

TOWARDS SUSTAINABLE UNIVERSITY RESIDENCES: COMPREHENSIVE ENERGY AUDIT, RETROFIT TECHNIQUES AND FINANCIAL IMPLICATIONS

CĂTRE REZIDENȚELE UNIVERSITĂRII DURABILE: AUDIT ENERGETIC CUPRINS, TEHNICI DE RETROFIT ȘI IMPLICAȚII FINANCIARE

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10.37410/EMERG.2025.3.07

Abstract: *A significant amount of energy consumption at a university campus is in their accommodation buildings. This study conducts an energy audit on one of these buildings. The objectives of the study include identifying the trends in energy consumption, suggesting, and implementing, retrofitting, and measuring the economic impact of such measures. Intensive data gathering and subsequent analysis in the implementation of minor behavioral changes, energy-saving equipment usage, and major renovation, resulted in several energy conservation options. These were then categorized as low, medium, or high-cost levels. The results of the baseline showed a much higher level of energy consumption, especially in the upper floors, where more air conditioning was required. The improvement in terms of the Building Energy Index from the baseline of 175 kWh/m² to 122.41 kWh/m² of energy consumption after the recommendations were implemented was significant. This reduction amounted to financial savings as well as a reduction in the environmental footprint of the building. The economic feasibility of the suggested retrofitting was also studied through examination of the payback period of the proposed measures. Traditional air conditioning systems were replaced with energy efficient inverter systems, which provided a payback period of 3.85 to 4.55 years, bearing in mind that capital costs were recovered through the savings in energy. This article demonstrates that the effective implementation of energy management strategies in university residential buildings that reduces both energy consumption and expenditure. This*

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enhances the sustainability of the environmental resources, and our findings provide a framework which may be suitable for use by other institutions.

Keywords: Sustainable Energy Management, Energy Efficiency, Carbon Footprint Reduction, Retrofitting techniques, Payback analysis

Rezumat: *O cantitate semnificativă din consumul de energie pe un campus universitar provine din clădirile de cazare. Acest studiu realizează un audit energetic asupra uneia dintre aceste clădiri. Obiectivele studiului includ identificarea tendințelor de consum energetic, sugerarea și implementarea măsurilor de modernizare, precum și evaluarea impactului economic al acestor măsuri. Colectarea intensă de date și analiza ulterioară în implementarea unor schimbări comportamentale minore, utilizarea echipamentelor de economisire a energiei și renovările majore au dus la mai multe opțiuni de conservare a energiei. Acestea au fost apoi clasificate pe niveluri de costuri scăzute, medii sau ridicate. Rezultatele liniei de bază au arătat un nivel mult mai ridicat de consum energetic, în special la etajele superioare, unde era necesară mai multă aer condiționat. Îmbunătățirea, în termeni de indice energetic al clădirii, de la nivelul de bază de 175 kWh/m² la 122,41 kWh/m², după implementarea recomandărilor, a fost semnificativă. Această reducere s-a tradus prin economii financiare și o reducere a amprentei ecologice a clădirii. Fezabilitatea economică a modernizărilor sugerate a fost, de asemenea, studiată prin examinarea perioadei de recuperare a investiției pentru măsurile propuse. Sistemele tradiționale de aer condiționat au fost înlocuite cu sisteme cu inverter eficiente din punct de vedere energetic, care au oferit o perioadă de recuperare de 3,85 până la 4,55 ani, având în vedere că costurile de capital au fost recuperate prin economiile de energie. Acest articol demonstrează că implementarea eficientă a schemelor de gestionare a energiei în clădirile rezidențiale universitare reduce atât consumul, cât și cheltuielile. Acest lucru îmbunătățește sustenabilitatea resurselor de mediu, iar concluziile noastre oferă un cadru care poate fi utilizat de alte instituții.*

Cuvinte cheie: Gestionarea durabilă a energiei, Eficiența energetică, Reducerea amprentei de carbon, Tehnici de modernizare, Analiza perioadei de recuperare

1. Introduction

With an increasing human population and urbanization, unprecedented pressure is being put on energy demands. The reliance on conventional sources of energy brings formidable challenges in environmental sustainability. The gases emitted by fossil fuels add to global warming and jeopardize the health of our planet and its inhabitants. Energy efficient practices and technologies can help reduce total energy use across various sectors. This will reduce utility bills and help ensure the sustainability of resource management. Equipment and

systems are upgraded or replaced for better efficiency in using energy, such as lighting, Heating, Ventilation and Air Conditioning (HVAC), insulation, among others. This makes sure that each unit of energy used works is used efficiently, minimizing energy wastage and improving operational performance, leading to a lower carbon footprint. Low energy consumption means less greenhouse gas (GHG) emissions, supporting environmental sustainability and reducing the building's impact on the environment.

The buildings are one of the major sectors that use a great quantity of energy; it accounts for more than one-third of global final energy consumption and almost 40% of total direct and indirect CO₂ emissions (IEA, 2024). Currently, in many countries, the cooling demand comprises a substantial majority, surpassing 70 % of the peak Electricity demand in residential buildings is particularly high on days characterized by very high temperatures. This act has catalyzed a pronounced interest in increasing energy efficiency related to building cooling (Zhang et al, 2024). Energy conservation of campus buildings has received much attention in recent years. Due to the rapid growth of educational sector and growing student numbers in the university, the energy consumption in campus building increases tremendously. In the year 2021, over 44 million students had enrolled in higher education institutions in China (MoE, China, 2021).

Infrastructural growth and the student enrolment rate in the higher education sector is a factor in increasing energy demand. Universities use energy through different types of loads, such as lighting, HVAC systems, lifts and elevators, laboratory and research apparatuses, cafeteria appliances, gym facilities, swimming pools, accommodation buildings, etc. Student accommodation buildings, housing many occupants having different habits in a single building are one of the major energy users within universities.

Campus Energy in China accounts for approximately 8 % of the total national energy consumption. Energy Use in Educational Establishments emerges as a significant aspect of China's end-use energy consumption, which is socially vital and cannot be disregarded. The establishment of a green campus characterized by high efficiency, wisdom, low-carbon consumption, and humanity has emerged as an urgent and necessary component of campus development (Li. J et al, 2024). Home appliances count as a major source of carbon emission at various levels of society. Replacing low-efficiency appliances with high-efficiency equivalent can effectively reduce environmental impact from the demand side (Guan et al, 2024). Yang et al, 2023 highlighted that most studies were given to commercial or residential buildings, much fewer research focused on college buildings, and especially the college dormitory buildings that contribute to large energy consumptions

of campuses. Characteristics of dormitory building energy consumption differ a lot from ordinary residential buildings because of differences in occupant type, occupancy duration, involved appliances, and so on (Yang et al, 2023).

Energy curtailment is an energy consumption reduction behaviour, such as switching off energy to appliances when these appliances are not in use which helps in reducing the overall energy consumption and the financial cost. Adoption of energy curtailment behaviour, purchasing energy-saving goods and adopting household energy efficiency measures such as adjusting cooling and heating temperatures, adopting renewable energy-based appliances are vital to enhance energy conservation (Piao et al, 2023).

It is important that energy users in buildings can manage a positive behavioural change in the pursuit of carbon neutrality, where engagement by the younger generation matters, and whose gender effect should not be ignored (Du J, 2022). The Smart meters can be used proactively to determine the daily energy consumption to provide effective optimization control. These smart meters are capable to communicate with one another to regulate energy usage (Qu J, 2022). Zhang et al, 2024, highlighted that the identification of factors that significantly affect energy-saving behaviours will result in a reduction in energy consumption for both the enterprise and society as a whole. Green consumption is a low-carbon behaviour lifestyle that can reduce unnecessary resource waste and decrease carbon emissions (Li L, 2024). There are so many energy-saving measures and corresponding variables in building energy-saving retrofits. For such a complex system as buildings, the design variables of every single measure may influence building energy consumption, GHG emission, investment cost, and benefit (Shen P et al, 2024).

The suggested implications of these studies would be to focus first on those interventions with short payback periods, usually in the range of 2-5 years, to ensure a faster return on investment and greater financial attractiveness for universities that wish to manage their finances more effectively. While technological improvement is the key to saving energy, occupant behaviour cannot be underestimated. Simple, individual measures may change behaviour in the use of lighting, air conditioning, and appliances within university residences to bring about changes in energy consumption.

The academic sector uses a significant amount of energy, contributing to overall energy consumption. Therefore, it is the duty of universities to demonstrate leadership by employing sustainable practices across all functional operations. Student accommodation buildings host different types of occupants, with varying habits and needs. Sustainable energy management incorporates an integrated approach to overcoming the challenge of meeting

the needs of this diverse set of users. There are several factors attributed to high energy consumption in university residences. HVAC systems are usually the highest energy users, especially in places where extreme climatic conditions are experienced. Lighting and inefficient appliances also result in large energy usage. These consumption patterns not only translate into high operational costs for universities but are also significant contributors to environmental degradation through greenhouse gas emissions. Conducting energy audits identify the areas of high energy use and opportunities for potential savings. A comprehensive energy audit enables a university to pinpoint specific equipment, systems, or occupant behaviours that may require interventions. It provides a data-driven foundation on which to formulate strategic energy management plans.

After consumption habits have been identified, retrofitting techniques may be required to improve energy efficiency. Options include low-cost alternatives, such as installing occupancy sensors and energy-efficient lighting, and higher cost solutions, such as inverter-based HVAC systems. A decision to apply for any retrofitting should be based on a cost-benefit analysis considering up-front costs, achieved savings, and the payback period. Financial analysis plays a key role in driving energy-saving initiatives within universities. It informs us of selecting the most appropriate investment potential, that provides the highest return over the most appropriate time-period (short, medium or long). Measures with short payback time are often considered more cost-effective and are often easier to get an agreement to implement. This research presents a practical framework, demonstrating an effective approach in combining an energy audit with retrofitting, and financial analysis to achieve environmental and fiscal sustainability.

2. Research Objectives

In this research, the targeted audit technique is employed for analysis of energy consumption by selecting a specific building. The University Hostel building is selected. The primary objective of this article is to identify the cause of high energy use in a single hostel building. The article provides policy and strategy recommendations that will assist energy conservation and reduce energy use in buildings. Additionally, we recommend energy-efficient technologies that simultaneously improve cost savings and reduce the Building Energy Index. We also allow for monitoring, measurement, and evaluation of the recommendations, leading to a reduction in the carbon footprint and presenting a financial analysis to show a fiscal saving.

3. The Case Study Building

The area of the hostel building under investigation for this case study is about 40,000 sq. feet and located within the MILA University campus in Nilai, Malaysia (see Figure 1). This Targeted Energy Audit is based on a report submitted by the facilities department, highlighting that the Energy Consumption in the Hostel Building is high, resulting in high energy bills. The hostel building covers four floors. Each floor has eight single rooms, ten twin sharing rooms, six twin premium rooms, and eight quadruple sharing rooms. There are a total of 32 rooms per floor. This comes to a total of 128 rooms in the functional area of the accommodation.



Figure 1 MILA University Hostel Building

Audit and measurement of readings were collected for a week, across all four floors, to observe and analyse the usage of electrical energy by individual rooms. Each floor has a utility room, where the energy meters are housed. Energy meter readings were taken at fixed times daily. In addition, inspections on each floor were made, assessing any energy wastage.

4. Estimation Of Energy Consumption

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

Table 1 List of Electrical Equipment and its Energy Rating

| 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 | 5,080 | 56.05% |
| SOCKET - FOR CHARGING LAPTOP AND MOBILE PHONE - 2 Nos FOR - 50W | 100 | 6 | 600 | 6.62% |
| SOCKET USED FOR IRONING - 1200W - 60% LOADED | 720 | 1 | 720 | 7.94% |
| WATER HEATER - DC INVERTER TYPE - 3600W - 50% LOADED | 1,800 | 1 | 1,800 | 19.86% |

Table 1 shows the average percentage distribution of electrical load in each room. The air conditioning unit is, by far, the highest user of energy, using over half of all energy usage. It is noticed, via the walk-through inspections, that these units are hardly ever switched off. The second heaviest energy user is the water heaters. These two appliances use about 75% of the energy within the hostel building.

5. Data Analysis

This data comprises readings taken individually from all the rooms at various levels of the entire building. This data is then analysed to determine the average energy consumptions in each level.

Table 2 provides the hostel building energy consumption across each level. The daily average energy demand per room is assessed at 6.78 kWh, and the average kWh consumption per day across all floors being 867.48 kWh. The average kWh consumption per month is estimated to be approximately 26,024.30 kWh with a maximum demand of 51.64 kW. In the estimation for maximum demand, a load factor of 0.7 has been used.

Table 2 Overall Hostel Building Energy Consumption Statistics

| | LEVEL 1 | LEVEL 2 | LEVEL 3 | LEVEL 4 | TOTAL |
|---|------------|------------|------------|------------|-------------------|
| Average Consumption (kWh) per room per day | 5.68 | 5.23 | 5.29 | 10.92 | 6.78 (average) |
| Total Energy Consumption per day | 181.64 | 167.21 | 169.26 | 349.38 | 867.48 |
| Energy Consumption per month | 5,449.15 | 5,016.15 | 5,077.65 | 10,481.35 | 26,024.30 |
| Maximum Demand - Floor wise (kW) | 10.81 | 9.95 | 10.07 | 20.80 | 51.64 |

We note that level 4 consumption is about double that of any of the other three levels, investigating why this is the case.

We found that the students on level 4 left the hostel less often, compared to the other three levels. It was also noticed that most of the students, who occupied level 4, were international students who prefer to cook their meals in their rooms, consuming additional electrical energy. Since level 4 is the top floor, the heat tends to accumulate, meaning that the students will run their air conditioning for longer. More precisely, the density of air decreases with an increase in temperature, meaning that, unless convection is prevented, hotter air will tend to rise through buildings. To include the external variable factor (outside temperature) in the analysis, the cooling degree days (CDD) extracted from the nearby Kuala Lumpur international airport (KLIA) weather station is used. By further analysing the data, the monthly consumption of each apartment is estimated assuming the trend of the unit consumption is constant throughout the month compared to the readings taken. Figure 2 depicts the total number of units used at every level and the total energy consumption of the whole hostel building. The maximum demand of each level is taken as the highest of the demands in that level.

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 3 Shows the Cooling Degree Days (CDD) value extracted from KLIA Weather Station (Degree days, 2024).

Table 3 Linear regression and CUSUM analysis based on Cooling Degree Days (CDD)

| DAY | LEVEL 1 | LEVEL 2 | LEVEL 3 | LEVEL 4 | TOTAL | CDD | PREDICTED | DIFF | CUSUM |
|---------|---------|---------|---------|---------|---------|-------|-----------|---------|---------|
| 1 | 211.79 | 203.83 | 216.93 | 397.64 | 1030.19 | 8.60 | 954.06 | 76.13 | 76.13 |
| 2 | 175.23 | 148.55 | 180.18 | 331.91 | 835.87 | 10.40 | 827.70 | 8.17 | 84.30 |
| 3 | 126.99 | 125.59 | 138.21 | 266.76 | 657.55 | 9.60 | 883.86 | -226.31 | -142.01 |
| 4 | 155.97 | 162.03 | 132.86 | 340.02 | 790.88 | 10.50 | 820.68 | -29.80 | -171.81 |
| 5 | 191.81 | 171.14 | 147.70 | 379.51 | 890.16 | 9.70 | 876.84 | 13.32 | -158.49 |
| 6 | 228.04 | 192.09 | 199.65 | 380.43 | 1000.21 | 10.20 | 841.74 | 158.47 | -0.02 |
| AVERAGE | 181.64 | 167.21 | 169.26 | 349.38 | 867.48 | 9.83 | 867.48 | | |

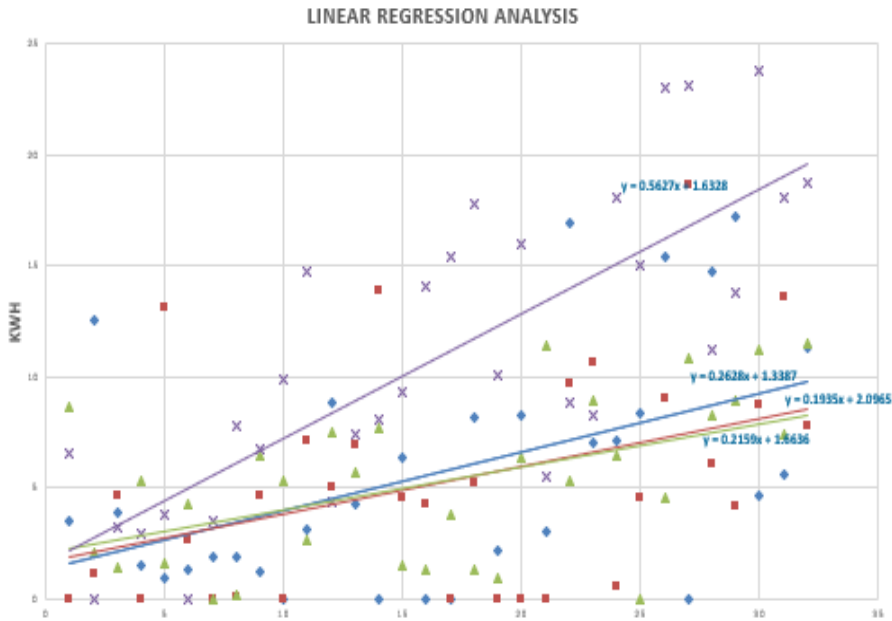


Figure 2 Linear Regression Analysis of different floors

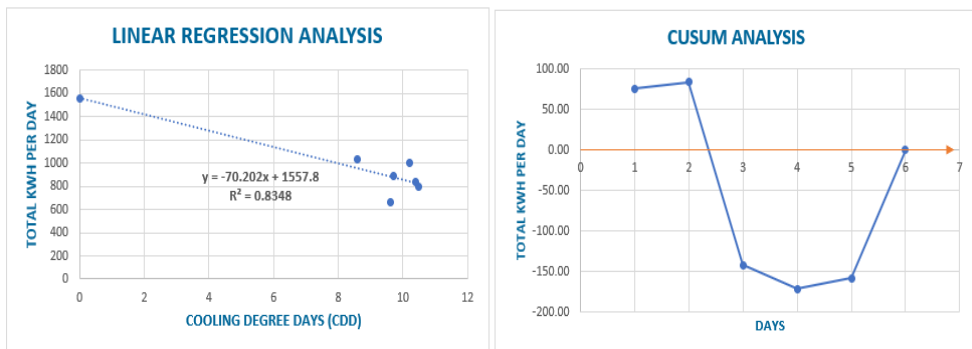


Figure 3. Linear Regression Analysis and CUSUM Analysis

Figure 3 shows the Linear Regression analysis and the CUSUM Analysis of the data obtained.

No significant changes were noticed in linear regression, which implies the degree days are not that effective in a Malaysian environment. CUSUM analysis provides the days when the consumption trend is less compared to other days. Further study can be made to understand the other conditions/factors that influence the reduction in consumption.

6. Potential Energy Saving Opportunities

Based on observation of the hostel energy consumption, the following Energy Management methods and technologies were identified to improve the Energy Efficiency of the building.

1. The primary cause of the high energy consumption is due to air conditioning units being left on, even when nobody is in the room. Further, restricted equipment such as fridges, microwave ovens and cookers were being used by many students.

2. Energy awareness among students was lacking.

3. The air conditioning units used in the hostel are normal split type non-inverter-based units. These units could be replaced with energy efficient inverter type units. The energy efficient air-conditioning units have variable compressor speed compared to normal units, resulting in less energy consumption.

4. Water heaters were found to be a high energy user. However, the water heaters are already of the energy-efficient type; thus, not much improvement can be made by retrofitting.

5. Policies should be in place to educate students on the importance of good energy management, that everybody has a role to play and every little help. This policy should be supported by the introduction of disciplinary action against those that refuse to change their behaviour, although disciplinary action should be a last resort once all other remedial actions have been exhausted.

6. Energy conservation awareness campaign(s) should be organized at regular intervals, and on an ongoing basis. The aim is to raise awareness among staff and students about energy conservation, the impact of global warming and greenhouse gas emissions. The aim is to make it socially unacceptable for staff/students to willingly waste energy.

7. Energy efficient devices, such as the use of occupational sensors with electronic door lock integrated systems should be retrofitted and justified not only through financial savings, but also through the environmental impact of such devices.

8. In this case study, we noted the absence of tinted windows. Tinted windows can help reduce the amount of heat that enters the room (Houlton, 2024), thus requiring less air conditioning to remove that excess heat.

9. Students were encouraged to use a 22°C temperature setting, which is the efficient mode for the air conditioner to function (U.S. Department of Energy, n.d.).

10. A further energy saving initiative would be to introduce prepaid cards for electrical energy utilization. Students would then have some realization how much energy they are consuming and the more they use, the more it would cost.

11. A continuous display of real time usage could be provided, so that all users could see energy use fluctuating. This information could be provided on the entire building, on a floor-by-floor basis, or even at the level of individual rooms.

12. The game room's air conditioning remained on throughout, even when empty. This kind of wastage can be controlled by security personnel who patrol the hostel on a regular basis, at least until movement sensors are fitted.

13. The D6T thermal sensor can detect stationary people based on body heat and can hence be used for the purpose of switching off useless lighting, air conditioning, etc. automatically (Omron, 2024).

7. List Of Potential Energy Savings And Methods Of Calculating Potential Energy Saving In Energy Units

Table 4 presents the recommended plans based on the energy audit findings. The No-cost and the Low-cost invested plans have already been implemented at MILA University. However, the medium-cost and high-cost investment plans, that require additional capital investment still need to be considered, and approved, by the senior leadership team.

Table 4 Energy Efficiency Measures Recommendations

| No | Investment Plans | Recommendation | Potential Energy Saving Method |
|----|-----------------------------|--|---|
| 1 | No Investment Plan | <ul style="list-style-type: none"> • Energy Conservation Awareness Campaign • Strict Measure on Students with Poor Attitude and consuming high energy even repeated warnings | Saving in kWh consumption can be achieved |
| 2 | Low-Cost Investment Plan | <ul style="list-style-type: none"> • Installing door lock energy switches in each room • Blinds for the windows | Saving in kWh consumption can be achieved |
| 3 | Medium Cost Investment Plan | <ul style="list-style-type: none"> • Occupational Sensors to be installed • Installation of Pre-paid Energy meters | Saving in kWh consumption can be achieved |

| No | Investment Plans | Recommendation | Potential Energy Saving Method |
|----|---------------------------|---|---|
| 4 | High-Cost Investment Plan | <ul style="list-style-type: none"> Installing Inverter based Air-conditioning units Installing Energy Efficient water heaters | Saving in kWh consumption can be achieved |

8. Energy Saving Measurement & Verification

In the first phase, the implementation of the No Investment Plan and the Low-Cost Investment Plans were implemented. After six months the effectiveness of these changes was measured. The same measurement philosophy was used before and after the changes to provide meaningful comparisons. Table 5 shows Energy consumption after the implementation of the first phase initiatives.

Table 5. Energy Consumption after implementation

| After Implementation | Level 1 | Level 2 | Level 3 | Level 4 | Total |
|-------------------------------------|----------|----------|----------|----------|----------------|
| Daily average demand (kWh) per room | 4.06 | 3.27 | 4.17 | 7.45 | 4.74 (Average) |
| Total kWh consumption per day | 129.99 | 104.56 | 133.60 | 238.37 | 606.52 |
| Total kWh consumption per month | 3,899.55 | 3,136.80 | 4,008.00 | 7,151.10 | 18,195.45 |
| Maximum demand | 7.74 | 6.22 | 7.95 | 14.19 | 36.10 |

Comparing Table 2 and Table 5, it can be clearly seen that there is a significant reduction in energy consumption. Figure 4 shows the comparison chart of kWh consumption and the Maximum Demand.

It is also noticed that there is a significant reduction in the maximum demand on all the levels of the hostel building. Figure 5 shows the percentage reduction of Maximum Demands of various levels.

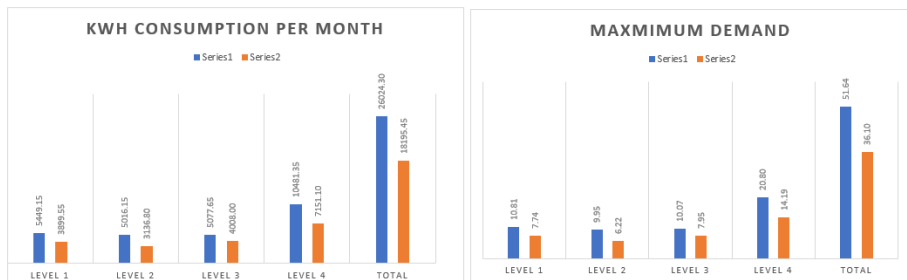


Figure 4. Comparison of Energy Consumption

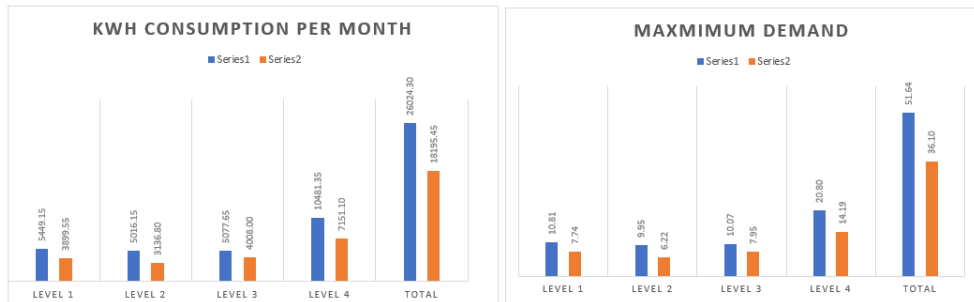


Figure 5. Percentage reduction of Maximum Demands of various levels

9. Financial Analysis

The financial analysis was done based on the measurement obtained after implementation of the no/low-cost energy efficiency measures. MILA University is classified under the TNB Medium Voltage General Industrial Tariff. For each kilowatt-hour (kWh) used, the rate is RM 0.337 per unit. Additionally, for each Kilowatt (kW) of maximum demand, the rate is RM 29.6 per kW.

9.1 Retrofit Cost Estimation

At present, all the rooms are fitted with non-inverter air conditioning units. Table 6a, 6b, 6c shows the estimate of payback for replacing them with Inverter Aircons. A high cooling seasonal performance factor (CSPF) rating indicates high energy efficiency. CSPF is a deciding factor that was used to identify and distinguish energy efficiency equipment. It was found that the CSPF for the existing Air-con units is 3.26, indicating that they are low energy efficiency-based. If the CSPF value is higher, so is the cost of the unit. Two new models (Daikin and Haier) have been suggested as replacement units, both of which are high energy efficiency units. For Daikin (resp. Haier), the CSPF is 7.4 (resp 5.46). The cost of Daikin will be more expensive compared to Haier. Table 8 shows an estimation for payback time of the proposed energy-efficient equipment.

The existing air-con unit has a consumption of 34,752 units per month, with an annual electricity cost of USD 29,513/Year. For the Daikin model, the existing aircon unit uses 19,968 units per month, with an annual electricity cost of USD 16,958/Year, requiring a capital investment of USD 48,344. Upon replacement, an annual savings of USD 12,555/Year at 43 % will be

attained with a payback period of 4 years. For the Daikin model, if it were to replace the existing aircon unit, its monthly consumption would be 28,416 units, and its annual electricity cost would be USD 24,132/Year. Requiring a capital investment of USD 24,461, replacing this would realize an annual saving of USD 5,381/Year, resulting in a payback period of 5 years, saving 18%.

Table 6a Cost Estimation – Non-Inverter type

| AIRCON UNIT | CSPF | W | Hr | Days | kWh / Month | rooms | levels | Total kWh | Energy Saving | Cost (USD) | Cost / year (USD) |
|-------------------------|------|-----|----|------|-------------|-------|--------|-----------|---------------|------------|-------------------|
| Non_inverter (Existing) | 3 | 905 | 10 | 30 | 272 | 32 | 4 | 34,752 | na | 2,459 | 29,513 |

Table 6b Estimation Simple Payback Calculation – Inverter type - Daikin

| OPTION 1 | | | | | | | | | | | | |
|------------------------------------|------|-----|----|------|----------------|-------|--------|-------------|---------------|------------|-------------------|--|
| AIRCON UNIT | CSPF | W | Hr | Days | kWh / Month | rooms | levels | Total kWh | Energy Saving | Cost (USD) | Cost / year (USD) | |
| Inverter - high CSPF Model: Daikin | 7 | 520 | 10 | 30 | 156 | 32 | 4 | 19968 | | 1,413 | 16,958 | |
| | | | | | | | | Savings | 14,784 | kWh | 12,555 | |
| | | | | | Price (USD) | | | Total (USD) | | | 43% | |
| Capex (RM) | | | | | 378 | 32 | 4 | 48384 | | | | |
| Payback | | | | | 4 years | | | | | | | |

Table 6c Estimation Simple Payback Calculation – Inverter type - Haier

| OPTION 2 | | | | | | | | | | | | |
|-------------------------------------|------|-----|----|------|----------------|-------|--------|-------------|---------------|------------|-------------------|--|
| AIRCON UNIT | CSPF | W | Hr | Days | kWh / Month | rooms | levels | Total kWh | Energy Saving | Cost (USD) | Cost / year (USD) | |
| Inverter - Medium CSPF Model: Haier | 5 | 740 | 10 | 30 | 222 | 32 | 4 | 28416 | | 2011 | 24132 | |
| | | | | | | | | Savings | 6,336 | kWh | 5,381 | |
| | | | | | Price (USD) | | | Total (USD) | | | 18% | |
| Capex (RM) | | | | | 191 | 32 | 4 | 24,461 | | | | |
| Payback | | | | | 5 years | | | | | | | |

9.2 Saving Achieved in Terms of BEI and Carbon Footprint

Table 7a and 7b shows the Estimation of Annual Cost before Implementation and the Percentage of Saving achieved after the No-cost & Low-cost Plans Implementation respectively.

Table 7a Estimation of Annual Cost before Implementation

| CONSUMPTION BEFORE IMPLEMENTATION | | | | | | |
|-----------------------------------|------------------|-----|-----------------------------|--------------------|-------------------------|----------|
| Units /Month | 26024.30 | kWh | Cost /Month (RM/Month) | 10299.62 | Annual Cost (USD/ Year) | 25955.05 |
| Max Demand | 51.67 | kW | Room Area | 13.94 | m ² | |
| | | | Hostel Area | 1,783.74 | m ² | |
| Annual Consumption | 31,2291.60 | kWh | BUILDING ENERGY INDEX (BEI) | | | 175.08 |
| | | | | | | |
| | CARBON FOOTPRINT | | 182690.59 | kgCO _{2e} | | |

Table 7b Percentage of Saving achieved after the No-cost & Low-cost Plans Implementation

| CONSUMPTION AFTER IMPLEMENTATION | | | | | | | |
|----------------------------------|------------------|-----|-----------------------------|--------------------|----------------------------|-----------|--|
| Units /Month | 18,195.45 | kWh | Cost /Month (RM/Month) | 7200.43 | Annual Cost (USD/Year) | 18,145.08 | |
| Max Demand | 36.10 | kW | Room Area | 13.94 | m ² | | |
| | | | Hostel Area | 1,783.74 | m ² | | |
| Annual Consumption | 218,345.40 | kWh | BUILDING ENERGY INDEX (BEI) | | | 122.41 | |
| | CARBON FOOTPRINT | | 127,732.06 | kgCO _{2e} | | | |
| | | | | | ANNUAL SAVING (USD / Year) | 7,809.97 | |
| REDUCTION OF CARBON FOOTPRINT | | | 54,958.53 | kgCO _{2e} | SAVING (%) | 30.09% | |

The total hostel useful area is 1,783.74 m². Thus, the building energy index (BEI) is estimated as 175 kWh/m². The carbon footprint can be

calculated as 182,590.59 kgCO₂e, based upon the new annual cost and with BEI estimated at 122.41 kWh/m². Its related carbon footprint is estimated as 127,732.06 kgCO₂e. It achieves an annual saving of USD 7,810/ Year (30.09%). The BEI, represents a reduction of 52.67 which, we believe, is significant. The corresponding reduction in the carbon footprint is 54,958.53 kgCO₂e.

10. Conclusion

This article presents a case study of an energy audit, resulting in retrofitting equipment, and financial analysis in enhancing energy efficiency within university residences. Quantifiable energy savings and reduced environmental impact resulted. Priority should be given to those cost-effective interventions supporting financial sustainability through short payback periods if long-term energy management plans are to succeed. Furthermore, responsible occupant behavior enhances technological developments to enable inclusiveness in making university residences sustainable. The energy audit identified concerning energy consumption patterns within the building. Overall energy use was high, with a particularly significant increase on the top floor. This can be attributed to increased air conditioning usage, likely due to factors such as heat accumulation on these upper levels. The Building Energy Index (BEI) served as a quantifiable measure of this inefficiency. Before any energy efficiency measures were implemented, the BEI stood at a high 175 kWh/m², translating to annual electricity costs of USD 29,555/Year. However, after implementing the planned energy-saving strategies, the BEI dropped significantly to 122.41 kWh/m². This improvement directly impacted on annual electricity costs, bringing them down to USD 18,145/Year.

The positive environmental impact is another key finding. By reducing energy consumption, the building's carbon footprint also decreased. Before implementing the efficiency measures, the carbon footprint was 182,590.59 kg CO₂e. Following the changes, this footprint dropped to 127,732.06 kgCO₂e, highlighting a notable environmental benefit.

In summary, the energy audit revealed areas for improvement and the implemented measures resulted in a significant reduction in energy use, translating to lower costs and a smaller environmental footprint. Annual electricity costs decreased by 30.09%, with total savings of USD 7,810/Year. These findings demonstrate the effectiveness of the chosen energy efficiency strategies.

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