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Original Article

Energy Efficient Lighting Design for Green Building Data Center at ISRO Complex Hyderabad

K. Srinivasa Rao[1], R. Heera Singh[2], K. Vaisakh[3]

[1,2]Department of Space, National Remote Sensing Centre, ISRO, Telangana, India.
[3]Department of Electrical Engineering, Andhra University College of Engineering, Andhra Pradesh, India.

[1]Corresponding Author : ksrinivasrao7@gmail.com

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Abstract *- The building infrastructure has been developing in a fast and rapid mode throughout the globe. Each and every developed and developing country is building huge infrastructure for industries, software offices, roads, buildings, and other infrastructure facilities. Developing this huge infrastructure consumes a lot of natural resources, water, and energy. Consuming these natural resources more will lead to the depletion of these resources, which is a great danger for future generations. Creating sustainable buildings will save these natural resources and the environment. Hence, developing Green buildings is the need of the hour in the construction industry today [1]. In developing green buildings, energy efficiency is the key factor for sustainable infrastructure. Energy is consumed for lighting, heating, ventilation, and air conditioning applications in the buildings. The requirement of the energy in a building can be optimized by using several techniques. This study and research focus on optimimising the requirement of energy needed for lighting in data center buildings [2]. In a building, around 25- 30 % of the energy is utilized for lighting applications. This paper focuses on designing the buildings for less artificial lighting and optimizing the lighting load requirement in accordance with the green building norms. The applicable energy-efficient lighting design practices in green buildings are explored in detail. The methodology for designing the optimized energy-efficient lighting has been studied and implemented in the project. The paper eludes a practical case study of the NRSC green building infrastructure developed at the Shadnagar campus in Hyderabad. The designing of the lighting system with the help of e-Quest software has been explained to find out the most energy efficient model for the buildings. Thus, this research explains the methodology the strategies required for achieving energy-efficient lighting in green buildings.*

Keywords *- Lighting, Energy efficiency, e-Quest, Sustainable building, LEED design.*

1. Introduction

Building infrastructure is being developed very rapidly throughout the world, especially in countries like India, China, America, European countries and other parts of the world. Buildings will consume a lot of natural resources like water, cement, wood, concrete, energy and other metals. Natural resources will be depleted if they are used extensively for the construction of buildings and other infrastructure. Conventional buildings are consuming more electrical energy for lighting, heating, ventilation, and air conditioning requirements. As construction activities have greatly increased over the past four decades, the demand for electrical energy has also increased to a greater extent. Conventional buildings will consume more energy for lighting applications in the buildings. It is estimated that around 35 % of the total electrical energy is consumed by buildings around the world. Due to this lot of pollution and more carbon deposits are released into the atmosphere. If buildings are consuming more and more power and the number of building infrastructure is increasing day by day in countries like India, then more electricity needs to be produced, which needs more economy and also a threat to the environment. Hence, there is a need to develop newer technologies that lead to less consumption of electricity in the building infrastructure. In Western countries in the year 1970, this energy crisis was noticed and searched for alternate energy-saving technologies. By the year 1980, some of the countries recognized the need for "sustainable development" for the first time. In India, the need for sustainable construction was recognized from the year 2000 onwards. India recognized that energy saving in building infrastructures can minimize the huge gap between demand and supply of electricity.

Developing environmentally friendly, sustainable and green buildings is one of the best solutions to minimize electrical energy consumption and to save natural resources. In India, Indian Green Building Council (IGBC) was formed by the Confederation of Indian Industry in 2001. Green buildings are environmentally friendly and resource-efficient buildings.

The Green Building concept is the practice of creating structures using processes that are environmentally friendly and resources efficient during the building life-cycle; selection of site, design, construction, operation, maintenance, renovation and destruction. They will be developed with the aim of less impact on the environment and the surrounding ecosystem. Healthier and good indoor air quality is maintained with a positive impact on occupant's health which boosts the productivity of the organization. It is a holistic approach to planning, designing, constructing, maintaining and operating the buildings throughout their life period. Green buildings reduce waste, pollution and harm to the environment.

Energy efficiency plays a key role in developing green and sustainable buildings. Buildings should be designed in such a way that the overall annual energy consumption should be as low as possible. Green buildings will use less energy for lighting compared to conventional buildings. Green buildings in India will follow Energy Conservation Building Code (ECBC)-2017 guidelines for designing energy-efficient buildings [3]. Also, National Building Code (NBC)- 2016 is the reference standard for lighting levels and HVAC [4]. Energy efficiency is applied to the building envelope, thermal comfort systems and controls, lighting systems and controls, electrical systems and renewable energy systems.

The present technologies used for lighting design in large-scale buildings are conventional methods which consume more power. Lighting is required for each and every building in the entire globe, whether it is residential, industrial, commercial or for any other purpose. This research emphasizes the novel design of the energy-efficient lighting scheme for data centres, office buildings and other similar establishments.

For green buildings, Leadership in Energy & Environmental Design (LEED) will give ratings as certified, silver, gold and platinum based on the energy efficiency achieved in the buildings [5]. This research explains the methodology used for achieving a platinum rating in the energy and lighting design division of LEED. In order to comply with the sustainable standards for building construction, ISRO implemented the design and construction of Green building structures for data centers and other facility buildings at various locations in the country [5].

IMGEOS, ISRO campus at Shadnagar, Hyderabad, Telangana is considered for this study. The building envelope is given below.

As shown in Figure 1, the facility buildings consist of four blocks: A, B, C, and D, which are the four sections of the IMGEOS facility. They consist of a satellite data reception area, control room, data processing division, disaster management area, etc.

Fig. 1 Building envelope

In this paper, the energy-efficient lighting is designed as per green building norms with the help of e-Quest software.

In this research study, the total energy consumption of that building is calculated annually and searched for methods to reduce the energy consumption to the possible extent so as to make a LEED Platinum-rated energy efficient building.

The e-QUEST energy analysis software is used to model the energy use for this study. The e- Quest is a very good and easy tool used to calculate the building energy. The e-QUEST energy analysis software operates on the DOE 2.1 simulation engine. All features of the DOE-2.2 simulation engine are enabled by this energy simulation tool, and it can do conformity evaluations in accordance with California's Title 24 energy code and LEED standards [6]. The e-Quest calculates hourly building energy consumption.

Both a baseline analysis and energy efficiency simulations are available with e QUEST. For the baseline analysis, e QUEST generates a second model of the structure that iscompliant with the regulations in effect at the time of the baseline (as per ASHRAE standard). The comparability of these two models allows us to verify if the model used to construct the actual design case complies with the baseline case. Alternate designs (scenarios) can be compared in terms of their energy efficiency using the Energy Efficiency Simulation. It facilitates clear and concise demonstration of the impact of parameter adjustments on energy usage and occupant comfort.

2. Methodology & Materials

For achieving energy efficiency in sustainable green feature buildings, the energy consumed for lighting load shall be minimal. As per the Energy Conservation Building Code and Bureau of Energy Efficiency norms, the LPD shall be less than 10 Watt / Sq. Meter area. The study building area comes under the hot region. Hence, passive solar techniques are used to design the buildings. There are 4 blocks called A, B, C, and

D, built in semicircular shape with maximum daylight view on both sides. There is a central courtyard connecting all the 4 blocks. The architectural design of the building is in such a way that it receives less heat gain coefficient and maximum sunlight [7].

LEED affects the lighting in four areas i.e. Sustainable sites, energy and atmosphere, indoor environmental quality and innovation in design. The prerequisites for earning points for energy (lighting) as per LEED are 1. Light pollution reduction 2. Energy performance 3. Controllability of systems 4. Day light & views 5. Interior lighting quality. The lighting scheme for this project is designed as per the LEED prerequisites.

For achieving energy efficient lighting, the following strategies are employed in this research study.

- Harvesting the natural sunlight for interior lighting
- Using energy-efficient light fixtures
- Using effective lighting controls

The above three strategies for achieving energy-efficient lighting are explained below.

2.1. Harvesting the Natural Sunlight for Interior Lighting

Natural sunlight is the best light that can be used by human beings which is nature-given and available at free of cost. There are several methods of using natural light to provide lighting inside the rooms of a building.

Solar passive techniques are used for getting the maximum sun light into the buildings and minimum heat intrusion. For the concrete roof buildings, natural sunlight will enter the buildings through the windows [8]. The energy lost through windows and doors will be around 20%. Hence energy efficient windows are used in green buildings.

In green buildings, the insulated glass used will have with low heat transmission value and a high light transmission value. This insulated glass will act as a heat barrier for sunlight and thus allows less heat inside the rooms, but it transmits more light inside the rooms so that natural sunlight will reach the rooms of the buildings [8].

In the subject project, insulated glass with double glazing for windows is used.

The double-glazed window will consist of two glass panes with a thin layer of air (or) inert between them, as shown in Figure 2. The gap will be around 6 – 20 mm and is hermitically sealed with argon gas to act as insulation [9].

A model of the double glazed window is shown below.

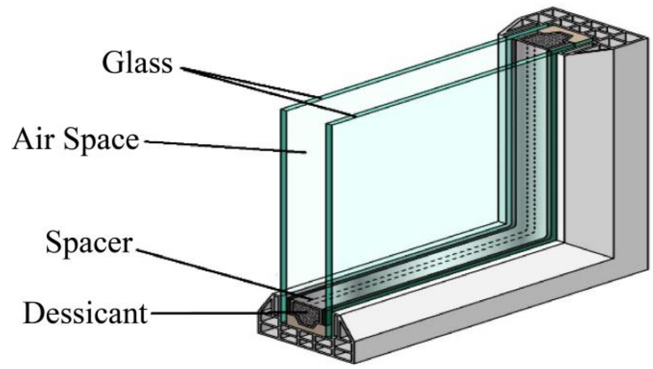

Fig. 2 Double-glazed window model

The following are the properties of the double-glazed windows used in the project.

Heat Transmission Value	: 35%
Light Transmission Value (LTV)	: 65%
U Value	: 2.1 W/m2°C
SHGC Value	: 0.55

By using the above double glazed window, the light transmission value inside the rooms will be 65 % LTV.

Double-glazed windows will be warmer in winter and cooler in summer. They reduce condensation and noise. Double glazing increases the safety and energy savings.

U Value – measurement unit is watts per m2 per degree Celsius (W/m2°C) and is a measure of the rate of heat gain (or) loss through glazing due to environmental differences between outdoor and indoor air. The lower the U-value, the better the insulation performance.

Solar Heat Gain Coefficient (SHGC) the proportion of total solar radiation that is transferred through the glass at normal incidence. It comprises the direct solar transmission and the part of the solar absorption dissipated inwards by radiation and convection. The lower the number, the better the solar performance.

The proportion of light transmitted by glazing is specified by the Visible Light Transmittance (LTV). With modern high-performance glazing systems, it is possible to use low-E coatings to allow the greatest amount of light in, while rejecting the solar heat gain through the glass. The higher the value, the better.

Similarly, in structures like go-downs, warehouses, and big factories with GI sheet roofs, natural daylight can be brought to the working floor by using polycarbonate sheets at regular intervals. Also, daylight pipes will be used to bring the natural sunlight to the interior corners of a building, shown in Figure 3.

Fig. 3 Daylight pipe

The daylight pipe is an innovative material which is used to bring the natural sun light into the interior portions of the buildings. It will have a light collector, light transmitter and light diffuser pipe. It is an excellent artificial light substitute to light the interior corners of the building facilities [10]. The Useful Daylight Index (UDI) inside the rooms after providing the above explained double glazed windows is calculated below [11].

The annual occurrence of daylight between 100 lux to 2000 lux on a work plane is called useful daylight illumination. This daylight is useful when it is glare-free, which eliminates the need for artificial lighting. ECBC compliance for UDI is a minimum of 40% of the floor area shall receive daylight in the range of 100-2000 lux for at least 90% of the year.

The project used the double-glazed window with Light Transmission value (LTV) of 65%, i.e. 2/3 rd. of the incident solar daylight will be transferred to the inside portions of the building envelope. From this, we can calculate the Useful Daylight Illuminance (UDI).

For checking the UDI compliance, a manual calculation method can be used. The methodology for calculating the UDI manually is,

- The Daylight Extent Factor (DEF) for each orientation is to be determined. For a building located in Hyderabad (Latitude > 17 degrees) with glazing of VLT >0.65, shading PF >0.4 and light shelves in windows, DEFs for windows in North=3.5, in South =3.0, in east =2.1 and West =1.8, Head weight is 3.0 m
- Calculate daylight floor area for fenestration clear of any opaque obstructions (A X B)
- For overlapping day-lit areas (corner windows), we need to subtract the overlapping day-lit area from the sum of day lit area

Fig. 4 UDI analysis

Orientation: NORTH, DEF 3.5, Fenestration Head Height H -3m

Window without Opaque Obstructions	Fenestration Width W (m)	A= H X DEF (m)	B=L1+W+L2(m) L1=L2=2m	Area Meeting the UDI requirements =A X B (m2)
N7	2.2	10.5	4.0	42.0
N6	2.2	10.5	4.0	42.0
N2	2.2	10.5	4.0	42.0
Window with opaque obstructions	Fenestration width W(m)	A=Distance till parallel Obstruction (m)	B=L1+W+l2(m), L1 =L2 = Distance to perpendicular Obstructions	Area meeting the UDI requirements = A X B(m2)
N1	2.2	11.0	0.3+2+0.3=2.6	28.60
N3	2.2	10.5	0.4+2+0.4=2.8	29.40
N4	2.2	11.0	0.4+2+0.4=2.8	30.80
N5	2.2	11.0	0.4+2+0.4=2.8	30.80
N8	1.8	11.5	0+1.5+1.0=2.5	28.75
Day lit area meeting UDI requirement				**274.35**

Orientation: EAST, DEF 2.1, Fenestration Head Height H -3m

Window without Opaque Obstructions	Fenestration Width W (m)	A= H X DEF (m)	B=L1+W+L2(m) L1=L2=2m	Area Meeting the UDI requirements =A X B (m2)
E1	1.8	6.3	1.0 + 1.8 + 1.0 = 3.8	23.94
E 5	5.9	6.3	1.0 + 5.5 + 1.0 = 9.5	59.85
Adjacent fenestration less than two meter apart	Fenestration width W(m)	A= H X DEF (m)	B=L1+W+L2(m), L1 ,L2 = One half of the Distance to adjacent fenestration	Area meeting the UDI requirements = A X B (m2)
E2	2.5	6.5	1.0+2+0.4=3.4	22.10
E3	2.5	6.5	0.2+2+0.3=2.5	16.25
E4	2.5	6.5	0.2+2+1=3.2	20.80
Day lit area meeting UDI requirement				**142.94**

Orientation: SOUTH, DEF 3, Fenestration Head Height H -3 m

Window without Opaque Obstructions	Fenestration Width W (m)	A= H X DEF (m)	B=L1+W+L2(m) L1=L2=1m	Area Meeting the UDI requirements =A X B (m2)
S1	1.3	6.4	1.0 + 1.2 + 1.0 = 3.2	20.48
S2	1.8	6.4	1.0 + 1.7 + 1.0 = 3.7	23.68
S3	21.2	9.2	1.0 + 21.2 + 1.0 = 23.2	213.44
Day lit area meeting UDI requirement				**257.60**

Orientation: WEST, DEF 1.8, Fenestration Head Height H -3m

Window without Opaque Obstructions	Fenestration Width W (m)	A= H X DEF (m)	B=l1+W+L2(m) L1=L2=2m	Area Meeting the UDI requirements =A X B (m2)
W3	2.0	5.8	1.0+2.0+1.0=4.0	23.20
W4	1.4	5.8	1.0+1.2+1.0=3.2	18.56
Window with opaque obstructions	Fenestration width W(m)	A=H X DEF (m)	B=L1+W+L2(m), L1 =L2 = Distance to perpendicular Obstructions	Area meeting the UDI requirements = A X B(m2)
W1	1.0	5.6	0.3+1+0.3=1.6	8.96
W2	1.0	5.6	0.3+1+0.3=1.6	8.96
Day lit area meeting UDI requirement				59.68

Over Lapping Area Calculations

Window with overlap areas	Width (m)	Depth (m)	Area (m2)
N4 & S1	3.2	3.5	11.20
S3 & E 5	3.4	6.8	23.12
Overlapping daylight area (b)			34.32

Total Day Light Area	
ORIENTATION	DAY Lit Area (m2)
NORTH	274.35
SOUTH	257.60
EAST	142.94
WEST	59.68
Total Day lit area (a)	734.57
Total overlapping day-lit area (b)	34.32
Total day lit area meeting UDI requirement during 90% of the year (a-b)	700.25

The useful daylight area for all the rooms is calculated as per the method explained above. After calculating the useful day light index (UDI) manually, as explained above, the necessary light fittings are designed by considering the required illumination in the respective area of the building.

For the said area of the building, the total day-lit area meeting UDI requirement during 90% of the year is 700.25 Sq. Mtr. The facility buildings have 20 labs like this in the A, B, C, and D blocks of the above-said complex buildings. The total day-lit area will be 14,005.00 sq mtr out of a total building area of 28,100 Sq Mtr. So, for this 49.84 % of the building area, the required illumination through artificial lights will be less than 50%.

2.2. Using Energy-Efficient Light Fixtures

Using the National Building Code's suggested illumination levels, created schematics for the interior lighting schemes and built the light fixtures. A minimum of 150 Lux was planned for all hallways and public areas. The plant room and other service spaces were designed for 200 Lux, the staircases for 70 Lux, and the parking lots for 30 Lux. The lobby, restrooms, and other common areas all had illumination levels between 200 and 300 Lux, as per the plan. LED, fluorescent, and compact fluorescent lights were installed everywhere tosave power.

Lighting software calculated how many lights would be needed to illuminate a given space adequately. LED as well as T5 and T8 fluorescent tubes, were developed with a focus on high-lumen output, compatibility with electrical devices, and the ability to be dimmed (or) controlled by a dimmer. The most energy-efficient lighting options, including LED and fluorescent lamps with the lowest CO_2 emissions, were studied. The lowest mercury content possible and the complete absence of lead were the criteria for selecting the lamps used.

By using energy-efficient LED light fixtures, the required power for lighting the buildings has come down by 25% compared to using conventional light fixtures. Task lights are used for specific areas where more illumination concentration at a place is required. LEDs are more efficient, long-lasting, unidirectional light, cooler and dimmable. Solar lights are used for garden areas where the electric lighting requirement is negligible. Daylight pipes are used for interior locations such as corridors, recreation rooms, general usage areas, etc. These are all innovative ideas to save more electrical energy for lighting in the project.

Fig. 5 Data center with LED light fixtures

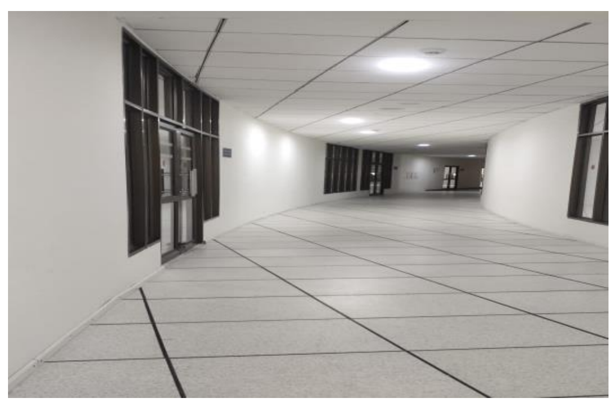

Fig. 6 Corridor with LED light fixtures

2.3. Lighting Controls

As per ECBC guidelines, 90% of the interior light fittings in a building larger than 300 Sq. Mtr shall be equipped with automatic control devices and occupancy sensors are to be provided in buildings with areas greater than 2,000 Sq. Mtr. Automatic control devices shall be in the day-lit areas meeting UDI requirements. Lux cum occupancy sensors (PIR) are used in all the rooms, which will detect the motion and respond to the heat pattern of the motion. These sensors will sense the movement of human beings, and if there is no movement of humans for a fixed time, they will switch off the lights automatically, thus saving power. They are reliable and inexpensive and rarely false triggers.

Dimming systems are used to dim the lights, which can save up to 50% of the power [12]. External lights are controlled by using the astronomical time switch (or) photo sensor, which automatically turns off the lights when daylight is available or when lights are not needed. Hostels/guest houses will be provided with a master control switch. Separate controls for task lights are used for under-shelf / under-cabinet lighting. Demonstration lighting shall have separate controls [13].

3. Modelling Process

To model the lighting design for this project, e-quest energy analysis software is used. e- Quest energy analysis software operates on the DOE 2.1 simulation engine. [14] by using this, all the possible outcomes can be analyzed. e-Quest is the software used to create simulations that incorporate building location, orientation, wall/window properties, daylighting, etc. It is state of the art building design technology used to simulate the building energy performance.

The inputs required for e-quest simulation are analysis objectives, building site information, weather data, building structures, shades, materials, operational schedule, internal loading, HVAC equipment performance, etc. It allows for complete building performance analysis. The lighting design of the entire campus with all of its light fittings information is simulated by using this software. The software gives the most energy efficient model that can be attained. It also helps the steps to be taken to increase the energy efficiency levels to the highest possible conditions.

e- Quest gives both the baseline analysis and energy-efficient analysis and also generates the second model compliant with ASHRAE standards. Alternate designs can be generated and compared with the baseline standard analysis by using this simulation software [15].

The report shows how the as-built design case fares against the baseline model to meet the standards of Appendix G of ASHRAE / IESNA 90.1-2004 (ASHRAE, 1989) [16].

In this report, six models are developed. One is a conventional model, four alternate models with green features, and one is the most energy-efficient as-built design model.

Figure 7 shows the design case inputs for lighting design using e-quest software. Figure 8 shows the lighting load profiles of the used software.

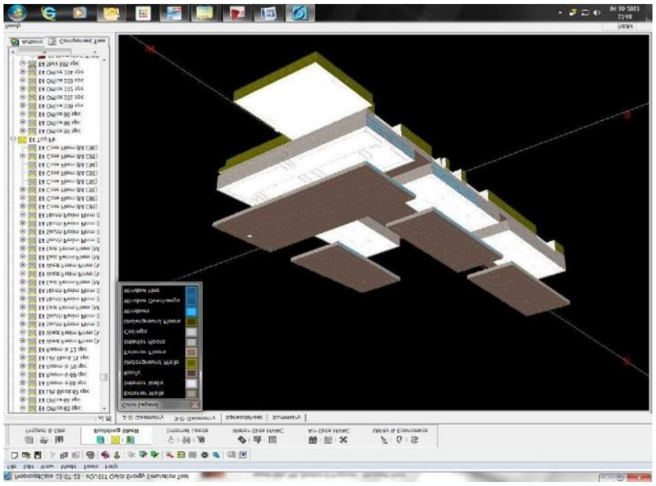

Fig. 7 Design case inputs

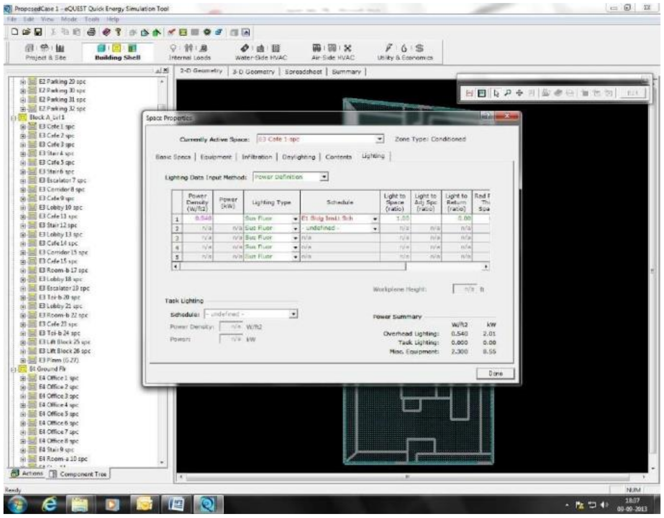

Fig. 8 Lighting load profile

Table 1. Scenario analysis in MWH Calculated

Input Parameters	Scenario 1 : (Conventional Design)	Scenario2: (Green Parameters Modified)	Scenario 3: (Green Parameters Modified)	Scenario 4: (Green Parameters Modified)	Scenario 5: (As Built Design)	Scenario 6: (ASHRAE Baseline)
Interior Lights	880	760	720	735	670	845
% Increase		15.11	15.11	15.11	15.11	-
Exterior Lights	19	18	17	16	15	16
Total	895	778	737	751	695	851
Savings	(-) 5.17%	8.57 %	13.39%	11.75%	21.26%	Ref

The above table shows the scenario analysis with MWH units for each scenario.

Scenario 1 is the conventional design used for building structures based on building practices. In this method, conventional lighting design practice is used. This is used for comparison with other scenarios for calculating the energy savings. Scenarios 2, 3, 4, and 5 are the alternate energy scenarios developed with different permutations and combinations of various building design parameters such as windows, walls, glazing, orientation, direction, different light fittings, and the allied control systems. The energy consumption in each scenario and the percentage of energy efficiency achievable with those parameters are obtained by simulation.

Scenario 6 is the ASHRAE baseline design, which is used to compare the other designs for the level of energy efficiency. Hourly energy consumption for the lighting of the buildings is used to reduce energy usage and improve the occupant's visual comfort. Energy in KWH units was used by simulating the ASHARAE 90.1-2018 minimally compliant baseline model, which is scenario 6 [16].

4. Results & Discussion

The energy-efficient lighting for the subject project is designed based on the following three major techniques.

- Harvesting the available natural daylight for 50% of the areas of the buildings. This is achieved through designing the buildings by using solar passive techniques. For this purpose, the buildings are designed in a circular shape, as shown in Figure 1, so as to gain solar daylight freely inside the rooms. To receive the maximum available daylight in the rooms, double-glazed windows are used with an Light Transmission Value (LTV) of 65%. Due to this, the required electrical lighting is reduced and hence the saving of the power.

  Natural day lit areas have other benefits, such as improving the people's ability to perform visual tasks, increasing productivity, reduce absents and illness.

- Energy efficient lights such as LED, T5 / T8, Task lights, Solar lights, etc. are used, which saves a lot of energy consumption and, at the same time, will provide better occupant comfort lighting without light pollution.

  Energy-efficient lights reduce the heat gain inside the rooms, thus reducing the cooling load requirements. Each KWH reduction in lighting energy reduces 0.4 KWH in cooling energy.

- Using the lighting controls such as occupancy cum daylight sensor, movement/ motion sensor, photo sensor/ astronomical switch etc., which will turn off the lights when there is no human occupancy and thus saves the wastage of electrical energy.

In conventional buildings, more energy is consumed for lighting, but in Green buildings, by adopting energy-efficient techniques, the requirement for electrical power for lighting is reduced to a greater extent.

The energy required for lighting the said campus was broken down into 6 scenarios with the help of e-quest simulation software. Each scenario represents different permutations and commutations. The electrical energy required for lighting all the blocks of the buildings in each of the 5 cases was calculated by taking scenario 6 as the reference case. The percentage of energy saving is calculated by comparing the baseline data with the actual design scenario (scenario-5) [17].

As per LEED, the required percentage of the energy savings is determined by comparing the design case with the baseline case to earn the necessary credits. According to LEED, a building must reduce its energy consumption by at least 10% when compared with baseline levels in order to qualify for LEED certification.

The above Table 1 gives the data of Mega Watt Hours (MWH) units required for lighting the buildings for all 6 scenarios of the study. The table gives the simulated data and the analysis in full. The energy consumption in each scenario was calculated and compared with the baseline data of ASHRAE (scenario-6). This simulation study of comparison was made to analyze the energy consumption in each case with different parameters and to select the optimum scenario with the highest energy efficiency [18].

From the above study, the table, it can be concluded that, scenario 5 results in energy saving of 21.26% as against the base case of ASHRAE scenario-6 as reference. These energy savings for lighting are possible due to the incorporation of solar passive techniques applied for the building design and also harvesting solar light to the interiors of the buildings, using the most efficient LED light fittings and their control systems.

Hence, it is found with the help of e-Quest design software that the energy required for lighting the buildings in the above project has been decreased to 695 MWH units as against 851 MWH units of electricity, as shown in Table 1, which results in a saving of 21.26% of electrical energy. By using the above simulation study, it is found that a campus with 28,100 Sq. Mtr area can save lighting energy requirement to the tune of 21.26% by harvesting the available sunlight for daylighting through the use of double-glazed windows, using energy-efficient LED lighting and lighting control systems.

LEED India has certified this project with platinum-level certification due to the savings achieved through the green building technology used for the design of energy-efficient lighting applications and its compliance with IGBC and ASHRAE standards.

5. Conclusion

The investigation reveals a minimum energy savings of 21.26% are achieved for the IMGEOS campus, and these are also realized in actual operating conditions. The measured energy is also in line with the final design case energy consumption scenarios.

The energy savings are achieved by harvesting the day light to the interiors of the buildings by the use of double-glazed glass and installing the energy-efficient LED light fixtures and allied controls for the lighting systems. Optimal lighting solutions are achieved by considering the integration of daylight, lamps, fixtures, controls, building configurations, internal furnishings, etc. Ideal lighting provides the appropriate level of illumination for the activity with minimum input of energy with required visual quality.

Sustainable buildings are a new concept in the construction industry since the start of the 21st century. Green building technology uses less quantum of natural resources, water and energy to develop the building structures. This report gives insight on 'how to save the electrical energy for building lighting requirements without compromising the comfort of the occupants. The report highlights the techniques used for achieving lighting energy efficiency as per the LEED requirements [19].

There are tangible and intangible benefits of energy saving in the green buildings. The tangible benefits are less Megawatt Hours (MWH) unit consumption, less cost of energy usage, etc. The intangible benefits are less carbon deposits due to energy saving, less pollution, less energy wastage, safety etc.

Data centers and IT infrastructure is growing day by day in India and abroad. ISRO is one the India's leading space research development organizations, which builds large-scale data centers to store satellite data and also communication data for various purposes. This documental report helps as a guideline for designing and achieving energy efficiency for lighting applications in large-scale data centers and similar nature of IT buildings.

These findings will help policymakers and designers to design more energy-efficient buildings and data centers / IT infrastructure buildings across India and the globe.

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