IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 7.047 ⩋ Vol. 10, Issue 1, January 2022

DOI 10.17148/IJIREEICE.2022.10106

LIGHTING ASSESSMENT & AUDIT OF SARASWATI COMPLEX – A CASE STUDY

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Abstract: An energy audit is a study of a plant or facility to determine how and where energy is used and to identify the measures for energy savings. Generally the institutes, library buildings, offices, rooms etc. are well designed without looking towards energy efficient lighting system. But during energy accounting, these buildings consume more energy as the energy required by energy efficient structure design for the same. This research paper aims at the identification of lighting based energy losses of saraswati complex (Library) of DCRUST Murthal, a state government funded university. This research paper implements the concepts of lighting methodology for calculating the lighting parameters manually that directly calculate the performance of the lighting system parameters in a single excel sheet. Finally the energy efficient measures are proposed for improving energy savings &illuminance level.

Keywords: lighting, energy audit, energy efficient,methodology, lux meter, circuit watt, illuminanceetc.

I. INTRODUCTION

An energy audit identifies where energy is consumed and how much energy is consumed in an existing facility, building or structure. Information gathered from the energy audit can be used to introduce energy conservation measures (ECM) or appropriate energy-saving technologies, such as electronic control systems, in the form of retrofits. Energy audits identify economically justified, cost-saving opportunities that result in significantly lowered electrical, natural gas, steam, andwater costs [1].

An energy audit is a study of a plant or facility to determine how and where energy is used and to identify methods for energy savings. There is now a universal recognition of the fact that new technologies and much greater use of some that already exist provide the most hopeful prospects for the future. Energy audit is an attempt to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Industrial energy audit is an effective tool in defining and pursuing comprehensive energy management programmed [1]

People nowadays are more concerned about energy efficiency and conservation. Energy Audit is considered as one of the comprehensive methods in checking the energy usage and wastage in commercial buildings, educational institutes, universities &industries etc.

An energy audit, therefore, is a detailed examination of facility‘s energy usageand costs and give suggestions to reduce energy losses which required no financial impact and further generates recommendations to reduce those uses and costs by implementing energy efficient technologies and operational changes.

The first thing inenergy auditing is the proper energy accounting. Energy accounting is the process of identification, collection, organization and monitoring of energy usage in the industries, commercial buildings, universities etc. Thus, Energy accounting & Energy Audit goes hand in hand. A comprehensive study of the lighting consumption will be carried out to identify the number of fixture installed, type of fixture installed, wattage of fixture, energy usage, etc. and calculations of lighting parameters and annual energy wastage. Being an educational institute major measure part of energy consumption is due to lightingSurvey of energy consumption electric load was done in the Saraswati complex of DeenbandhuChhotu Ram University of Science & Technology.The paper provides input data coolection. Section-3 gives the measuring instrument used in the paper, Section-4 implements the lighting methodology &section 5 gives the results. Conclusions are put forth in Section-6.

II. INPUT DATA COLLECTION FOR LIGHTING ENERGY AUDIT

The first and important part of lighting based energy audit is the input data collection. Although Saraswati complex (library) contains bulk load like chiller plant, motors, etc. 30% of the total load is of lighting and out of this 2-4% of the energy consumption can be reduced by installing efficient fixtures. This section gives a brief background about lighting, various basic terminologies, definitions used in Saraswati complex with regards to lighting, and manual implementation of methodology is described in this section. A walk through audit has been conducted during visits to assess the illumination requirement of the building and scope of improvement in illumination level with an objective of cutting down the electrical energy consumption & cost of electricity.

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MBA 1st year room	80	3.3	64	0
MBA 2nd year	80	3.3	64	0
MHA 1st year	40	3.3	6	0
MHA 2nd year	40	3.3	6	0
Computer lab1	88	3.3	60	0
Presentation room	88	3.3	80	0
Faculty office	32	3.3	4	0
Chairperson(humanities)	32	3.3	4	0
Cabin	40	3.3	16	0

Table 2.1: Details of Input data Saraswati complex

Area	**Area ofRoom In Meter square (m^2)**	**Mounting Height in Meter (h_m)**	**No of FTL with Electronic Ballast (T5)**	**No of. CFL Lamps**
Library	497.25	3.4	168	20
Periodical section	49.5	3.3	9	0
Librarian , Assistant librarian room, deputy librarian room	25	3.3	6	0
Auditorium	144.8	3.3	152	0
1st floor	816	3.3	348	20
Book store	72	3.3	24	0
2nd floor	816	3.3	350	22
Centre for research & innovation & development lab	144.8	3.3	152	0
Computer center	221.96	3.3	153	0

Table 2.2: Input data for 3rd floor

III. MEASURING INSTRUMENT USED IN LIGHTING

LUX METERS

Lux meters corrected for V-lambda are used for measurement of illuminance. The accuracy of 5 % and suitable range up to 10000 lux should be used. Lux meters are used to measure illumination (light) levels. Most lux meters consist of a body, a sensor with a photo cell, and a display panel. The sensor is placed under the light source. The light that falls on the photo cell has energy, which is transferred by the photo cell into electric current. The more light is absorbed by the cell, the higher the generated current. The meter reads the electrical current and calculates the appropriate value of either Lux or Foot candles.

This value is shown on the display panel. This instrument is very simple to operate. The sensor is to be placed at the work station or at the place where intensity of the light is to be measured, and the instrument will directly give the reading on the display panel.

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 7.047 ⁜ Vol. 10, Issue 1, January 2022

DOI 10.17148/IJIREEICE.2022.10106

The following measures should be taken when working with lux meters:

- Using accurate illuminance meters for measurement.
- Sufficient number and arrangement of measurement points within the interior.
- Ensuring that no obstructions from surfaces affect measurement.
- The sensor is to be properly placed on the work station to obtain an accurate reading (Proper positioning of illuminance meter)
- Due to the high sensitivity of sensor it should be stored safely
- Check the operating manual of the monitoring equipment for more detailed instructions on safety and precautions before using the equipment.

Figure 3.1 Lux Meter

Therefore, adequate light intensity plays an important role in protecting us from danger and damage to health. The light intensity of 1 Lux corresponds to a light flux of one lumen falling on a surface of one square meter. Figure 3.2 shows the panel description of a lux meter.

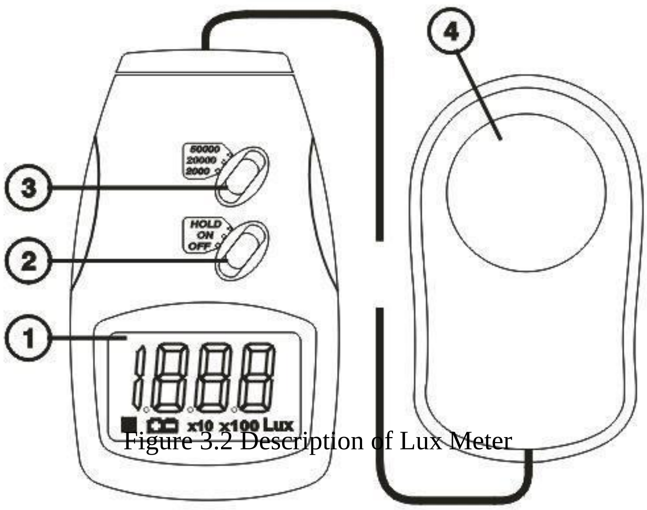

Figure 3.2 Description of Lux Meter

1. LCD display
2. Turn off, turn on, value hold
3. Range select button
4. Photo detector

IV. IMPLEMENTATION OF LIGHTING METHODOLOGY

This section deals with the energy efficiency of the lighting system of the saraswati complexof DCRUST, Murthal. For the sake of the simplicity for manual calculation of lighting performance & lighting parameters, only five rooms of the Saraswati complex of the DCRUST, Murthal are taken into consideration. These five rooms are so chosen that they have difference in area, function, energy usage, lighting levels etc.& taken these five rooms as five cases namely case A, Case B, Case C, Case D and Case E. Reading hall is considered as Case A, Library(Periodical section)is considered

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Case B, 1st Flooris taken as Case C, Auditoriumis as Case D, Computer Centreis taken as Case E. The input lighting data of these five cases is shown in table 4.1.

Case	**Area in m^2**	**Mounting Height in metre (H_m)**	**No of CFL**	**No of FTL with Electronic Ballast (T5)**
Case A	264.31	3.3	20	168
Case B	49.5	3.3	0	9
Case C	816	3.3	20	348
Case D	144.8	3.3	0	152
Case E	221.96	3.3	0	153

Table 4.1Input parameters information for different cases

Based on the lighting methodology to calculate ILER, the following steps are performed as:

1st Step Floor Area: Table 4.2 shows the room area of these five cases based on length and width of the room.

Cases	Case A	Case B	Case C	Case D	Case E
Area m^2	264.31	49.5	816	144.8	221.96

Table 4.2 Room Area for different cases

2nd Step Room Index(RI): Table 4.3 shows the room index of these five cases which is calculated based on the equation

Room Index(RI) $= \frac{\text{Lenght X Width}}{\text{Hm(Lenght+Width)}}$, where H_m = Mounting height (Which is the height of the lighting fittings above the horizontal working plane.)

Cases	Case A	Case B	Case C	Case D	Case E
Room Index	1.09	1.05	1.45	1.65	.937

Table 4.3 Room Index for different cases

3rd Step Total Circuit Watts: Based on the given input data, total circuit watts are calculated. Now, the total circuit watts are calculated according as shown in table 4.4.

Total Circuit Watts =Number of lamps X (Wattage of lamp + Circuit loss)

Cases	Case A	Case B	Case C	Case D	Case E
Total Circuit Watts(W)	3008	234	5440	2432	2446

Table 4.4Total Circuit Watts for different Cases

4th Step Watts per square meter: Table 4.5 shows the watts per square meter for these five cases.

Cases	Case A	Case B	Case C	Case D	Case E
Watts per square metre W/m^2	11.38	4.72	6.66	16.80	11.02

Table 4.5 Watts per square meter

5th Step Average illuminance: Based on the room index the minimum number of the luminance measurement points is decided as per the following RI table,To accurately determine the illuminance on the working plane, the greater the number of measurement points is better. This will account for any wide variations of Illuminance in calculation of the average.

Table 4.3 shows the room index of these five cases. The room areas of case A and C and E are very large so measurement points taken for these areas is subdivided into four & five parts.Here for only cases A, B and D are presented for measurement points.

Case A room area has been divided into four sub-parts A(1),A(2),A(3),A(4)

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DOI 10.17148/IJIREEICE.2022.10106

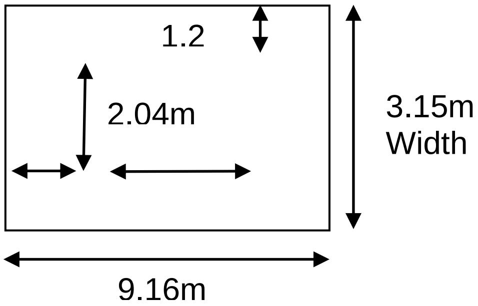

Figure 4.1 Measurement points for Case A (1)

Figure 4.2 shows the measurement points forCase A (2) where illuminance value to be measured.

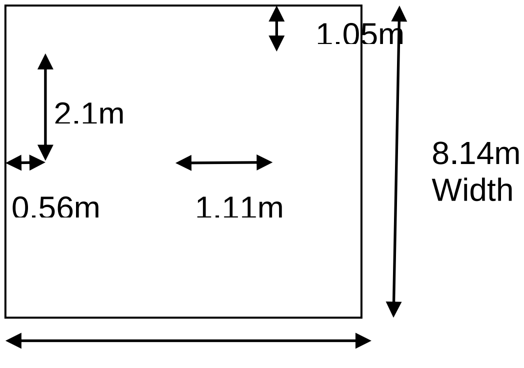

Figure 4.2Measurement points for Case A (2)

Figure 4.3 shows the measurement pointsforCase A (3) where illuminance value to be measured.

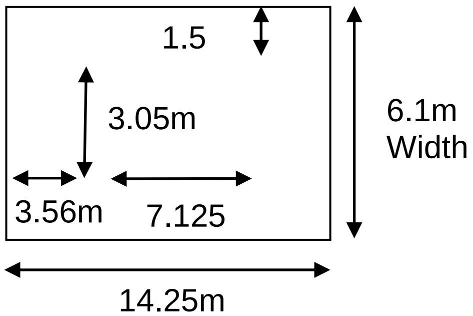

Figure 4.3Measurement points for Case A(3)

Figure 4.4 shows the measurement points forCaseA(4) where illuminance value to be measured

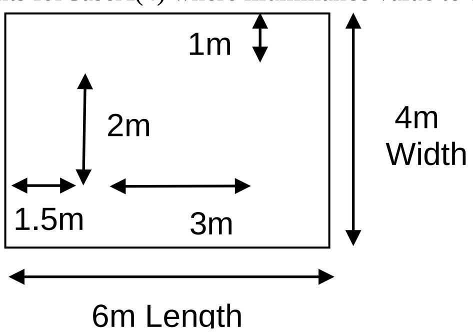

Figure 4.4Measurement points for Case A(4)

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Impact Factor 7.047 ⋇ Vol. 10, Issue 1, January 2022
DOI 10.17148/IJIREEICE.2022.10106

Similarly, fig 4.5 shows the measurement points for Case B

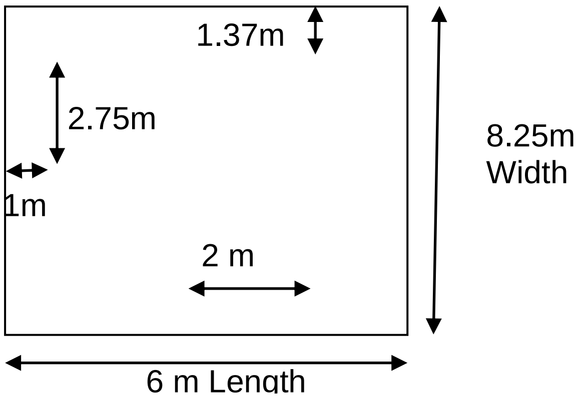

Figure 4.5 Measurement points for Case B.

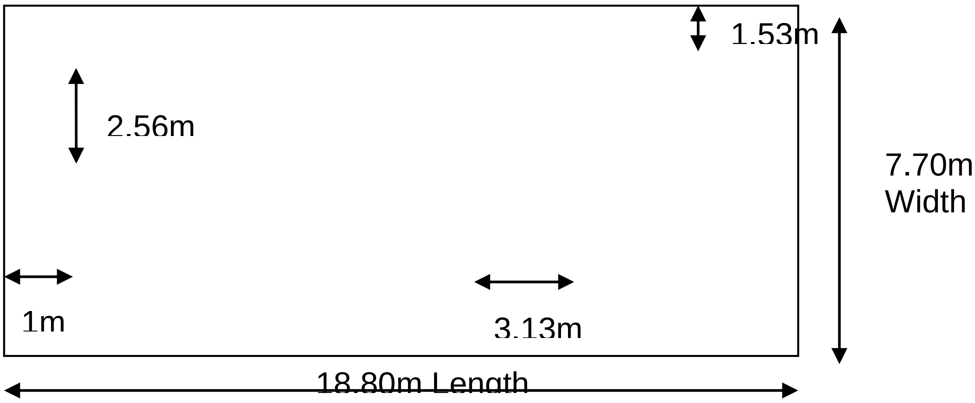

Figure 4.6Measurement points for Case D

Again these five cases A, B, C, D, E are further divided into four sub-cases based on the room lighting condition table 4.6 shows these sub-cases based on room lighting conditions.

Room Condition	**Case A**	**Case B**	**Case C**	**Case D**	**Case E**
Day Light & Light on	Case A.1	Case B.1	Case C.1	Case D.1	Case E.1
Only Day light	Case A.2	Case B.2	Case C.2	Case D.2	Case E.2

Table 4.6 Room Condition according to different cases

For the sake of simplicity, only illuminance values for case A and B are shown. Table4.7 shows the Illuminance Value of the Case A.1, Case A.2

Cases	**Illuminance Value**								
Case A.1	162	158	152	185	166	185	125	165	162
	170	168	169	208	121	122	123	116	116
	149	63	82	200	226	194	196	228	
Case A.2	37	15	20	47	70	30	10	8	18

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	48	8	15	33	33	9	4	4	11
	50	4	8	180	75	65	70	150	

Table 4.7 Illuminance Value for Case A

Table 4.8 shows the Illuminance Value of the Case B.1, Case B.2

Cases	Illuminance Value								
Case B.1	118	115	100	123	121	138	115	105	121
Case B.2	11	13	16	10	6	5	3	4	3

Table 4.8Illuminance Value for Case B

Table 4.9 shows the Illuminance Value of the Case D.1

Cases	Illuminance Value								
Case D.1	155	260	106	122	205	205	86	185	102
	167	82	17	105	177	90	72	178	78

Table 4.9 Illuminance Value for Case D

Table 4.10 shows the E_{av}value for the different sub cases

Case	Average Illuminance	Case	Average illuminance
Case A.1	158.11	Case B.1	117.33
Case A.2	38.53	Case B.2	7.89
Case C.1	192.16	Case D.1	132.055
Case C.2	76.86	Case E.1	149.31
		Case E.2	96.11

Table 4.10 Average illuminance for Cases

6th Step Correction Factor value: Correction Factor is applied to these rooms according to the correction required in the luminaries for the different sub cases of Case A,B, C & D is shown below table 4.11.

Case A	Case B	Case C	Case D	Case E	Case F	Correction Factor
Case A.1	Case B.1	Case C.1	Case D.1	Case E.1	1.08	Case A.1
Case A.2	Case B.2	Case C.2	Case D.2	Case E.2	1	Case A.2

Table 4.11Correction Factor value for different Cases

7th Step Net Illuminance value Table 4.12 shows the net illuminance which is calculated for the different sub cases of case A, B,C,D& E

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Case A	**Net Illuminance value**	**Case B**	**Net Illuminance value**
Case A.1	170.75	Case B.1	126.71
Case A.2	38.53	Case B.2	7.89
Case C	Net Illuminance value	Case D & Case E	Net Illuminance value
Case C.1	207.53	Case D.1	142.62
Case C.2	76.86	Case E.1	161.25
		Case E.2	96.11

Table 4.12Net Illuminance value for Case A, B, C, D& E

8th Step Lux per watt square meter: Watts per square meter value is calculated from the table &for the all the cases is shown in table 4.2, therefore lux per watt square meter is calculatedas shown in table 4.13

Case A	**Lux per watt square meter($Lux/W/m^2$)**
Case A.1	15.00
Case A.2	4.51
Case B.1	26.84
Case B.2	1.67
Case C.1	31.16
Case C.2	11.54
Case D.1	8.49
Case E.1	14.63
Case E.2	8.72

Table 4.13Lux per watt square meter for Case A, B, C, D& E

9th Step Target Lux: The target lux based on room index is given in lighting methodology. From the table, target lux for Case A is 34$Lux/W/m^2$. Similarly for Case B, Case C, Case D and Case E are 36$Lux/W/m^2$

10th Step Installed Load Efficacy Ratio: Installed Load Efficacy Ratio for these five cases is calculated as shown in table 4.14

Case No.	**Installed Load Efficacy Ratio**	**Case No.**	**Installed Load Efficacy Ratio**
Case A.1	0.375	Case B.1	0.75
Case A.2	0.32	Case B.2	0.046
Case C.1	0.86	Case D.1	0.21
Case C.2	0.32	Case E.1	0.406
		Case E.2	0.242

Table 4.14Installed Load Efficacy Ratio for Cases

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V. RESULTS

This section of the paper consists the results based on the manual calculation that gives the suggestions on ILER ratio & their annual energy wastage. The results of the manual calculation of the lighting parameters for Case A, B, C, D & E are given in table 5.1

Cases	Suggestion	Cases	Suggestion
Case A.1	Urgent action required	Case B.1	Good lighting condition
Case A.2	Urgent action required	Case B.2	Very poor IL luminance level so urgent action required
Case C.1	Good lighting condition	Case E.1	Very poor illuminance level so urgent action required
Case C.2	Very poor illuminance level so urgent action required	Case E.2	Very poor illuminance level so urgent action required

Table 5.1: Results of the manual calculation of the lighting Parameters

12th step Annual Energy Wastage:

(1 - ILER) X Watts X No. of operating hours X No. Working Day -------------------- (1)

The annual energy wastage is calculated based on the equation no. , i.e, (1 - ILER) X Watts X No. of operating hours X No. Working Day as shown in below:

By including the assumption that lamps were ON in the library for 8 hours per day & 220 days in a year, the annual energy wastage is calculated.

Case A.1 Annual Energy Wastage = (1 - 0.375) X 3008 X 8 X 315
= 4737.6 kWH/annum
Case A.2 Annual Energy Wastage = (1 - 0.32) X 3008 X 8 X 315
= 5154.5 kWH/annum
Case B.2 Annual Energy Wastage = (1 – 0.046) X 234 X 8 X 220
= 3928.9 kWH/annum
Case C.2 Annual Energy Wastage = (1 – 0.32) X 5440 X 8 X 220
= 6510 kWH/annum
Case D.1 Annual Energy Wastage = (1 – 0.21) X 2432 X 8 X 220
= 3381kWH/annum
Case E.1 Annual Energy Wastage = (1 – 0.406) X 2448 X 8 X 220
= 2559.2kWH/annum
Case E.2 Annual Energy Wastage = (1 – 0.242) X 2448 X 8 X 220
= 3265.82kWH/annum.

5.1 General Recommendations:

The recommendations given below in the saraswati complex requires no additional cost. These measures help in improving the energy savings.

- Optimum usage of day lighting in the library by opening of the curtains.
- Installation of "exclusive" transformer for lighting.
- Lamps should be placed at the lower mounting height in the saraswati complex.
- Clean the tubes and lamps that are dusty must be cleaned to increase the luminosity.
- Use of daylight where ever is possible in the saraswati complex,

52 Specific Recommendations:

By implementing these specific recommendations a total saving of20-25% can be achieved without compromising much on the existing facilities and comforts.

- At present 6 T5 tubes are controlled by one switch by a small change in circuit we can connect it in alternate tubes i.e. Split switching should be used may be such that first and fourth tubes may be included in installation.
- Delamping should be done where there is no requirement of tubes such that where natural light is sufficient like in ground floor in middle of library there is sufficient lighting.

DOI 10.17148/IJIREEICE.2022.10106

- By using photo sensors we can save the energy as it detects the amount of light and switch off light where there is no requirement as at some areas 10 T5 tubes are working by 1 switch by using photo sensor we can easily control the tubes.

5.3 Energy Efficient Measures:

I. Delamping: In open areas with sufficient natural which had higher than standard illumination, removing 1 tube each from approximately 300 fittings using 4x28W tubes operating approximately 3000 hours per year could save 100800 kWh of electrical energy per year.

II. Use of signage's and automatic lighting control systems such as sensors for areas where lights were not turned off when area is brightly lit and nobody was in public zone, rooms and toilets. Hence by installing signage's to create awareness and remind users to switch of lights, sensors and automatic control systems which automatically switch off lights in unused areas substantial electrical energy can be saved.

NO.	Energy Efficient Measurement	Annual Energy savings kWh		Annual Cost Saving RM	Investment Costs RM	Payback period
	LOW COST MEASURES					
1.	Delamping 100 Lamps		100800	30000	NIL	Instant
2.	Use of Signage's, sensors and automatic control systems		150000	45000	60000	1.3 years

Table 5.22: EEMs for Lighting

VI. CONCLUSIONS

Generally the institutes, library buildings, offices, rooms etc. are designed without taking into consideration of the use of energy efficient lighting system. But during energy accounting, these buildings consume more energy as the energy required by energy efficient structure design for the same. These buildings, rooms, offices tec. consume approximate 35% of the energy used due to lighting. To achieve energy efficiency based on lighting system a comprehensive survey was carried out in the library From the initial data survey it was found that illuminancelevel is poor as well as energy wastage is high. This research paper implements the concepts of lighting methodology for calculating the lighting parameters manually that directly calculate the performance of the lighting system parameters in a single excel sheet Finally the recommendations are suggested for improving energy savings &illuminance level of the DCRUST, Murthal.

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