



Energy Management Opportunities Through Energy Efficiency Retrofit for Hostel Building

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KEYWORDS

Energy Audit
Energy Efficiency
CSPF
Simple Payback
Carbon Footprint

ABSTRACT

An energy audit conducted on a building is also known as a building energy assessment. It can summarise the whole idea of a building's energy use. Conducting an audit can help business owners determine how much energy a building uses and how much of this energy is useful. It also determines where it is losing energy and which problem areas and fixes should be prioritized to make the building more efficient and comfortable. An energy audit should be the first step before making and energy-saving improvements. A targeted audit was conducted on the selected hostel building to identify the energy management opportunities and possible implementation of energy efficiency retrofit techniques. Regression and CUSUM analysis were performed on the obtained data to study the pattern of energy consumption. Recommendations were made on the energy management opportunities for energy conservation and saving with the estimation of carbon footprint.

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1. INTRODUCTION

This Targeted Energy Audit initiative is based on a report submitted by the preliminary studies which highlighted that the Energy Consumption in the Hostel Building is noticeably high and the electricity bill is expensive and it has a significant contribution to overall Annual Energy Charges [1] [2]. The Department of Electrical and Electronics Engineering initiated an Targeted Energy Audit in the specified building in order to study the pattern of energy consumption, issues, energy conservation opportunities and tabled the findings via the Energy Audit Report [3]. The building chosen for the audit is Manipal International University's Hostel building. The hostel is a 4-floor building, each floor consists of 8 Single rooms, 10 twin sharing room, 6 twin premium rooms and 8 quadruple sharing rooms. A total of 32 Rooms are available per floor. This adds up to a total of 128 rooms in the functional half of the whole hostel. The hostel floors are segregated to 2 males' floor and 2 females' floor. The hostel energy consumption contributes a significant part in the campus electricity bills.

2. RESEARCH OBJECTIVES

2.1 The following are the research objectives

- To identify the root-cause of the high Energy Utilization in the Hostel Building
- To provide recommendations on the Policies and Strategies to be adopted to enhance Energy Conservation and to reduce Energy Consumption
- To recommend Energy Efficient Technologies for improved Cost Saving
- To reduce the Building Energy Index for the chosen building
- To monitor, measure and evaluate the recommendations
- To reduce the Carbon Footprint through the Energy Efficient measures
- To do the Financial Analysis to determine the Annual cost of Saving

Energy audits of this scope can serve as a crucial foundation or launch pad for the introduction and implementation of energy management systems (EMS) in

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businesses and other institutions [4]. Energy auditing activities are required to identify the best actions to take to use energy efficiently to ensure the sustainability of energy in the future. [5]. In order to achieve net-zero emissions of carbon dioxide through decarbonization, energy efficiency is also a crucial factor [6]. The Building Energy Index (BEI), which is expressed in kWh/m²/year, is the ratio of the total energy utilised by a building in a year to the built area of the building. [7]. Energy efficiency technologies are implemented in various sectors such as construction, industries, transport and health science and telemedicine etc [8]. Energy storage devices are also being introduced [9] [10]. The preliminary audit and the measurement of readings were conducted for a week in all 4 floors to observe and analyse the usage of energy by individual rooms. The approach used for the audit was to record the units consumed by individual rooms daily for a week. The readings were taken at a fixed time. Each floor has a utility room which consist of the energy meters of the respective rooms on that floor. In addition to these readings in the duration of the audit we conducted walkthrough inspections on each floor to access any wastage of energy. The area of the Hostel building is around 40,000 square feet and located within the campus.

3. ESTIMATION OF POWER CONSUMPTION IN EACH ROOM

Table 1 shows the list of available electrical equipment with its power rating and its contribution percentage. Six numbers of compact fluorescent tube lights, one unit of non-inverter type aircon unit, two number of sockets for charging, additional one socket for ironing and one unit of dc inverter type water heating are used in each room.

Table 1. Power Consumption of each room

HOSTEL ROOM POWER CONSUMPTION ESTIMATION				
Equipment	W	Hrs	Wh	%
COMPACT FLOURESCENT TUBE - 6 Nos - 24 W	144	6	864	9.53%
AIRCON - 1HP - NON-INVERTER TYPE - 905 W INPUT - CSPF = 3.26 - 70% LOADED	635	8	5080	56.05%
SOCKET - FOR CHARGING LAPTOP AND MOBILE PHONE - 2 Nos FOR - 50W SOCKET USED FOR IRONING - 1200W - 60% LOADED	100	6	600	6.62%
WATER HEATER - DC INVERTER TYPE - 3600W - 50% LOADED	1800	1	1800	19.86%
			9064	Wh/day
			9.064	kWh/day

		271.92	kWh/Month
RM	Maximum Consumption	91.64	kWh/day
		23.75	kWh/Month
		712.5	kWh/Month
RM		240.11	

Figure 1 shows the percentage distribution of load in each room. It's obvious that the heavy consumption is mainly due to the aircon unit. In most cases, it's never switched off. The second heavy consumption is the water heater.

Power Audit - Consumption Percentage

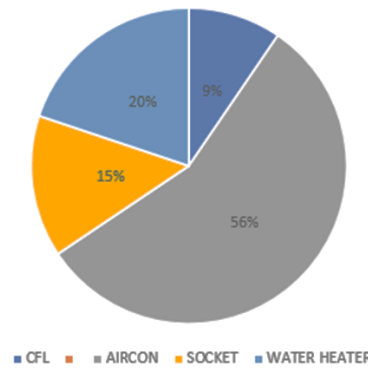


Fig. 1. Percentage of Load Distribution

3.1 Data Collection and Analysis

The collected data on the meter readings for the period of audit is shown in Table 2. This data consists of readings taken from all the rooms of various levels of the entire building. This data is then analysed to determine the consumptions by floor and by different timings of the day.

Table 2. Levelwise Power Consumption

DAY	KWH	KWH	KWH	KWH
ROOM NO	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
1.00	3.56	0.00	8.66	6.55
2.00	12.57	1.17	2.11	0.01
3.00	3.93	4.67	1.45	3.19
4.00	1.49	0.00	5.37	2.94
5.00	0.93	13.16	1.64	3.79
6.00	1.33	2.69	4.26	0.00
7.00	1.88	0.00	0.00	3.53
8.00	1.86	0.10	0.14	7.79
9.00	1.23	4.69	6.42	6.75
10.00	0.00	0.00	5.34	9.91
11.00	3.14	7.13	2.69	14.75
12.00	8.88	5.07	7.47	4.41
13.00	4.27	6.97	5.75	7.45

14.00	0.00	13.88	7.70	8.08
15.00	6.39	4.56	1.48	9.32
16.00	0.00	4.26	1.37	14.09
17.00	0.00	0.00	3.80	15.37
18.00	8.18	5.19	1.35	17.83
19.00	2.20	0.00	0.95	10.10
20.00	8.26	0.00	6.39	15.99
21.00	3.05	0.00	11.39	5.49
22.00	16.89	9.66	5.28	8.85
23.00	7.03	10.68	8.97	8.30
24.00	7.16	0.61	6.46	18.08
25.00	8.37	4.59	0.00	15.02
26.00	15.39	9.02	4.54	23.01
27.00	0.00	18.63	10.88	23.13
28.00	14.77	6.09	8.27	11.27
29.00	17.26	4.22	8.96	13.77
30.00	4.69	8.71	11.23	23.75
31.00	5.59	13.65	7.42	18.09
32.00	11.32	7.81	11.50	18.77
TOTAL	181.64	167.21	169.26	349.38

It is obvious to note that the level-4 consumption is significantly high compared to the other levels of the hostel. Special attention is given to the level-4 in view of determining the root cause of heavy consumption. The consumption on the number of rooms is found to be above the daily average demand. Measurements were taken for a continuous seven days at the fixed time daily. Measurements were done in each room to estimate the kWh consumption. It is found the Power factor Correction equipment is already installed. Table 3 shows the overall hostel building energy consumption statistics. The daily average demand per room is found to be 6.78 kW and the total average kWh consumption per day is 867.48 kW. The total average kWh consumption per month is estimated to be 26024.30 kWh and the maximum demand is 51.64 kW. A demand factor of 0.7 is used in the estimation of maximum demand.

Based on the data obtained, it can be noticed that the consumption mainly depends on the number of students in one room, level of the floor and the attitude of the students. The Table 4 shows the data of rooms higher than the daily average.

Table 3. Overall Energy Consumption Statistics

BEFORE IMPLEMENTATION	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	TOTAL
DAILY AVERAGE DEMAND (KWH) PER ROOM	5.68	5.23	5.29	10.92	6.78
TOTAL KWH CONSUMPTION PER DAY	181.64	167.21	169.26	349.38	867.48
TOTAL KWH CONSUMPTION PER MONTH	5449.15	5016.15	5077.65	10481.35	26024.30
MAXIMUM DEMAND	10.81	9.95	10.07	20.80	51.64

Table 4. Overall Energy Consumption Statistics

	ROOMS	ABOVE AVERAGE	%
LEVEL 1	32	12	0.375
LEVEL 2	32	11	0.34375
LEVEL 3	32	11	0.34375
LEVEL 4	32	22	0.6875
TOTAL	128	56	0.4375

It can be clearly seen that Level 4 consumes a huge amount of power. This is due to the frequency of the students on level 4 going out is much less compared to the remaining 3. It is also noticed that most of the students in level 4 are international students. Since it is the top floor the intensity of heat that can be accumulated in the room is also more on the top floor which may cause the students to keep the air conditioning running for longer hours. The heat rise is the reason to this. The heat will rise from lower rooms to upper rooms. More accurately, the density of air decreases as temperature rises, so hotter air will tend to rise up through buildings, where convection is possible.

By further analyzing the data the monthly consumption of each apartment is estimated assuming the trend of unit consumption is constant throughout the month compared to the readings taken. The number of days in a month is assumed to be 30 days for the calculations. Figure 3 shows the total number of units consumed for every level and total energy consumption of the whole hostel building. The highest of the demands in each level is taken as the Maximum Demand (MD) for that level.

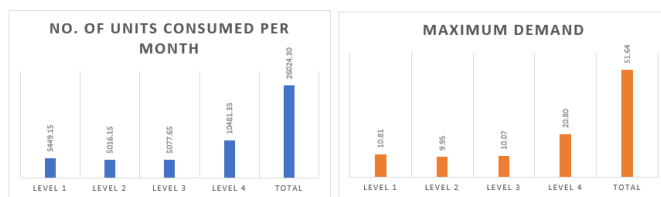


Fig. 2. Floorwise units consumption with MD

On the collected data a linear regression analysis was done for the entire hostel. The working of the linear regression is shown below. The Table 5. Shows the Cooling Degree Days (CDD) value extracted from KLIA Weather Station using the degreedays.net website [11].

Table 5. Linear Regression and CUSUM Analysis

TOTAL kWh	CDD	PREDICTED kWh	DIFFERENCE	CUSUM
1030.19	8.6	954.0628	76.1272	76.1272
835.87	10.4	827.6992	8.1708	84.298
657.55	9.6	883.8608	-226.3108	-142.0128
790.88	10.5	820.679	-29.799	-171.8118
890.16	9.7	876.8406	13.3194	-158.4924
1000.21	10.2	841.7396	158.4704	-0.022

The Figure 4 shows the Linear Regression analysis and the CUSUM Analysis of the obtained data. No significant changes were noticed in linear regression that implies the degree days are not that effective in Malaysian environment.

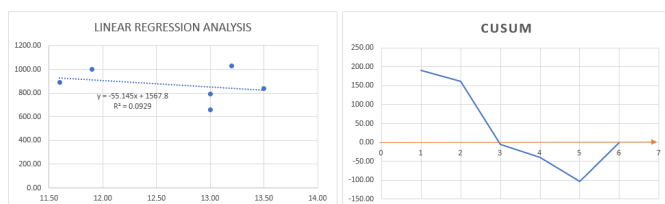


Fig. 3. Linear Regression and CUSUM Analysis

3.2 Methods and Technologies of Energy Efficiency Used

Various methods and technologies of energy efficiency were used to improve the energy conservation and saving. Based on the observation of the hostel energy consumption, the following Energy Management methods and technologies are used to improve the Energy Efficiency of the building.

- The main root-cause of the high energy consumption is mainly due to air conditioning units are left ON even though nobody in the room. Further, non-allowed equipment such as Fridge, microwave oven, cookers are found to be used by many students. This mainly goes towards the students' attitude. It was found that Energy Saving Awareness was lacking.
- All air-conditioning used in the hostel are normal split type non-inverter-based air conditioning units. These units can be replaced with energy efficient inverter type air conditioning units. The energy efficient air-conditioning units have a variable compressor speed compared to the normal units, which consume much less power.
- Water heaters were also found to be heavy load; however, the used water heaters are already energy efficient type, thus not much improvement can be made by retrofit.
- Strict policies are to be in place to warn the students with poor attitude on Energy conservation. It was recommended to introduce more disciplinary regulations to educate the students with poor attitude. To provide warning letters for those students with the room above average demand. On the third warning, students should be expelled from Hostel Accommodation.
- Energy Conservation Awareness Campaign must be organized regularly to educate the staff and students on Energy Conservation and highlight the effects of Global warming and Greenhouse gas emissions.
- Recommended to use Energy Efficient devices such as Occupational Sensors or alternatively the electronic door lock with Energy saving switch integration system to prevent wastage of energy.
- Another observation made was the absence of tints on the hostel room windows. Tinted windows can limit the heat that enters the room which in turn saves energy since the air conditioning would consume less power to cool the rooms. Also, students can be encouraged to use a temperature setting of 22°C which is considered the efficient mode for air-conditioning to function at.
- Another effective way of conserving power is to encourage students to use common areas at the hostel. The common area at the hostel has a very calm and pleasing

environment. By encouraging the students to use these areas and inducing social gatherings the consumption of units in multiple rooms can be reduced and improve social activities of individuals at the hostel.

- One of the most effective forms of conservation of energy would be to implement a prepaid power system. The concept of such implementation would make students value power much more since every KWH consumed is being charged in real time. The concept works like a touch and go card. It requires to be topped up for power to be consumed.
- Common areas such as the games room were noticed to have the air-conditioning running continuously, even though there were no occupants. Wastage of such energy can be limited by guards who patrol the hostel who could knock it off when the rooms are empty.

3.3 List of Potential Energy Savings and Methods of Calculating Potential Energy Savings in Energy Units

The following Energy Efficient Methods were employed to improve energy savings:

- Energy saving through Energy Efficient Technology Equipment Substitution
- Energy conservation techniques to reduce the kwh consumption through appreciation and incentives
- Reducing the unnecessary wastage through strict policies and regulations
- Reduction of Maximum Demand through Demand Management

The Table 6 provides the recommended plans based on the observations. The proposed No cost and the Low-cost investment plans are to be implemented immediately. However, the medium cost and high-cost investment plans are under consideration for the implementation by the senior management of the institution.

Energy conservation awareness campaign was found to be effective and special counselling were initiated to identify can counsel the students with attitude issues. Door lock power switches and blinds were installed in each room.

Table 6. Energy Efficiency Measures Recommendations

INVESTMENT PLANS	RECOMMENDATION	POTENTIAL ENERGY SAVING METHOD
No Investment Plan	i. Energy Conservation Awareness Campaign ii. Strict Measure on Students with Poor Attitude and consuming high energy even repeated warnings	Saving in kWh consumption can be achieved
Low-Cost Investment Plan	i. Installing door lock Power switches in each room ii. Blinds for the windows	Saving in kWh consumption can be achieved
Medium Cost Investment Plan	i Occupational Sensors to be installed	Saving in kWh consumption can be achieved

High-Cost Investment Plan	ii. Installation of Pre-paid Energy meters	Saving in kWh consumption can be achieved
	i. Installing Inverter based Air-conditioning units	
	ii. Installing Energy Efficient water heaters	

4. FINANCIAL ANALYSIS

The financial analysis was done based on the measurement obtained after implementation of the proposed energy efficiency measures recommended and implemented. Only the No cost and Low-cost implementation plans were implemented. The medium cost and high-cost implementation plans are considered for future implementation. The TNB Medium Voltage General Industrial Tariff is applicable to the institution in which per kwh is charged at RM0.337 per unit and the Maximum Demand charges is RM 29.60 per KW.

4.1 Simple Payback Estimation for Replacement of Inverter Aircons for all Rooms

Currently, only non-inverter aircons are used in all the rooms. A simple payback estimation for the Replacement of Inverter Aircons for all the rooms is performed. It is one of the recommendations to replace the existing non-inverter-based air-con with Inverter Air Conditioning units. The Simple Pay Back calculation is given below:

A higher Cooling Seasonal Performance Factor (CSPF) means a higher energy efficiency. CSPF is used as a deciding factor to identify the Energy Efficiency Equipment. The CSPF for the existing Air-con units is found to be 3.26 which indicates low energy efficient. The cost of the aircon increases as the CSPF value increases. Thus, two new aircon models (Daikin

and Haier) are recommended as the high energy efficiency replacement units. Daikin model is having the CSPF of 7.4 whereas the CSPF of Haier model is 5.46. Obviously, the cost of Daikin is more expensive compared to Haier model. Table 7 shows the simple payback estimation of the proposed energy efficient equipment.

The monthly energy consumption and annual electricity cost of the existing aircon unit is 34,752 units and RM 140,537.09 respectively. For the Daikin model, the monthly energy consumption and annual electricity cost of the existing aircon unit is 19,968 units and RM 80,750.59 respectively. A capital cost of RM 230,400 is required to be invested. On replacing, an annual savings of RM 59,786.50 (42.54%) is achieved with the payback period of 3.85 years.

For the Daikin model, the monthly energy consumption and annual electricity cost of the existing aircon unit is 28,416 units and RM 114,914.30 respectively. A capital cost of RM 116,480 is required to be invested. On replacing, an annual savings of RM 25,622.80 (18.23%) is achieved with the payback period of 4.55 years.

5. SAVINGS ACHIEVED IN TERMS OF RM, BEI AND CARBON FOOTPRINT

Table 8 shows the financial analysis of the Energy Efficiency Measures implemented based on the recommendations. The monthly and the annual cost of electricity before the implementation is found to be RM 10,299.62 and RM 123,595.45 respectively. The total hostel useful area is 1783.74 m2. Thus, the Building Energy Index (BEI) is estimated as 175 kWh/m2. The corresponding carbon footprint is calculated as 182,590.59 KgCo2e.

Table 7. Simple Payback Estimation on Proposed modification

SIMPLE PAYBACK CALCULATION											
AIRCON UNIT	CSPF	Watts	Hr	Days	kWh / Month	rooms	levels	Total kWh	Energy Savings	Cost (RM)	Cost / year (RM)
Non_inverter (Existing)	3.26	905	10	30	271.5	32	4	34752		11711.42	140537.09
OPTION 1											
Inverter - high CSPF (Proposed)	7.4	520	10	30	156	32	4	19968		6729.216	80750.592
Model: Daikin								Savings	14784	kWh	Annual Cost Saving RM 59786.496
					Price						% Saving 42.54%
				Capex (RM)	1800	32	4	230400			
			Payback	3.85371		years					
OPTION 2											
Inverter - Medium CSPF (Proposed)	5.46	740	10	30	222	32	4	28416		9576.192	114914.3
Model: Haier								Savings	6336	kWh	Annual Cost Saving (RM) 25622.784
											% Saving 18.23%

Capex (RM)	910	32	4	116480
Payback	4.54595	years		

Table 8. Financial Analysis of Energy Efficiency Measures

TNB TARIFF	RM 0.337 per unit	0.337	ENERGY AND COST SAVING ESTIMATION THROUGH ENERGY EFFICIENT TECHNOLOGY SUBSTITUTION			
	RM 29.6 kW	29.6				
<i>CONSUMPTION BEFORE IMPLEMENTATION</i>						
<i>Units /Month</i>	26024.3	<i>kWh</i>	<i>Cost /Month (RM)</i>	10299.6211	<i>Annual Cost (RM)</i>	123595.453
<i>Max Demand</i>	51.67	<i>kW</i>	<i>Room Area</i>	13.9355	<i>m²</i>	
			<i>Hostel Area</i>	1783.744	<i>m²</i>	
<i>Annual Consumption</i>	312291.6	<i>kWh</i>	<i>BUILDING ENERGY INDEX (BEI)</i>			175.08
<i>CARBON FOOTPRINT</i>			182690.59	<i>KgCo_{2e}</i>		
<i>CONSUMPTION AFTER IMPLEMENTATION</i>						
<i>Units /Month</i>	18195.45	<i>kWh</i>	<i>Cost /Month (RM)</i>	7200.42665	<i>Annual Cost (RM)</i>	86405.1198
<i>Max Demand</i>	36.1	<i>kW</i>	<i>Room Area</i>	13.9355	<i>m²</i>	
			<i>Hostel Area</i>	1783.744	<i>m²</i>	
<i>Annual Consumption</i>	218345.4	<i>kWh</i>	<i>BUILDING ENERGY INDEX (BEI)</i>			122.41
<i>CARBON FOOTPRINT</i>			127732.06	<i>KgCo_{2e}</i>		
					<i>ANNUAL SAVING (RM)</i>	37190.33
<i>REDUCTION OF CARBON FOOTPRINT</i>			54958.53	<i>KgCo_{2e}</i>	<i>% SAVING</i>	30.09%

The monthly and the annual cost of electricity after the implementation is found to be RM 7,200.43 and RM 86,405.12 respectively. Based on the new annual cost, the Building Energy Index (BEI) is estimated as 122.41 kWh/m². The corresponding carbon footprint is calculated as 127,732.06 KgCo_{2e}.

An annual saving of RM 37,190.33 is achieved which is equivalent to 30.09% savings. Corresponding the reduction in the BEI is 52.67 which is quite significant and the corresponding reduction in Carbon Footprint is 54958.53 KgCo_{2e}.

Overall, the saving of 30.09% is achieved just by implementing the no cost and low-cost implementation plans. Further savings can be achieved if the management approves the medium cost and high-cost energy efficient measures.

6. CONCLUSION

Energy we consume daily is not realised unless an audit is conducted. Most people are ignorant about the fact that energy is one of the important roles that play in humans' life. Large energy consuming buildings of universities, companies and industries can make a significant change in the consumption of energy in a country. The consumption at Manipal International University hostel is not to a level of over consumption but this

existing consumption can be minimised further if the initiative were taken by the cooperation of students and staff.

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