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Energy Audit for an educational building which operates in Middle East climatic conditions

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Abstract— *The Energy Audit done for an educational building which is working for last 20 years in the Middle East region. This region has extreme climatic conditions for both summer and winter. In summer the temperature reaches up to 48^0c or 49^0c. The energy consumption comes high at summer season. The audit conducted for electric energy consumed largely for air conditioning as well as other uses like lighting and teaching accessories. Important results getting with retrofitting the building envelop and change of lightings to LEDs. Simple payback period got as 5.49 years. A considerable savings in carbon emission is also accounted as a result of this retrofitting.*

Keywords— Energy audit, Building envelop, Energy Conservation Measures, Energy load profile, Simple payback period.

I. INTRODUCTION

Energy usage and its audit is a crucial business for any establishment. The financial benefits through the energy savings are not negligible and more important in the present energy scenario. On the other hand, the energy savings is the savings for the better environment. Auditing the energy usage and finding ways to reduce the expenses in energy utilization plays a vital role for any business establishment. The energy audit encompasses analysis of energy usage for each and every usage points within the building.[1] This audit will give out the measures to improve energy efficiency of all the equipment or facilities which uses the energy. These measures should not affect any normal performance of the building or the establishment. The ultimate aim of the energy audit is reducing the energy usage without any negative impact for the establishment and provides better savings on the long run.

Objectives of energy audit may vary according to the asset management policy. Usually it aims to understand how energy is used within the system and to find efficient measures for improvement of energy efficiency [2]. The energy audit is being done as per the type of industry or asset, functions, size of the industry and the depth of energy utilization etc. Mainly the energy audit can categorized in to two such as preliminary audit or walk through audit and the detailed audit or diagnosis audit.

Tailored rating observations are followed in this audit. The aim of the tailored rating observation is the simulation of the real conditions and behavior of the building in order to the specific requirement during the operations [3]. This approach gives an accurate results and evaluations.

Making an inventory of all electrical loads aims to answer two important questions: where the electricity is used? How much and how fast is electricity used in each category of load? By analyzing these two questions, the prioritization of the electricity-saving opportunities can be done [4]. Magnitude of energy loads is also monitored.

II. ENERGY AUDIT PREPARATION FOR THE SELECTED BUILDING

Initially the audit criteria to be defined for an effective energy audit benefits. For the selected building, following criteria has taken in to consideration. The building chosen for this energy audit is the one from a leading engineering college in Muscat, Oman. The campus includes several buildings for academic and administration uses. The building selected is centrally located which includes an assembly hall in first floor and some lecture halls on the ground floor. An IT server room is also operates from the energy connectivity of this building. The building includes common utility spaces and two stare cases. All the interiors of the building are equipped with air conditions and the lightings provided throughout the spaces. The building operates minimum 12 hours per day and five days a week.

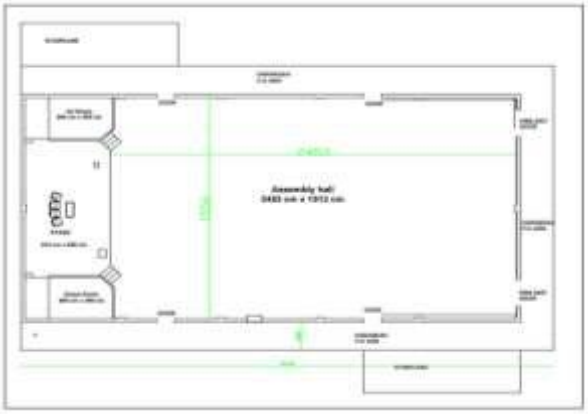

Fig.1: Lay out of Assembly Hall building

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The audit plan aims to bring out the energy usage profile for the building and detailed analysis of Air Conditioning and lighting systems. Since the building particularly includes an assembly hall, the air conditioning and lighting have to be assessed for the best performance in minimum energy usage. Assembly hall meant for gathering group of people and the comfort level is of course very important. If the optimum conditions for comfort and energy usages are not achieved, higher difference in consumption will happen. Preliminary audit or walks through audit have to be done at the beginning for an overall observation of the functions of the building. This will brought out the frequency and period of usage of all the functions of the building. The detailed audit or diagnosis audit performed for each system wise analysis of the existing usage.[5]

III. METHODOLOGY

The building uses only electricity energy from the government grid. The electricity connection already isolated from the other buildings in campus. The energy bills and energy meter readings collected from the central services of the college. They recorded energy meter readings daily basis. The peak summer usages are avoided since the assumptions and the estimates may be deviated from the root cause. The Muscat region comes high summer temperatures and excessive usage of air conditioning systems. That season to be studied separately.

The energy meter gives directly the kWh readings. The reading gives only the total usage, since the energy meter is connected to input of the electric panel. The smart WiFi energy meter used to find the individual usage of the systems particularly air conditioners for detailed diagnosis.

IV. ANALYSIS OF ENERGY USAGE

4.1 monthly bills

Analysis of energy usage can be best utilized the regularly provided electricity bills. When considering the electricity bills it has to be considered for the different components of the unit charges.The electricity charge includesonly charges for used energy units. Bill charges for 1 kWhis OMR 0.020.The municipal dues as 0.02% of the energy usage charge. There is no extra slab for quantum of usage or peak period usage. The classification provided only about commercial or domestic. In both the cases the electricity charges are well subsidized.

Table.1: Energy meter readings and effect days for the selected period of operations in OMR

#	Month	Bill date	Current reading	Previous reading	Units Consumed	No of Days	Charges	Municipal dues	Total Charges
1	42656	21/10/2013	541140	520619	20521	29	410.420	8.208	418.628
2	42687	24/11/2013	562589	541140	21449	34	428.980	8.580	437.560
3	42717	22/12/2013	576081	562589	13492	28	269.840	5.397	275.237
4	42383	31/01/2014	593025	576081	16944	36	338.880	6.778	345.658
5	42414	28/02/2014	605779	593025	12754	28	255.080	5.102	260.182
6	42443	31/03/2014	631313	605779	25534	31	510.680	10.214	520.894
7	42474	30/04/2014	648678	631313	17365	30	347.300	6.946	354.246
8	42504	31/05/2014	668937	648678	20259	31	405.180	8.104	413.284
9	42535	30/06/2014	680393	668937	11456	30	229.120	4.582	233.702
10	42565	16/07/2014	695954	680393	15561	16	311.220	6.224	317.444
11	42596	27/08/2014	721804	695954	25850	42	517.000	10.340	527.340
12	42627	23/09/2014	743387	721804	21583	27	431.660	8.633	440.293
13	42657	22/10/2014	761496	743387	18109	29	362.180	7.244	369.424
14	42688	18/11/2014	777765	761496	16269	27	325.380	6.508	331.888
15	42718	23/12/2014	797032	777765	19267	35	385.340	7.707	393.047
16	42384	22/01/2015	810223	797032	13191	30	263.820	5.276	269.096
17	42415	17/02/2015	820393	810223	10170	26	203.400	4.068	207.468
18	42444	15/03/2015	834419	820393	14026	26	280.520	5.610	286.130
19	42475	19/04/2015	858874	834419	24455	35	489.100	9.782	498.882
20	42505	19/05/2015	884535	858874	25661	30	513.220	10.264	523.484

4.2 Lighting

Florescent tube lights are using for the entire lighting except the stage lighting in the hall. Each fluorescent lighting units carries four tubes of 18w capacity. The main hall is using only on demand and the other lecture hall are using for regular teaching activities. On all this usages lights are in full use for the time period. A detailed data is available for Assembly hall usage for two years. From that data the average usage for the Assembly hall per month is 63 hours. The Table.2provided here is the observation from the walk through survey. In lecture hall usage per day is 10 hrs and weekly 5 days. I took 23 work days per month for finding monthly usage. Common passage lightings are using on all evening of work days. Passage lights are using daily at least 3 hours and a support usage found with nominal lighting throughout the night.

Table.2: Survey on lighting inventory

#	Area	Type of lighting	Number of units	Energy load in kW	Average usage per	Monthly Energy in kWh
1	Assembly hall	Florescent tubes 4 x 18 = 72w	60	4.32	63	272.16
2	Stage&green room	LED units 14 w	14	0.196	63	12.348
3	Lecture hall 1	Florescent tubes 4 x 18 = 72w	18	1.296	230	298.08
4	Lecture hall 2	Florescent tubes 4 x 18 = 72w	18	1.296	230	298.08
5	Lecture hall 3	Florescent tubes 4 x 18 = 72w	18	1.296	230	298.08
6	Lecture hall 4	Florescent tubes 4 x 18 = 72w	18	1.296	230	298.08
7	Lecture hall 5	Florescent tubes 4 x 18 = 72w	18	1.296	230	298.08
8	Lecture hall 6	Florescent tubes 4 x 18 = 72w	18	1.296	230	298.08
9	Passages	Florescent tubes 4 x 18 = 72w	80	5.76	93	535.68
		Total	**262**	**18.052**		**2608.67**

4.3 Teaching accessories

In all the rooms there are some teaching accessories which are having moderate usage while the functioning of the halls.

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Table.3: Survey on teaching aids in lecturer halls

#	Description	Type	Quantity	Power rating
1	Lecture hall 1	Projector	1	300 w
		Sound System	1	30 w
2	Lecture hall 2	Projector	1	300 w
		Sound system	1	30 w
3	Lecture hall 3	Projector	1	300 w
		Sound system	1	30 w
4	Lecture hall 4	Projector	1	300 w
		Sound system	1	30 w
5	Lecture hall 5	Projector	1	300 w
		Sound system	1	30 w
6	Lecture hall 6	Projector	1	300 w
		Sound system	1	30 w
7	Assembly Hall	Projector	1	300 w
		Sound system	1	1000 w
		Mixer	1	550 w
		Focus Lights	6	120 w
Total			**21**	**3651 w**

4.4 It server room

The building includes an IT server room which operates in full swing throughout the day and every day. IT sever room which draws 10 kW constant for all the time. Energy usage per hour for the IT server room comes as 10kW.

4.5 Air conditioning units.

The main hall provided with five HVAC packaging units of the capacity of 5 tonnage. All other lecturer hall and rooms are provided 2 Tonnagecapacity.

The total energy demand is as follows

Total lighting load = 17.856 kW

Total teaching accessories load = 3.651 kW

IT Server room =10.000 kW

Air conditioning Load = 94.110 kW

Total connected Energy Load=<u>125.617 kW</u>

Table.4: Air Conditioning units installed in the building

#	Description	Room No	Type	Qty	Power rating	Total Power
1	Classroom	A001	AGT-2T	4	2.400 kW	9.600 kW
2	Classroom	A002	AGT-2T	4	2.400 kW	9.600 kW
3	Classroom	A003	AGT-2T	4	2.400 kW	9.600 kW
4	Classroom	A004	AGT-2T	4	2.400 kW	9.600 kW
5	Classroom	A005	AGT-2T	4	2.400 kW	9.600 kW
6	Classroom	A006	AGT-2T	4	2.400 kW	7.200 kW
			Dai-2T	1	2.410 kW	2.410 kW
7	Assembly Hall	A101	Cooline-Package-11.5T	5	7.300 kW	36.500 kW
					Total	**94.110 kW**

V. DETAILED DIAGNOSIS ANALYSIS OF ENERGY USAGE

Assembly hall

Monthly usage of main assembly hall is provides major contribution in electricity bills. But this hall is not a regular usage point. As per the separate requirements, the assembly hall is using for that time period. So this is to be considered separately. TheFig.2 shows the monthly usage of assembly hall in hours.

The average usage per month for the period is 44 hrs.The energy usage for Assembly hall per hour

= AC load + Lighting Load + Hall accessories load

= 36.5 + 4.32 + 1.97 = <u>42.79 kW</u>

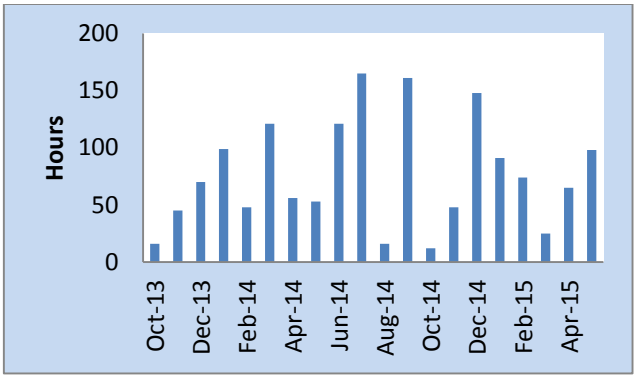

Fig.2: Usage of Assembly hall in hours

Lecturer Halls

Average usage of lecture halls per day (8 am to 8 pm) is observed as 6.5hrs per day. On an average, working days in a month has taken as 22 days. So monthly usage estimated as 6 x 22 = 132hrs per month.Energy usage for 6 lecturer hall per hour

= 6 x (AC Load + lighting load + teaching accessories load)

= 6 x (9.6 + 1.296 + 0.33) = 67.356 kW

IT Server Room

Usage of IT server room is continuous throughout the day and it is rated as 10 kW. There are some other equipment in IT server room including AC but not connected to this building lines.

Passage lights

Apart from this core usage common passage lighting is using daily.Passage lights are using 3 hours per day in all week days.

Energy usage for passage lights per hour = number of light units x power rating x time

= 80 x 72 x 1= 5760 W = 5.76 kW

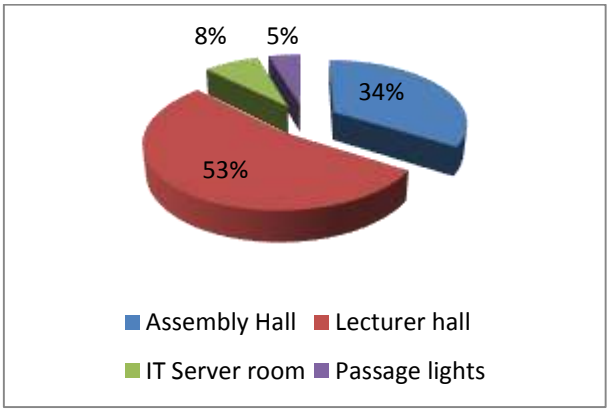

Fig.3 : Energy consumption pattern location wise

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VI. ESTIMATED CONSUMPTION AND ACTUAL CONSUMPTION

Comparing connected load and Consumed Energy, a difference of 4.79% coming which is negligible. Energy consumption per month as per the energy meter readings is 18195.800 kWhwhile the estimated usage of energy with the connected load is 19112.108kWh. For taking an average, 20 months considered.

Table.5: Comparative statement for Actual and estimated consumption

#	Location	Connected load in kW	Usage time / month in Hours	Consumption per month in kWh
1	Assembly Hall	42.790	44	1882.760
2	Lecturer Halls	67.356	143	9631.908
3	IT Server room	10.000	720	7200.000
4	Passage lighting	5.760	69	397.440
5	**Estimated consumption per month**			**19112.108**
6	**Average consumption per month taken by Energy meters**			**18195.800**
7	Percentage differance in actual and Estimation			4.79

VII. LOAD FACTOR

It is the ratio of energy consumed over a period of time in kWh to the energy which would have been consumed for the maximum demand [4]. It is normally taken in percentage.

$$LoadFacotr = \frac{Energyusedduringaperiodin kWh\ x\ 100}{Maximumdemand\ \times timeunderconsideration}$$

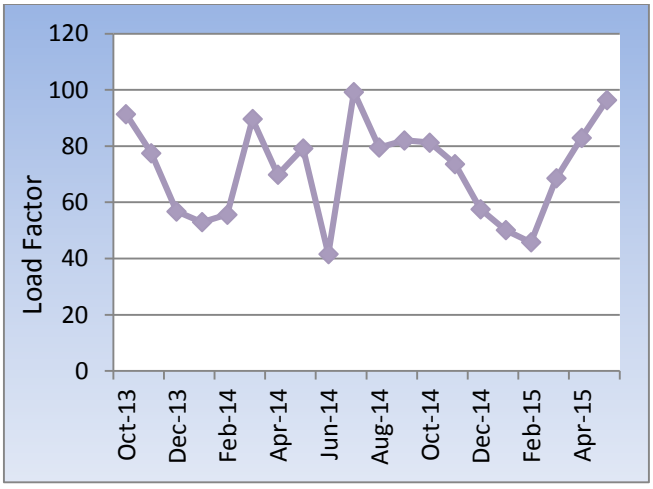

Fig.4: Load Factor plot for the seasonal variations

Load factor gets very low in December, January and February months. The reason might be the winter season of the region. Usage of the air conditioning for these months will be very less. In July 2014 the load factor reaches close to the 100% since the peak summer period. In June 2014 marked as very low Load factor. The reason investigated and found that the month Ramzan fasting was observing in the region so the building usage was less.

VIII. LOAD PROFILE

Load profile is the analysis for the energy usage for a particular day and this pattern gives a good observation about the loading of the system. Here it is providing a load profile for the day 4th January 2016. The building has 5 Distribution Boards for all the systems. Anideal DB selectedwhich is having a moderate usage throughout the day.

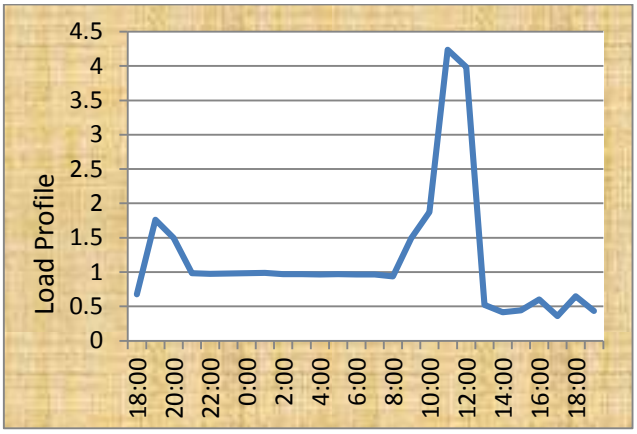

Fig.5 : Load profile for a typical day

IX. IDENTIFYING ENERGY EFFICIENCY AND COST REDUCTION OPPORTUNITIES

The energy efficiency opportunities can trace out by close monitoring of load factor performance and periodic Load Profile performances. For identifying cost reduction opportunities, initially the energy demand control to be reviewed and analyze thoroughly[6]. The second step is the analysis of equipment effectiveness or performance with a standard benchmark. Tracing out the operational and maintenance sequences schedules to be reviewed. Finally the better or modern alternative to the equipment or its accessories can bring out more energy efficient measures to the system.

X. DIAGNOSTIC ANALYSIS FOR IMPROVEMENTS IN LIGHTING

The existing lighting units are florescent tubes and one unit includes 4 tubes of 18 watts. So, one unit requires 72 watts power. Moderate illumination is getting with the help of reflectors but this can improve further with the modern LED lights. For achieving same illumination, less number of LED lightings is enough. Calculations provided with the same number of light units.

More switching controls can save excess light usage over the demanded level. At present single switches operates many lighting units at once. Automatic Switching controls can also be used for passage lightings.

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10.1 Power savings through the led installations

Table.6: Table of retrofitting on lighting energy

#	Area	Type of lighting	Number of units	Energy load in kW	Average usage per month in hours	Energy in kWh
1	Assembly hall	LED units - 14 w	60	0.84	63	52.92
2	Stage and green room	LED units - 14 w	14	0.196	63	12.348
3	Lecture hall 1	LED units - 14 w	18	0.252	230	57.96
4	Lecture hall 2	LED units - 14 w	18	0.252	230	57.96
5	Lecture hall 3	LED units - 14 w	18	0.252	230	57.96
6	Lecture hall 4	LED units - 14 w	18	0.252	230	57.96
7	Lecture hall 5	LED units - 14 w	18	0.252	230	57.96
8	Lecture hall 6	LED units - 14 w	18	0.252	230	57.96
9	Passages	LED units - 14 w	80	1.12	93	104.16
		Total	**262**	**3.668**		**517.188**

Existing power consumption for light units= 72 watts

Power of LED unit for equal illumination (or 10% better) = 14 watts

Existing monthly energy consumption for lighting = 12872.9 kWh

Usage of LED lights instead of florescent lamps = 517.188 kWh

Savings in energyfor lighting = 2608.668 – 517.188 = 2091.48 kWh

Savings in energy cost = 2091.48 x 0.02 = 41.829 OMR per month

10.2Diagnostic analysis for improvements in air conditioning

Assembly Hall area to be conditioned is very large as the height of the hall is about 6 meter. Reduction in this volume by decreasing the ceiling height will save AC usages for the Assembly hall. Thermal leakage of the ceiling recorded as shown inFig.6

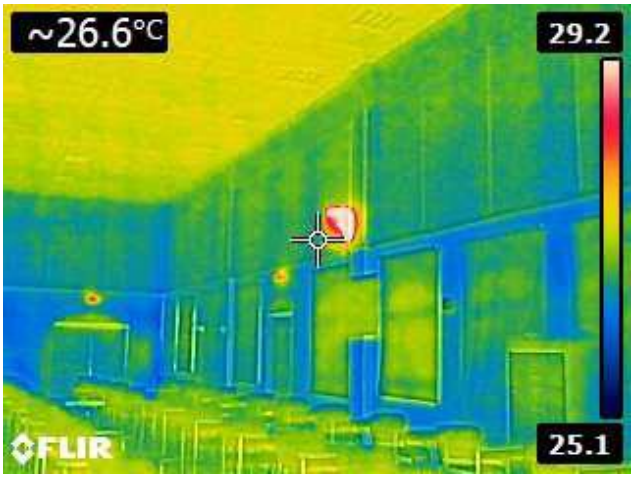

Fig.6: Thermo graphic image of heat gain through ceiling of Hall

Another point of thermal leakage is through window blinds. That can analyze through the figure captured as shown inFig.7. Dark blinds are using but the window glasses are plain and the blinds are insufficient size. These images captured during a winter season (06/01/2016). So on summer season thermal leakage impact will be more and the air conditioning load increases.

Building envelops to retrofit with the usage of less heat conductive materials in interiors. All the curtain blinds used in the lecture hall is of split leaf type and doesn't work good to protect heat radiation from outside.

Temperature controls for all the AC systems are separate for each one. So that ACs are in unbalanced loading in majority of the time. Common control for room temperature for avoiding individual system overloading and balanced operations can maintain throughout the usage.

Savings in energy for air conditioning need to get from the lecture hall since more energy is utilizing for this areas. Usage hours are more for Lecturer halls. Also the split AC systems are provided for all the lecture halls which draw more power. As per the investment concerns, the change of systems is not economical. More concentrated operational and maintenance attentions can put in place to reduce AC loads.

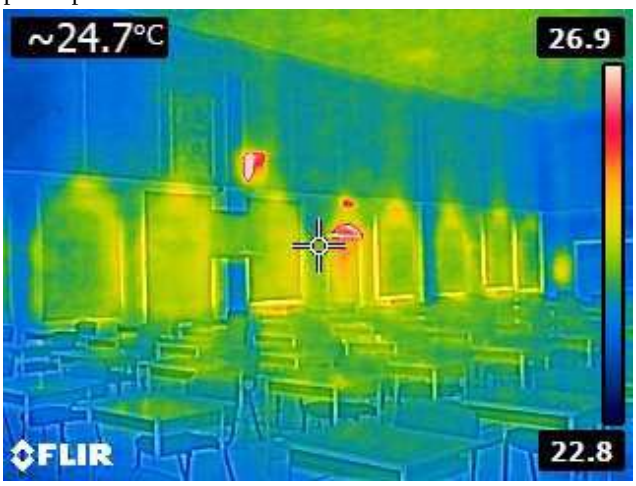

Fig.7: Thermo graphic image of heat gain through window blinds

On estimation, 8% AC load can reduce through the above said recommendations. That is 8 % of 94.11 kW is 7.52 kW.

Monthly ACs are functioning 1443 hrs average

So, savings in energy units is

= 7.52x1443 = 10851.36 kWh

Cost savings through reduction in energy usage = 217.027 OMRper month

XI. IMPLEMENTATION OF ENERGY EFFICIENCY MEASURES

The action points for implementing energy efficiency measures for lightings are as follows

In the previous sections the light energy comparisons made with LED fittings which are the latest technology in the field. From online portals, one LED light of 14w and

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60x60 size costs 35 OMR. Number of units to be replaced is 248 nos.

Purchase cost for LED lights= 248x35= 8680 OMR

Fitting charges = 600 OMR

Scarp value for the existing fittings = 200 OMR

Net cost for the LED replacement

= 8680+600-200 = **9080 OMR**

The action points for implementing energy efficiency measures for ACs are as follows

- Implement proper maintenance procedures for AC systems, since the package units are not in regular use. It requires proper check for energy effectiveness
- Rework on thermal insulation for Main hall and all the lecture halls
- Windows and blinds are focal points to maintainthermal effectiveness
- Ceiling of Assembly hall is another weak point of thermal insulation. Need to be maintained properly and reduction in ceiling height will improve the comfort level of hall
- Synchronized temperature control for each hall will improve system efficiency and energy savings

Estimated cost for the recommendations=8000 OMR

(Provided by a local contractor who is attending similar projects)

XII. COST BENEFIT ANALYSIS FOR IDENTIFIED OPPORTUNITIES OF IMPROVEMENT

As detailed in the previous sessions, the total savings in energy bills is

Table.7: Savings in energy expenditure and expenses for retrofitting

Category	Savings		Expenses
	Monthly	Yearly	
Lighting	41.829	501.948	9080
Air conditioning	217.027	2604.324	8000
Total		OMR 3106.272	OMR 17080.000

XIII. SIMPLE PAYBACK PERIOD ANALYSIS

Simple Payback Period analysis gives a one shot result for a financial investment. It gives the time period for covering the initial investment through annual returns.[7] SPP doesn't consider any other recurring costs and the discount value. Here it is chose SPP because the life expectancy for all these recommendations cannot be judged without further investigation

$$SPP = \frac{Initialinvestment}{annualreturns}.$$

$$SPP = \frac{17080}{3106.272} = 5.49 \text{ years}$$

Here the SPP is getting as 5.49 years. In the above sections the savings per month is calculated for the expected load factor of 100%. Only at one month the Load Factor achieved near to 100%. So, further investigations are required to find more accurate estimations. Energy billing has come less for some of the months than the energy savings found. The reason could be the lower load factor values.

XIV. CONCLUSION

The information about the energy usage of this building brings out the connected load usage is not utilizing to the optimum. The load factor comes to the desired value of 100% only once in the investigating period. The reason could be the importance of the building such as the assembly hall is a vital point of the campus and the IT server is also connected to the same building.

The energy reading shows high fluctuations from February 2014 to August 2014. This period requires much detail investigation for both the energy readings and usage data. Like this fluctuations needed to be avoided.

5.49 years of payback period is not much economical but the future benefits will be generating revenue further.More over the reduction in carbon emissions and benefits to the nature is the real impact with this investment. Savings in energy usage is the savings for nature and the nation [8].

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