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Technical, Economic and Environmental Studies Of Various Indoor Illumination Systems in an Educational Institution

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Abstract:** This study involves the various indoor illumination systems used in an engineering institution in the coastal town of Karnataka, India. The various types of illumination systems used currently are incandescent lamps, CFL lamps and fluorescent tube lights. Incandescent lamps are being used in washrooms of college building, CFLs in hostel corridors, hostel toilets and tube lights in offices, class rooms, laboratories and hostel rooms. For the experimental study a test rig was prepared with the luminaries currently used in the institution. Incandescent lamps of 10 W, 40W, 60 W, 100 W and 200 W, CFL of 9 W, 11 W, 15 W, 20 W, 35 W and LED bulbs of 4.7 W, 9 W, 10 W, 12W, 23 W were used in the test rig. Tube lights used are electronic choke, T8 of 36 W, T 12 of 40 W and LED tube lights of 4 W, 8 W, 20 W, and 22 W were used. This institution has 3 academic blocks A, B and C as well as two hostel buildings one for boys and the other for girls. The total installed illumination systems found are as follows. A block 5600 W, B Block 1464 W, C block 1,440 W, Boys hostel 3,200 W, Girls hostel 1,994 W and hence the total installed illumination systems used are of 11,710 W. As the institution is located in rural place the voltage variation was observed to be from 218 V to 245 V during the study. The incandescent lamps were found consuming 50% more power than the rated wattage, CFL were consuming 37% more power than rated wattage and LED lamps 7 % more power than rated power. The study concludes that by using new technology luminaries, we can conserve energy, environment with a simple payback period of less than an annum. The illumination equipment was bought during commencement of the institution during 2012 and have lost efficacy over the years.

Keywords:** Energy Conservation, Indoor illumination, CFL, Incandescent lamps, LED tube lights

I. INTRODUCTION

Energy is a very important resource today, fossil fuels are finite in nature, man is burning all this fossil fuel whether it for transportation or electrical and any other various purposes and is causing environmental issue. The CO_2 level in the present atmosphere is nearly four hundred PPM and it is very dangerous. Because the CO_2 level increase global warming is taking place and because of that the icebergs in the northern hemisphere like Greenland is melting which intern are responsible for the water level rise in the oceans. This rise in water level in the ocean will sink the coastal places like Goa, Karwar, Malvan, Maldives etc and all others small islands globally. For this issue human beings are only responsible and not animals and plants. This is called as anthropologic pollution. An estimated 1.1 billion humans which is 14.5% of world population did not have access to the electricity according to the energy access outlook 2017. A lot of people suffer from suffer from poor quality of electricity supply. Around 84.8% of those without electricity access which resides in rural areas and more than 95% of those without electricity access are in countries like sub-Saharan Africa and developing Asia. This clearly gives scope for enhanced capacity requirement of power generation or reducing the current consumption by adopting demand side management.

A. Energy Scenario in India

Rural population in India constitute almost 72% of its total population. At present 80% of the total villages in the country has access to grid electricity; leaving a balance of approximately 125,000 villages still waiting to be connected to the grid. Out of this 25,000 are difficult ones where extension of grid is neither technically possible nor economical [3]. Today, the rural electrification programs within the different states of India are widely diverse. Eight states (Andhra Pradesh, Goa, Haryana, Maharashtra, Kerala, Punjab, Tamilnadu and Nagaland) have achieved 100% village electrification.

Table I India: Electricity Sector Data [10]

Electricity coverage	99.97% (January 2019)
Installed capacity	356100 MW
Share of Fossil Energy	79.8%
Share of Renewable Energy	17.3%
GHG Emissions from electricity Generation (2017)	2,194.74 Mt CO2
Average electricity Use (2017-18)	1,149 Units per capita
Transmission and Distribution Losses (2016-17)	21.42%
Industrial Consumption (% of total, 2017-18)	41.48%
Commercial Consumption (% of total, 2017-18)	5.51%
Traction Consumption (% of total, 2017-18)	1.27%
Agriculture Consumption (% of total, 2017-18)	18.08%

The utility electricity sector in India has one national grid with an installed capacity of 356.100 GW as on 31st march 2019. Renewable power plants which include large hydro also, constituted 34.5% of total installed capacity. During the fiscal year 2017-18 the gross electricity generated by utilities in India was 1303.49 TWh and the total electricity generation (utilities and non-utilities) in the countries was 1486.5 TWh. The gross electricity consumption was 1149 KWh per capita in the year 2017-18. India is world's 3rd largest producer and 3rd largest consumer of electricity. Electric energy consumption in agriculture was recorded highest (17.89%) in 2015-16 among all countries. The per capita electricity consumption is low compare to many countries despite cheaper electricity tariff in India. [10]

India has surplus power generation capacity but lacks adequate infrastructure for supplying electricity to needy people. In order to address the lack of adequate electricity supply to all the people in the country by March 2019, the Government of India launched a scheme called "Power for all". This scheme will ensure continuous and uninterrupted electricity supply to all households, industries and commercial establishment by creating and improving necessary infrastructure. It is a joint collaboration of the Government of India with states to share funding and create overall economic growth. India's electricity sector is dominated by fossil fuels and in particular coal which in 2017-18 produced about 3/4th of all electricity. However, the Government is pushing for an increase investment in renewable energy. The national electricity plan of 2018 prepared by the Government of India that the country does not need additional non-renewable power plants in the utility sector until 2027, with the commissioning of 50,025 MW coal-based power plant under construction and achieving 275000 MW total installed renewable power capacity after retirement of nearly 48,000 MW old coal fired plants. [10]

India has achieved 100% electrification of all rural and urban households. As of 4 January 2019, 211.88 million rural households are provided with electricity, which is nearly 100% of the 212.65 million total rural households. Up to 4 January 2019, 42.937 million urban households are provided with electricity, which is almost 100% of the 42.941 million total urban households.

B. Illumination

A lumen is the measurement of light output from a lamp often called the tube or a bulb. All lamps are rated in lumens. For e.g. A 100W incandescent lamp produces about 1750 lumens. The distribution of light on a horizontal surface is called its illumination, which is measured in foot-candles or lux. A foot-candle of illumination is lumen of light distributed over 1sq. Ft (0.09-meter sq.) area. Another lighting term is efficacy which is the ratio of light output from a lamp to electric power it consumes and is measured in LPW (lumens/watt)[7]

II. METHODOLOGY

In our college we have seen that we have got different types of lighting fixtures namely incandescent bulb, CFL lamps, T8 and T12 tube lights. But presently we do not have LED tube lights. In the market we have seen that LED lights have come which are more energy efficient so we thought of studying comparative analysis of various lighting system i.e. incandescent lamp, CFL lamps, LED lamps, T8 & T12 tube lights, LED tube lights. The college has got two hostel buildings (boys & girls) one building has 61 rooms where 40 rooms are occupied. Whereas girls hostel has 24 rooms. Our college has got three academic buildings i.e. administrative (block A), civil engineering building (block B) and mechanical engineering (block C). we have calculated the number of tube lights, bulb of this building. We have also referred the electricity bills of this college for the last two years for cost estimation and power factor data.

We have found that our college is harvesting lot of day light by virtue of its large windows; also the walls are painted in white so that the light is reflected from the wall surfaces and it is not absorbed. We want to study the performance of this illumination system with respect to power factor, current, wattage as well as efficiency of the illumination system.

Fig I Experimental Setup Of Various Type Of Illumination System

The experimental set up is as shown in figure 1 above. It consists of 5 luminaries each of incandescent lamps, CFL and LED lamps with a digital multimeter, power factor meter and ammeter. The wattage of lamps is as follows. Incandescent lamps of 10 W, 40W, 60 W, 100 W and 200 W, CFL of 9 W, 11 W, 15 W, 20 W, 35 W and LED bulbs of 4.7 W, 9 W, 10 W, 12W, 23 W, Tube lights used are electronic choke, T8 of 36 W, T 12 of 40 W and LED tube lights of 4 W, 8 W, 20 W, 22 W were used. New LED and CFL of various ratings were procured from local markets of reputed brand only. As regards T8 and T12 old ones used in the campus were used for the study. Dark room of Engineering Physics laboratory was used for taking the illumination levels of the lamps. New measuring equipments like Watt-hour Meter, PF meter, Luxmeter, Ammeter were procured for the study.

Table II Rated Values (Based On Labels) For Various Types Of Bulbs Based On Mfr Data

Bulb Wattage in Watts "W"	Voltage V	Current I in Amps	Frequency Hz	Power Factor PF	Lumens ln	Real Power Consumed in W = V X I X PF	Efficacy Lumens/Watt
LED Lamps							
4.7	240	0.021	50	0.93	470	4.7	100
9	240	0.05	50	0.75	900	9	100
10	240	0.048	50	0.86	1100	10	110
12	240	0.06	50	>0.9	1200	13	92
23	240	0.095	50	0.9	2300	21	110
CF Lamps							
9	240	0.05	50	0.85	430	10.2	42
11	240	0.061	50	0.85	570	12.44	46
15	240	0.075	50	0.85	765	15.3	50
20	240	0.099	50	0.85	1150	20.2	57
35	240	0.28	50	0.50	2400	33.6	71
INCANDESCENT							
10	230	0.043	50	1.01	310	9.99	31
40	230	0.180	50	1.001	580	41.4	14
60	230	0.260	50	1.003	710	59.98	12
100	230	0.43	50	1.011	1340	99.98	13.4
200	250	0.8	50	1	3000	200	15

In the given table below (table 3&5) all the values were taken using calibrated voltmeters, ammeter, single phase analyser and lux meter. The values taken from the lux meter were in "lux" so it was converted into lumens using the following formula. Φ_v(lum) = Ev (lx) x Area ($m^{2)}$

All the readings were taken by placing the light sensor at a distance of 0.34 meter from the light source. [11]

Table III Experimental Values For Various Types Of New Bulbs (Actual)

Bulb Wattage, in 'W'	Voltage 'V' in Volts	Current 'I' in Amps	Frequency 'Hz'	Power Factor	Wattage (from meter), W	Lumens 'lm'	Efficacy Lumens/ Watt
LED							
4.7	241	0.021	50	0.99	5.05	517	110
9	241	0.04	50	1	9.64	654	77
10	241	0.043	50	1	10.36	983	98
12	241	0.04	50	1	12.4	765	64
23	243	0.1	50	1	24.3	1450	63
CFL							
9	243	0.04	50	1	9.72	490	54
11	243	0.042	50	1	11.74	535	49
15	243	0.06	50	1	16.5	860	57
20	244	0.08	50	1	21.7	1074	54
35	243	0.3	50	0.55	72.9	1875	54
INCANDESCENT							
10	244	0.09	50	1	21.9	66	6.6
40	244	0.41	50	1	112.1	490	12.25
60	244	0.54	50	1	135.3	703	11.7
100	243	0.92	50	1	226.9	1173	11.73
200	243	1.5	50	1	364.4	1903	9.5

The supply voltage in the campus is found to be greater than 230 V during the entire study. The power factor of CFL lamps was quite low at 0.55 when compared to incandescent lamps and LED tubelights.

Table IV Rated Values For Various Types Of Tube Lights (Based on Rated power and illumination)

Tube light Wattage, 'W'	Voltage 'V'	Current 'I' in amps	Frequency Hz	Power Factor	Lumens 'lm'	Efficacy Lumens/Watt
T8, 36W	230	0.156	50	1	2500	69
T12, 40W	230	0.18	50	1	2500	62.5
LED(T5), 4W	230	0.014	50	1	400	100
LED(T5) 8W	230	0.034	50	1	800	100
LED(T5) 20W	240	0.083	50	1	3000	150
LED(T5) 22W	230	0.095	50	1	2640	120

The efficacy of various indoor illumination systems are as follows. T8 – 69 Lm/W, T12- 62 Lm/W, LED TL – 100Lm/W. Hence it is observed that as far as tube lights are concerned LED ones give the highest efficacy among all based on the rated data given by manufacturers.

TABLE V Experimental Values For Various Types Of Tube Lights (Based on Actual Consumption and illumination)

Tube light Wattage, 'W'	Voltage 'V'	Current 'I' in amps	Frequency Hz	Power Factor	Wattage (from meter), W	Lumens 'lm'	Efficacy Lumens/Watt
T8, 36W	220	0.153	49.9	1	33.72	1000	30
T12, 40W	218	0.16	50	1	34.88	920	26
LED(T5), 4W	217	0.024	50	1	5.2	512	99
LED(T5), 8W	218	0.043	50	1	9.372	750	80
LED(T5), 20W	219	0.0865	50	1	18.9	2240	118
LED(T5), 22W	217	0.0935	50	1	20.28	1700	84

During experimentation it is found that once again the LED tube lights give the highest efficacy among all tube lights t the tune of 84 to 118 lumens / watt as compared to just 26 and 30 lm/W by earlier technology fluorescent lamps.

Table VI Rated AND Observed Wattage FOR Bulbs

Rated Wattage In 'W'	Observed Wattage In'W'	Over Rated Power In %
LED		
4.7	5.05	7.4
9	9.64	7.1
10	10.363	3.63
12	12.43	3.45
23	24.3	5.6
CFL		
9	9.72	8
11	11.74	6.3
15	16.58	9.52
20	21.58	7.06
35	72.9	51.9
INCANDESCENT		
10	21.96	54.6
40	112.1	64.3
60	135.3	55.7
100	226.9	55.9
200	364.4	45.1

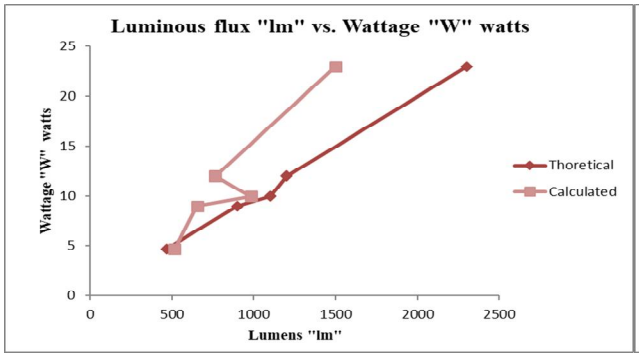

Fig II Wattage Vs Lumens For Led Bulbs

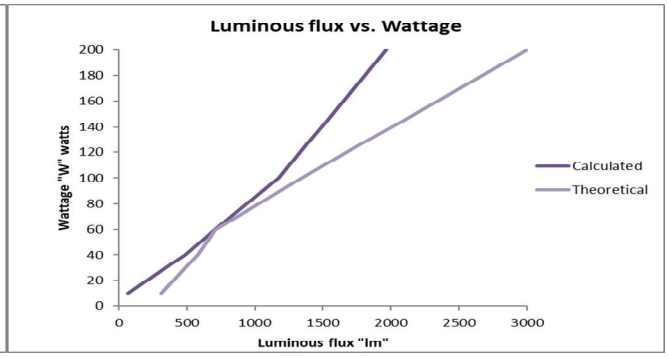

Fig III Wattage Vs Lumens For Incandescent Bulbs

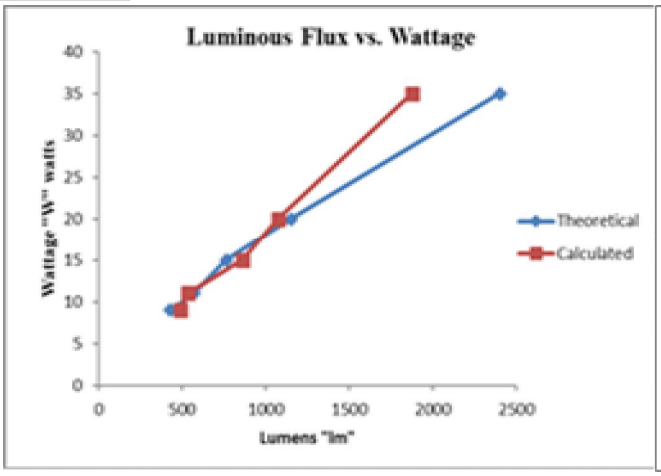

Fig IV Wattage Vs Lumens For CFL Bulb

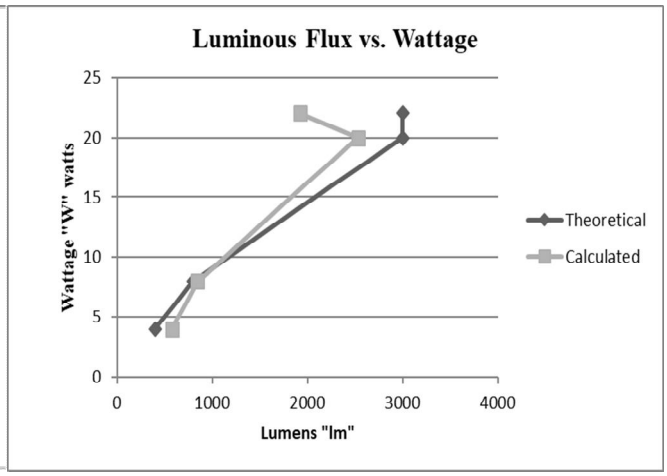

Fig V Wattage Vs Lumens For Led Tube Lights

The specifications from the various manufacturers ie s theoretical values and compared with the values that observed during testing of the lighting fixtures, it is found that the actual vales differ from the rated values as shown in above tables (2-6) and graphs (3-5). We found that the the LED bulbs take 7% more power than specified , CFL's take 31% more power than specified and Incandescent bulbs take almost 50% more power than specified . yhis shows us that CFL are more more efficient than incandescent bulbs and LED's are more efficient than both CFL as well as Incandescent bulbs. Wheareas all tubelights are consuming less power than the rated on it.

A. Economical Analysis

Secondly we recognise that the present lighting fixture in our institution has less efficiency and conssum more power and new tachnologies such as LED tubelights or bulbs are available in the market. Incase we want to replace existing with the new technology LED tubelights of 4 ft length of 20W than the payback period wiil be with in year.

The different types and numbers of tubelights, bulbs present in our college and hostel blocks wre collected for analysis. Wattages and quantities of various lights were used and caculated the power consumption.

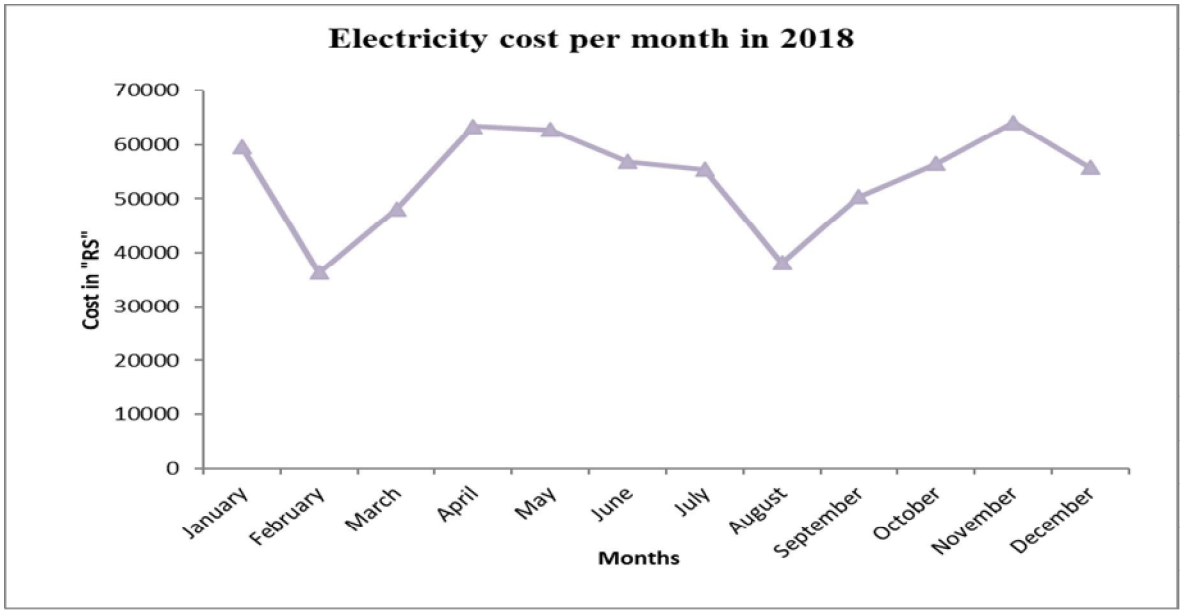

Fig VI Monthwise Electricity Cost For The Year 2018

It is observed from figure 6 that due to vacations in Jan and July the power consumption is less than the average as students are away from the institution. The average monthly cost is Rs 50,000 per month.

Table VIII no. of tubelights and bulbs at gsit

Buildings	Number of 36 W tubelights	Number of CFL Lamps of 11 W
Administrative (Block A)	98	4
Civil Engineering (Block B)	40	0
Mechanical Engineering (Biock C)	40	2
Boys Hostel	68	56
Girls Hostel	45	34

Theoratical calculation : (Tubelights used are T8 36 W & T12 40 W)
No. of tubelights in boys hostel = 68 X 36 = 2448W
No. of tubelights in girls hostel = 45X36 = 1620W
No. of tubelights in Block-A = 98 X 36 = 3528 W
No. of tubelights inBlock-B = 40 X 36 =1440 W
No. of tubelights in Block-C = (32X 36) + (8 X 40) =1472W
For CFL (11W)
No. of CFL in boys hostel =56 X11 = 616 W
No. of CFL in girls hostel =34 X 11 = 374 W
No. of CFL in Block-A = 4 X 11 = 44W
No. of CFL in Block-C = 2X 11 =22W

Table IX Recommended Lighting Levels[12]

Space type	Maintained average illuminance at working level (lux)
Bedroom	300
Lecture hall	400
Computer practice room	30
Single offices	400
Open plan offices	400
Conference rooms	300
Sports hall	300
Corridor	50
Stairs	50
Restroom	300
Washroom, bathroom ,toilets	300
Metal working or welding	300
Machine lab	300
Laboratory	500

Table X Cost Estimation Of Changing Existing T12 Tube Lights With 12w Led Tubelights For All 5 Buildings

Building	No. of tubelights	Price of 12W LED tubelight	Total cost
Block A	98	350	34,300
Block B	40	350	14,000
Block C	40	350	14,000
Boys Hostel	68	350	23,800
Girls Hostel	45	350	15,750
			Total = Rs. 1,01850

Table XI Cost Estimation Of Replacing Cfl To 9w Led Bulb For Al 5 Buildings

Building	No. of bulb	Price of 9W LED bulb	Total cost
Block A	4	249	996
Block B	0	249	0
Block C	2	249	498
Boys Hostel	56	249	13,944
Girls Hostel	34	249	8,466

Total Rs.= 23,904

There are 291 no. of tubelights (T8 36W) which gives 1130 lumens and consuming 10508Watts. If we replaced all this tubelights with 12W LED tubelights which gives 1080 lumens and consuming 3492Watts, than we can reduce 67% of power comsumption per hour.And the replacement cost will be Rs 1,01850 and the payback period for this will be only with in 1 year. However there are 96 no. of CFL lamps (11W) which gives 533 lumens and consuming 1056 Watts. If the institution replaces all this CFL lamps of 11W by LED bulb of 9W ehich gives 653 lumens and consuming 864Watts, than we can reduce 20% power consumption per hour. And the replacement cost will be Rs 23,904 and the payback period for this will be only with in 1 year.
Hence this forms our Economical study of the project.

B. Environmental Implications

Environment consideration depends on the savings occurred by change in lighting fixtures so the amount of energy saving is converted into CO_2 and accordingly we have calculated CO_2 emissions reduction per year.

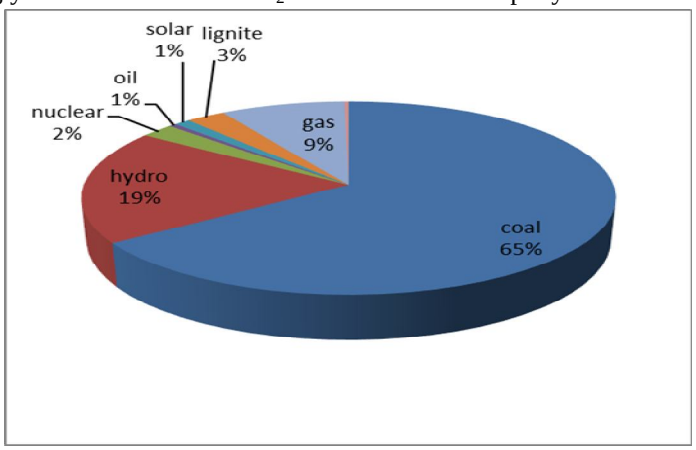

Fig VII Electricity Generation Resources Used In India

From above pie-chart we can see that 65 % of for power generation in India is from coal, which emits CO_2. The emissions per unit of electricity are estimated to be in the range of 0.91-0.95 kg/kWh for CO_2 (generation only). If we consider 20% as T&d losses that the per unit CO2 emissions will be 1.09-1.14 Kg.

C. Calculation of Environmental Impact (CO_2 Emissions)

Calculation approach – station level

CO_2 emissions of thermal stations were caculated using the formula below:

$AbsCO_2(station)_y = \sum_{i=1}^{2} FuelCon_{i,y} \text{ X } GCV_{i,y} \text{ X } EF_i \text{ X } Oxid_i$

AbsCO2,y Absolute CO2 emission of the station in the given fiscal year ‘y’

FuelConi,y Amount of fuel of type i consumed in the fiscal year ‘y’

GCVi,y Gross calorific value of the fuel i in the fiscal year ‘y’

EFi CO2 emission factor of the fuel i based on GCV

Oxidi Oxidation factor of the fuel

The CO_2 emissions can be reduced by installation of new generation illumination of new generation illumination system to the extent of 20 tonnes per annum.

Total Energy saved by replacing T8 and T12 by LED tube lights considering power charges at May 2019 rate of Rs 7.6 per kWh. Energy consumed 25% of 7000 units = 1750 units/month. Considering 20% T7D losses in power supply 0.2 x 1750 = 2100 Kg CO_2 = 21000 kg of CO_2 annually.

III. CONCLUSIONS

The study found that the supply voltage is high in the campus and though there is new technology available viz. LED tube lights the institutions are still using T8 tubelights and CFL for indoor illumination. The new technology LED lamps can be a good replacement with lesser power requirement and the payback period is also less than a year. The CO2 emissions can be reduced by installation of new generation illumination systems to the extent of 20 tonnes per annum. The incandescent lamps were consuming 55% more power than the rated power. The study can be extended to include external illumination systems and also other parameters of interest like harmonics and power quality in future. As there is change in technology and as the equipment age they loose their efficacy and hence it is prudent to study the systems at regular intervals and retrofit the luminaries with new technology fittings.

IV. ACKNOWLEDGMENT

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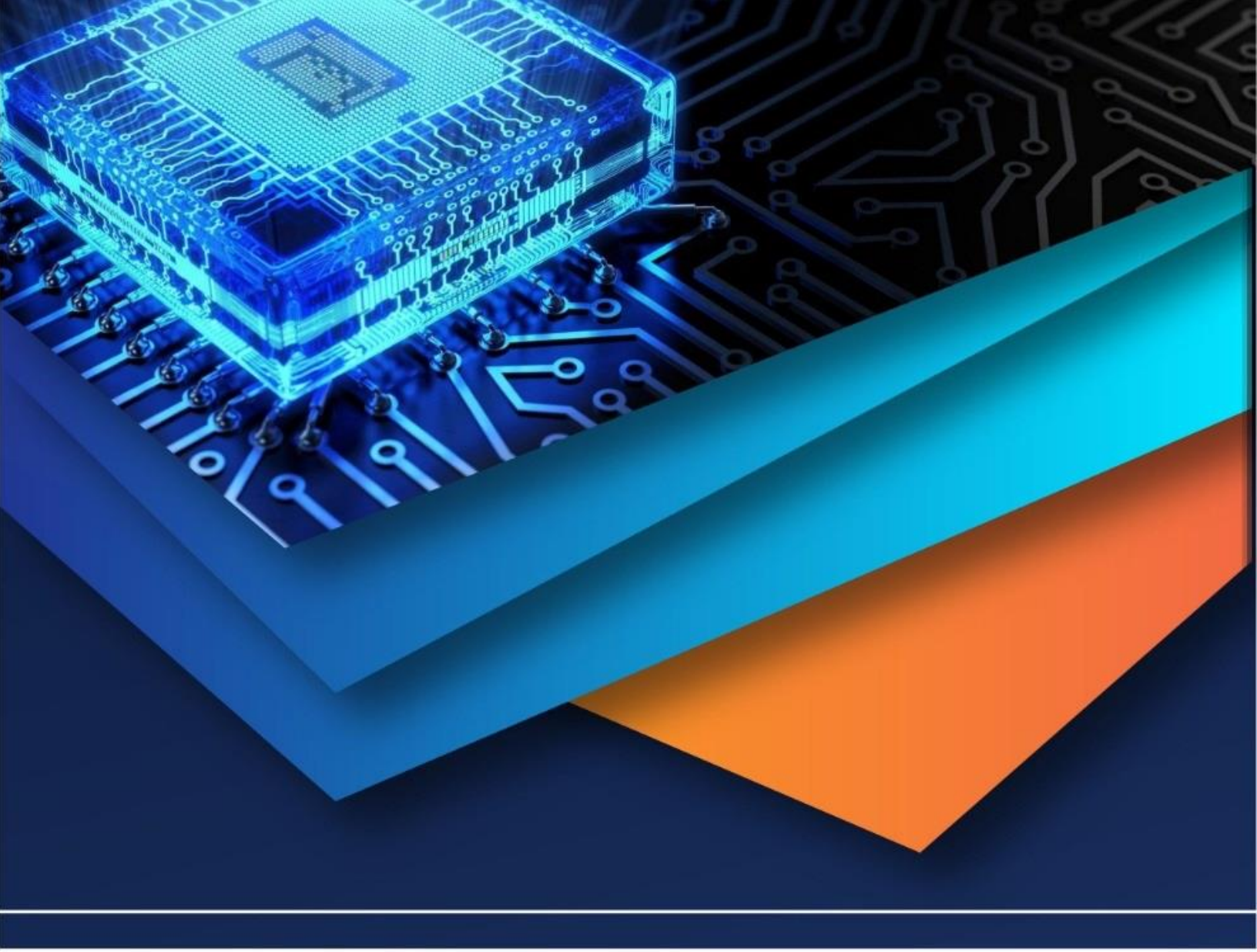

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