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Estimating LPD Based Energy Consumption for an Institute Building: A Comparison with Baseline Lighting Design

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***Abstract*:-** Today's world is the world of cities and we are bound to make the cities modern and smart in order to accommodate all facilities required for the occupants of modern age. At the same time,it is of utmost importance to deliver the required facilities at the minimum expenditure and maximum reliability of energy which might use Distributed Generation as energy is dependent on our natural resources and also involves cost factor.Climate conditions and air quality are also continuously becoming worse day by day due to pollution and excessive emission of green house gases like CO_2, giving rise to use of non-conventional energy sources for power generation. Saving of electrical energy does not only save money but also contributes to a clean atmosphere and conservation of natural resources. In this paper, a building of an institute has been taken to study the energy consumption behavior of a building.Calculations have been made to estimate the energy expenditure of the building using LPD considering each and every room using baseline lighting design i.e. ECBC reference. The actual consumption of all rooms i.e. proposed lighting scheme and hence that of the building is also calculated. The two consumption expenditures have been compared and it is found that in the proposed lighting design energy consumption is showing around 21.16% of saving as compared to that of baseline lighting scheme.

***Keywords*:** Baseline lighting scheme, Proposed lighting scheme, Light Power Density(LPD), Distributed Generation

I. INTRODUCTION

A smart city stands for a concept of resources efficiency,traffic control efficiency,power utility efficiency, waste management efficiency,water supply efficiency, efficient law enforcement, efficient transportation system, effective power generation, efficient health services, modern libraries, result oriented education system, healthy atmosphere with low pollution, availability of all consumable and non consumable items of use for mankind with the help of effective information and communication systems, fast internet, effective policies followed by result oriented implementation. Population in our country is rapidly moving towards cities and hence it is the requirement of the time to well equip the cities to receive the incoming crowd and provide the people an excellent platform for development. Smart city is also preferred for reducing congestion, air pollution, boost local economy, to promote interactions and ensure security. Main features of smart city also includes making governance citizen-friendly, increasing rely on online services, giving an identity to the city, enhancing it's own heritage, supplying solutions to infrastructure and services in area based development. The smart cities mission also requires dedicated smart people to actively participate in reforms and governance. Other features of smart city are assured electricity with about 10% of it coming from solar, waste water recycling, sanitation including solid waste management, rain water harvesting, smart metering, robust IT connectivity and digitalization, pedestrian friendly pathways, intelligent traffic management, smart parking, energy efficient street lighting, innovative use of open space, visible improvement in the area, safety of citizens and improved quality of life.

Sustainable energy sources are in great demand due to climate becoming worse as dangerous level emission of green house gases like CO_2. The policy makers are now bound to improve energy efficiency and are also promoting smart grids.[1] This effort has come out in the form of smart building and smart grid and being used in smart cities. The earlier used Building Energy Management System (BEMS) needsto be improved to real time based analysis i.e. the heating, ventilation and air conditioning(HVAC) setting should be real time based dynamic as per external condition outside building and with the fixed setting as in earlier building energy management systems[2].Microgrid customer engineering economic model(MCEEM) is prepared to estimate the demand of a building or a complex.

Distributed generation has also become a very popular and useful concept as it has onsite generation and control of power for distributed consumers[3]. For some important buildings like important political centers, important defense centers and offices, important transport controlling centers like railway stations, airports, shipyards etc., one can not afford power failure,but in case of failure of grid itself power failure has to be there which can only be avoided if the building has a dedicated distributed generation. Under normal circumstances the generation from distributed generators will be fed to the grid.

Content in paper was organized as Section 2 highlights the Light analysis of building. Further section 3 focus on Result and Discussion followed by Conclusion Section.

II. LIGHTING ANALYSIS OF THE BUILDING

A building of an institute was selected to perform analysis on energy consumption. The building has two floors including so many rooms, drawing halls, office rooms and washrooms. All the rooms are given a identity number and a drawing map of the building is arranged.The rooms on first floor and ground floor have various orientations and differs also in duration and amount of receiving sunlight. As per energy conservation building codes(ECBC) 2017 used in this study lighting system differs in their requirement for offices, hospitals, operation theaters, assembly, institutes, washrooms, drawing halls, shopping complex, mixed use buildings.For example the light power density of library is required to be 12.2 watts per meter square and LPD for gymnasium is required to be 10 w/m. sq.

The lighting analysis has been prepared for an institute building having two floors and the total modeling area of the project is approximately 7300 square meter. A whole building energy analysis was performed for estimating the building lighting performance throughout the year.

Drawing map of the ground floor and the first floor along with projected three dimensional view of the building was prepared using design builder.

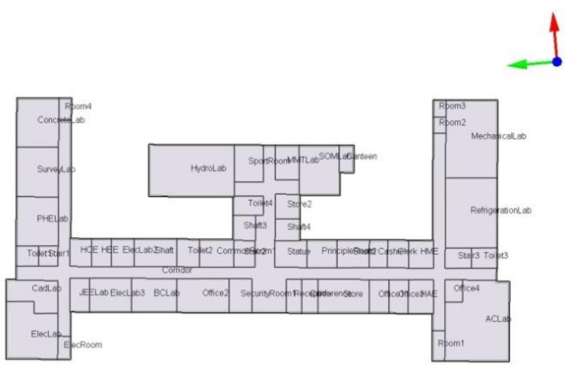

Fig 1 Ground floor plan of the building

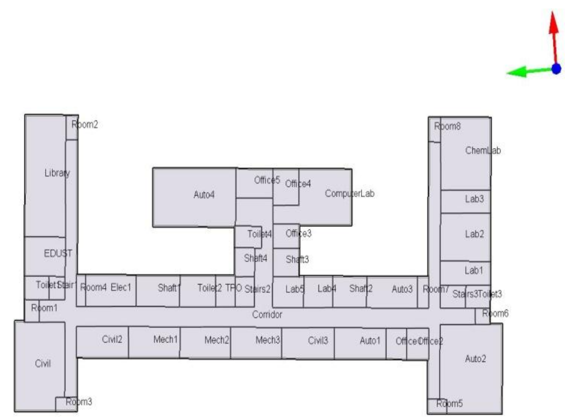

Fig 2 First floor plan of the building

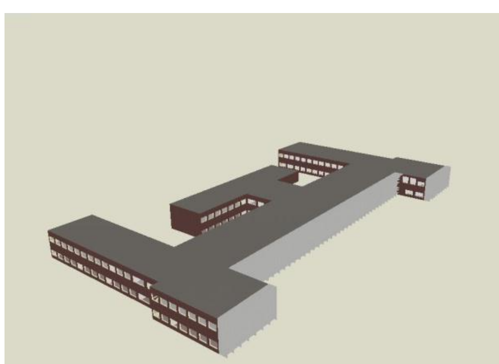

Fig 3. 3D Front view of the building

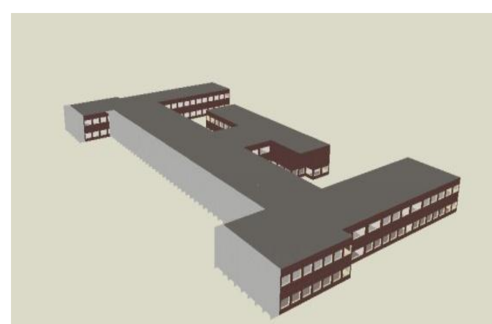

Fig 4. 3D Angle view of the building

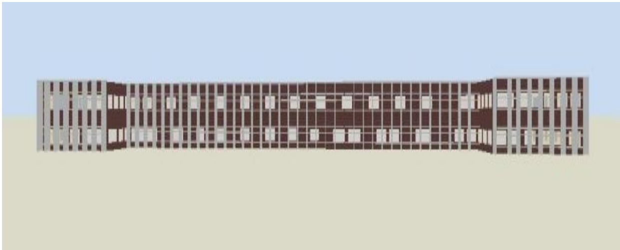

Fig 5. Front view of the building

Fig 6. Back view of the building

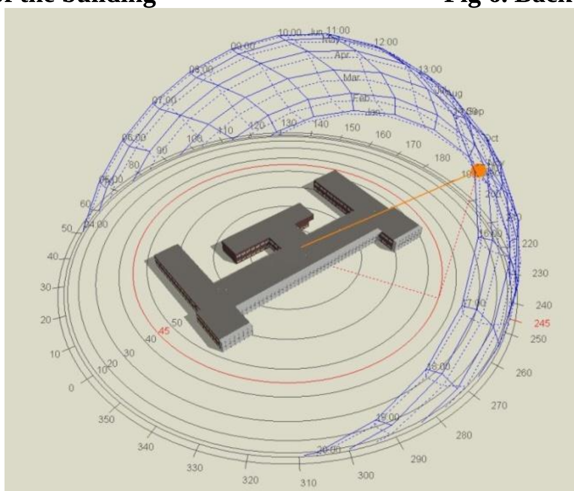

Fig 7. Sunrise and sunset pattern of the building

Sunrise and sunset pattern of the building was prepared to analyze the amount and duration of the sunlight received in different rooms in different seasons of the building which will be useful for further analysis for energy saving using sunlight.

III. RESULT AND DISCUSSION

3.1 Estimation of Baseline energy consumption of the building:

Surface area of all individual rooms was measured and light power density as per ECBC was referred. Scheduled hours of working classes in the rooms was estimated and then total power for a room and the energy consumption in kWh was calculated for each and every room and hence the total energy consumption as per ECBC standard was estimated. Working hours for lighting has been assumed to be 47.87 hours per week and the baseline energy consumption has been calculated for one year. As per baseline lighting design of ECBC the energy usage per annum comes out to be 1,95,569 kWh for the given building.

Table 1. Interior Lighting

Zone	Lighting Power Density [W/m2]	Zone Area [m2]	Total Power [W]	Scheduled Hours/Week [hr]	Consumption [kWh]/year]
FF:AUTO1	13.7	73.81	1011.2	47.87	2523.95
FF:AUTO2	13.7	251.1	3440.12	47.87	8586.54
FF:AUTO3	13.7	73.32	1004.42	47.87	2507.04
FF:AUTO4	13.7	217.98	2986.36	47.87	7453.96
FF:CHEMLAB	13.7	166.42	2280	47.87	5690.89
FF:CIVIL	13.7	199.12	2727.97	47.87	6809.03
FF:CIVIL2	13.7	75.12	1029.09	47.87	2568.6
FF:CIVIL3	13.7	75.64	1036.27	47.87	2586.53
FF:COMPUTERLAB	13.7	156.51	2144.18	47.87	5351.89
FF:EDUST	13.7	73.98	1013.47	47.87	2529.61

FF:ELEC1	13.7	72.6	994.6	47.87	2482.54
FF:LAB1	13.7	55.51	760.46	47.87	1898.11
FF:LAB2	13.7	111.59	1528.84	47.87	3815.99
FF:LAB3	13.7	53.2	728.77	47.87	1819.02
FF:LAB4	13.7	42.13	577.12	47.87	1440.5
FF:LAB5	13.7	44.55	610.34	47.87	1523.42
FF:LIBRARY	13.7	227.08	3110.95	47.87	7764.95
FF:MECH1	13.7	73.81	1011.2	47.87	2523.95
FF:MECH2	13.7	73.2	1002.84	47.87	2503.09
FF:MECH3	13.7	73.2	1002.84	47.87	2503.09
FF:TPO	13.7	28.47	389.99	47.87	973.4
GF:ACLAB	13.7	242.47	3321.77	47.87	8291.16
GF:BCLAB	13.7	76.67	1050.38	47.87	2621.75
GF:CADLAB	13.7	70.27	962.74	47.87	2402.99
GF:CONCRETELAB	13.7	102.59	1405.51	47.87	3508.16
GF:ELECLAB	13.7	133.79	1832.97	47.87	4575.09
GF:ELECLAB2	13.7	31.42	430.51	47.87	1074.56
GF:ELECLAB3	13.7	72.18	988.89	47.87	2468.28
GF:HAE	13.7	42.8	586.31	47.87	1463.44
GF:HCE	13.7	30.71	420.66	47.87	1049.98
GF:HEE	13.7	27.46	376.15	47.87	938.86
GF:HME	13.7	34.92	478.41	47.87	1194.12
GF:HYDROLAB	13.7	218.07	2987.52	47.87	7456.84
GF:JEELAB	13.7	33.75	462.32	47.87	1153.95
GF:MECHANICALLAB	13.7	201.82	2764.96	47.87	6901.36
GF:MMTLAB	13.7	41.77	572.22	47.87	1428.27
GF:PHELAB	13.7	104.14	1426.65	47.87	3560.92
GF:REFRIGERATIONLAB	13.7	185.05	2535.21	47.87	6327.89
GF:SOMLAB	13.7	99.41	1361.9	47.87	3399.29
GF:SURVEYLAB	13.7	105.25	1441.87	47.87	3598.91
GF:CORRIDOR	7.1	724.26	5142.24	47.87	12835.1
FF:CORRIDOR	7.1	772.83	5487.08	47.87	13695.8
GF:TOILET4	7.7	29.02	223.45	47.87	557.74
GF:TOILET2	7.7	32.1	247.19	47.87	616.98
GF:TOILET1	7.7	22.91	176.38	47.87	440.24
GF:TOILET3	7.7	25.79	198.58	47.87	495.67
FF:TOILET4	7.7	26.83	206.63	47.87	515.74
FF:TOILET2	7.7	51.57	397.07	47.87	991.08
FF:TOILET3	7.7	25.81	198.72	47.87	496
FF:TOILET1	7.7	25.81	198.72	47.87	496
GF:STAIR2	5.5	29.73	163.5	47.87	408.1
GF:STAIR1	5.5	20.46	112.52	47.87	280.85
GF:STAIR3	5.5	27.93	153.63	47.87	383.46
FF:STAIRS2	5.5	27.45	151	47.87	376.89
FF:STAIRS3	5.5	27.97	153.81	47.87	383.92
FF:STAIR1	5.5	17.74	97.54	47.87	243.47
GF:PRINCIPLEROOM	10	42.07	420.74	47.87	1050.17
GF:CLERK	10	29.15	291.54	47.87	727.7
GF:CASHIER	10	25.31	253.1	47.87	631.74
GF:ROOM4	10	12.67	126.66	47.87	316.15
GF:OFFICE2	10	89.76	897.6	47.87	2240.41
GF:SECURITYROOM1	10	38.52	385.22	47.87	961.51
GF:OFFICE3	10	33.44	334.36	47.87	834.55
GF:OFFICE1	10	33.44	334.36	47.87	834.55
GF:OFFICE4	10	20	200	47.87	499.2
GF:ROOM1	10	17.81	178.08	47.87	444.48

GF:ROOM2	10	9.69	96.93	47.87	241.93
GF:ROOM3	10	9.69	96.93	47.87	241.93
FF:OFFICE3	10	28.89	288.86	47.87	720.99
FF:OFFICE4	10	42.74	427.44	47.87	1066.89
FF:OFFICE5	10	49.99	499.93	47.87	1247.83
FF:ROOM4	10	13.81	138.11	47.87	344.73
FF:ROOM2	10	12.35	123.5	47.87	308.26
FF:ROOM7	10	16.26	162.63	47.87	405.92
FF:OFFICE1	10	29.89	298.9	47.87	746.05
FF:OFFICE2	10	31.64	316.37	47.87	789.66
FF:ROOM8	10	12.59	125.87	47.87	314.16
FF:ROOM6	10	10.68	106.82	47.87	266.63
FF:ROOM5	10	11.63	116.28	47.87	290.25
FF:ROOM3	10	12.68	126.82	47.87	316.56
FF:ROOM1	10	14.9	149.05	47.87	372.02
GF:CONFERENCE	10	27	270.03	47.87	673.99
GF:RECEPTION	10	27	270.03	47.87	673.99
GF:ELECROOM	6.8	13.56	92.23	47.87	230.2
GF:STORE2	6.8	30.3	206.04	47.87	514.28
GF:STORE	6.8	87.74	596.63	47.87	1489.2
GF:SPORTSROOM	8	54.26	434.11	47.87	1083.54
GF:COMMONROOM1	8	47.68	381.45	47.87	952.09
GF:CANTEEN	8	18.02	144.16	47.87	359.83
GF:STATUE	8	44.52	356.14	47.87	888.92
Total			78352.96		195569

.Table 2. Proposed Interior Lighting

Zone	**Lighting Power Density [W/m2]**	**Zone Area [m2]**	**Total Power [W]**	**Scheduled Hours/Week [hr]**	**Consumption [kWh]**
FF:AUTO1	10.8	73.81	797.15	47.87	1989.68
FF:AUTO2	10.8	251.1	2711.92	47.87	6768.95
FF:AUTO3	10.8	73.32	791.81	47.87	1976.35
FF:AUTO4	10.8	217.98	2354.21	47.87	5876.12
FF:CHEMLAB	10.8	166.42	1797.37	47.87	4486.25
FF:CIVIL	10.8	199.12	2150.52	47.87	5367.7
FF:CIVIL2	10.8	75.12	811.25	47.87	2024.88
FF:CIVIL3	10.8	75.64	816.91	47.87	2039.01
FF:COMPUTERLAB	10.8	156.51	1690.31	47.87	4219.01
FF:EDUST	10.8	73.98	798.94	47.87	1994.15
FF:ELEC1	10.8	72.6	784.07	47.87	1957.04
FF:LAB1	10.8	55.51	599.49	47.87	1496.32
FF:LAB2	10.8	111.59	1205.22	47.87	3008.22
FF:LAB3	10.8	53.2	574.51	47.87	1433.97
FF:LAB4	10.8	42.13	454.96	47.87	1135.58
FF:LAB5	10.8	44.55	481.15	47.87	1200.94
FF:LIBRARY	10.8	227.08	2452.43	47.87	6121.27
FF:MECH1	10.8	73.81	797.15	47.87	1989.68
FF:MECH2	10.8	73.2	790.56	47.87	1973.24
FF:MECH3	10.8	73.2	790.56	47.87	1973.24
FF:TPO	10.8	28.47	307.43	47.87	767.36
GF:ACLAB	10.8	242.47	2618.63	47.87	6536.09
GF:BCLAB	10.8	76.67	828.04	47.87	2066.78
GF:CADLAB	10.8	70.27	758.95	47.87	1894.33
GF:CONCRETELAB	10.8	102.59	1107.99	47.87	2765.55

GF:ELECLAB	10.8	133.79	1444.97	47.87	3606.64
GF:ELECLAB2	10.8	31.42	339.38	47.87	847.1
GF:ELECLAB3	10.8	72.18	779.57	47.87	1945.8
GF:HAE	10.8	42.8	462.2	47.87	1153.66
GF:HCE	10.8	30.71	331.62	47.87	827.72
GF:HEE	10.8	27.46	296.52	47.87	740.13
GF:HME	10.8	34.92	377.14	47.87	941.35
GF:HYDROLAB	10.8	218.07	2355.12	47.87	5878.39
GF:JEELAB	10.8	33.75	364.45	47.87	909.68
GF:MECHANICALLAB	10.8	201.82	2179.68	47.87	5440.49
GF:MMTLAB	10.8	41.77	451.09	47.87	1125.93
GF:PHELAB	10.8	104.14	1124.66	47.87	2807.15
GF:REFRIGERATIONLAB	10.8	185.05	1998.56	47.87	4988.41
GF:SOMLAB	10.8	99.41	1073.61	47.87	2679.73
GF:SURVEYLAB	10.8	105.25	1136.66	47.87	2837.1
GF:CORRIDOR	5.5	724.26	3983.43	47.87	9942.64
FF:CORRIDOR	5.5	772.83	4250.55	47.87	10609.39
GF:TOILET4	5.5	29.02	159.61	47.87	398.38
GF:TOILET2	5.5	32.1	176.56	47.87	440.7
GF:TOILET1	5.5	22.91	125.98	47.87	314.46
GF:TOILET3	5.5	25.79	141.85	47.87	354.05
FF:TOILET4	5.5	26.83	147.59	47.87	368.39
FF:TOILET2	5.5	51.57	283.62	47.87	707.91
FF:TOILET3	5.5	25.81	141.94	47.87	354.29
FF:TOILET1	5.5	25.81	141.94	47.87	354.29
GF:STAIR2	5	29.73	148.64	47.87	371
GF:STAIR1	5	20.46	102.29	47.87	255.32
GF:STAIR3	5	27.93	139.66	47.87	348.6
FF:STAIRS2	5	27.45	137.27	47.87	342.62
FF:STAIRS3	5	27.97	139.83	47.87	349.01
FF:STAIR1	5	17.74	88.68	47.87	221.33
GF:PRINCIPLEROOM	8.2	42.07	345.01	47.87	861.14
GF:CLERK	8.2	29.15	239.07	47.87	596.71
GF:CASHIER	8.2	25.31	207.54	47.87	518.03
GF:ROOM4	8.2	12.67	103.86	47.87	259.24
GF:OFFICE2	8.2	89.76	736.03	47.87	1837.14
GF:SECURITYROOM1	8.2	38.52	315.88	47.87	788.44
GF:OFFICE3	8.2	33.44	274.17	47.87	684.33
GF:OFFICE1	8.2	33.44	274.17	47.87	684.33
GF:OFFICE4	8.2	20	164	47.87	409.34
GF:ROOM1	8.2	17.81	146.02	47.87	364.47
GF:ROOM2	8.2	9.69	79.48	47.87	198.38
GF:ROOM3	8.2	9.69	79.48	47.87	198.38
FF:OFFICE3	8.2	28.89	236.86	47.87	591.21
FF:OFFICE4	8.2	42.74	350.5	47.87	874.85
FF:OFFICE5	8.2	49.99	409.94	47.87	1023.22
FF:ROOM4	8.2	13.81	113.25	47.87	282.67
FF:ROOM2	8.2	12.35	101.27	47.87	252.77
FF:ROOM7	8.2	16.26	133.36	47.87	332.86
FF:OFFICE1	8.2	29.89	245.1	47.87	611.77
FF:OFFICE2	8.2	31.64	259.42	47.87	647.52
FF:ROOM8	8.2	12.59	103.21	47.87	257.61
FF:ROOM6	8.2	10.68	87.59	47.87	218.63
FF:ROOM5	8.2	11.63	95.35	47.87	238
FF:ROOM3	8.2	12.68	104	47.87	259.58
FF:ROOM1	8.2	14.9	122.22	47.87	305.06

GF:CONFERENCE	8.2	27	221.42	47.87	552.67
GF:RECEPTION	8.2	27	221.42	47.87	552.67
GF:ELECROOM	5.5	13.56	74.6	47.87	186.19
GF:STORE2	5.5	30.3	166.65	47.87	415.96
GF:STORE	5.5	87.74	482.57	47.87	1204.5
GF:SPORTROOM	6	54.26	325.58	47.87	812.66
GF:COMMONROOM1	6	47.68	286.08	47.87	714.07
GF:CANTEEN	6	18.02	108.12	47.87	269.88
GF:STATUE	6	44.52	267.1	47.87	666.69
Total			61776.54		154194.36

Table 3. Comparison of Proposed Lighting Design v/s Baseline lighting design

Design Case	**Energy Usage (kWh/year)**	**Energy Cost (Rs/year)**	**Energy Savings (%)**	**Energy Cost Savings (%)**
Baseline Lightning Design as per ECBC 2017	1,95,569.00	15,64,552.00	-	-
Proposed Lightning Design	1,54,194.00	12,33,553.92	21.16%	21.16%

3.2.Proposed Lighting Power Density:

Proposed lighting power density is defined as space by space method of calculating power consumption considering each and every room separately using actual lighting equipment used in rooms and using the actual area of rooms. Scheduled lighting hours are assumed to be 47.87 hours per week and the consumption has been calculated for one year. It is observed that in the proposed lighting scheme the annual electrical energy consumption is 154194.36 kWh which was 195569 kWh in baseline lighting design.

IV. CONCLUSION

As compared to baseline lighting design, the proposed lighting design shows saving of 41375 kWh in a year i.e. a saving of approximately 21.16%. The Table 3 shows the comparative energy saving in proposed lighting design. Further in the proposed lighting scheme instead of tube lights, LED lights may be used and enhanced saving in energy may be calculated. Again further step may be the use of lighting sensors which may cause lights to be switched off when sufficient sunlight is available in that region and the breakeven point for saving and expenditure of sensors may be obtained.

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