and South direction (of second window) the daylight levels were decreased by 720.56 lux, 25.69 lux and 195.60 lux respectively.

6.3 Analysis of Thermal Comfort

In all these two configurations indoor room temperature was observed to vary within 2 to 3 degrees Celsius only when compared with outdoor temperature. The outdoor temperature recorded on field was 30°C.

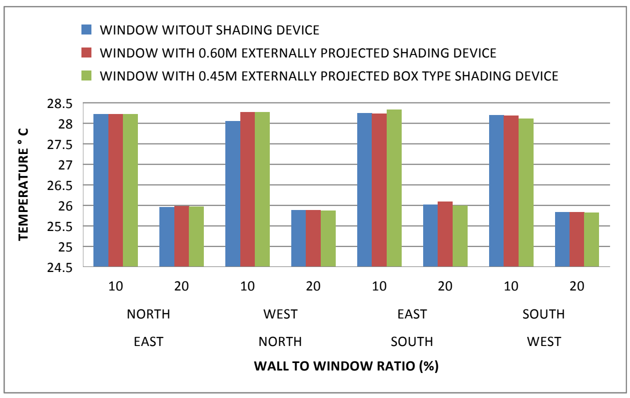

Figure 11. Temperature analysis

7. Conclusion

In this study only two parameters were considered for evaluation namely wall to window ratio (10% and 20%) and types of shading devices (0.60m externally projected shading device and 0.45m externally projected box) as per mentioned . Simulation result of configured parameters show that if provide 10 % wall to window ratio for both the windows (first window with balcony facing to West

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side and second window facing to South side) in this experimental example, after providing a box type shading device to the window, the average daylight level observed was 338.83 lux and indoor temperature observed was 28.12°C; but in case of 20 % wall to window ratio daylight level observed was 410.69 lux and temperature as 25.83°C. Thus, a positive change in the visual and thermal environment was achieved by providing 10% wall to window ratio. In this manner, Architects and Designers can evaluate daylight parameters on the basis of simulation model. As shown in the present study that the alternative for various parameters to achieve a day lit space which is primarily lit with natural light and combines high occupant satisfaction with the visual and thermal environment with overall low energy use for lighting, heating and cooling. This study proposed a methodology as a pre design tool during design process to find out the solution for reducing energy consumption by residential sector.

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