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Energy Profiling and Building Energy Index for Residential College of Government University

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Abstract

Building energy profiling involves analyzing and understanding energy consumption across various systems within a building. The growing number of students residing in UTHM's residential college has resulted in increased energy consumption, which leads to energy waste and higher operational expenses. For this study, Tun Dr. Ismail Residential College (KKTDI) was selected to examine its energy consumption patterns and the breakdown of energy usage and also determine the Building Energy Index (BEI). The energy profiling process at UTHM Residential College comprised several stages: selecting a suitable building for the audit, collecting both desktop and field data, analyzing energy consumption patterns, identifying the breakdown of energy usage within the building systems, and calculating the BEI for KKTDI Residential College. The results reveal that KKTDI displays a varied energy consumption pattern throughout 2023. Weekly energy profiling indicates that energy consumption on weekdays is slightly higher than on weekends. In contrast, daily energy consumption patterns show that energy usage remains stable during weekdays compared to weekends. The analysis of energy usage within the building systems reveals that general equipment is the largest contributor to energy consumption, followed by lighting and the Air Conditioning and Mechanical Ventilation (ACMV) system. The BEI for KKTDI is lower than the MS1525:2019 BEI standard, indicating that the residential college uses less energy to meet its operational requirements. These findings emphasize the value of analyzing energy utilization in buildings to identify consumption patterns and assess building efficiency. This data can be leveraged in the future to locate inefficiencies and pinpoint potential energy savings throughout the building.

1. Introduction

Malaysia's energy consumption will continue to rise in conjunction with the country's goal of becoming a developed country. It has been proven that the building sector in Malaysia is the largest energy user, consuming over 40% of the total electricity usage for various activities [1]-[3]. This contributes to environmental emissions such as greenhouse gases due to excessive energy usage in the building [4]-[7]. To address this concern, Malaysia has implemented an energy efficiency program in residential, industrial and public institution buildings to reduce wasteful energy consumption and promote sustainable development [7]-[12]. By examining how energy is utilized in buildings, energy profiling is a method for identifying energy consumption patterns, inefficiencies, and potential areas for energy improvement [13]-[14]. It acts as a preliminary audit to gain a detailed understanding of user energy consumption, which can then be used to improve energy efficiency, reduce operational costs, and minimize environmental impact.

Building Energy Index (BEI) is one of the important aspects of energy profiling used to indicate building energy performance. BEI can be measured using a ratio between the annual energy consumption of a building (kWh/year) and its gross floor area [15]-[23]. According to MS1525:2019, the ideal building energy index (BEI) in the building is 200 kWh/m^2/year [24]. The highest BEI indicates that the building uses more energy to meet its operational needs. The highest energy consumption contributes to higher operating costs and a larger carbon footprint. While a lower BEI typically indicates better energy performance in the building.

Conducting energy profiling in the residential college is essential since university buildings are consistently occupied, leading to higher energy consumption. High energy consumption can result in energy waste, which raises the university's operational costs. A similar situation exists at UTHM resulting from the increasing number of students living in the residential college. Energy waste occurs when more energy is used than necessary to perform an activity within the facility. It often stems from inefficient energy practices, outdated equipment, or poorly optimized systems, leading to unnecessary consumption of energy resources. Therefore, these studies aim to analyze the energy consumption pattern, breakdown of energy usage, and the BEI range in the UTHM residential college.

2. Background Study

A student residential college is a housing facility or dormitory specifically designed for college or university students. These residential colleges are more than just dorms and typically serve as a community for students to live in, engage with one another, and participate in academic and social activities. Residential colleges vary in structure and organization but share a common feature. Energy consumption in residential colleges faces a unique challenge due to the high demand for energy usage in the facilities. The higher energy consumption in student residential colleges is mainly due to the large number of occupants, leading to increased demand for lighting, cooling, and other activities. Frequent use of common areas like computers and study rooms also adds to energy use. Furthermore, students' intensive use of modern devices and appliances such as laptops raises energy usage. Older buildings with outdated energy systems, which are less energy-efficient, contribute to higher energy usage. Thus, energy profiling is required to better understand energy usage patterns in the student residential college.

In 2017, a research study was conducted at KKTDI Residential College to examine the energy profile of a public university's residential college [25]. The study aimed to monitor energy consumption over six months, with the data used to analyze average energy usage during the semester and semester break. The findings revealed that energy consumption was higher during the semester than during the break. The study was confined to evaluating the average energy consumption over a six-month period and determining the building energy index for KKTDI Residential College. Thus, this study can be considered a preliminary energy audit for monitoring energy consumption in residential colleges. In 2019, a case study on Tun Fatimah Residential College (KKTF) was conducted to investigate the possibility of energy savings [26]. The study intends to determine building energy usage, user behavior, and energy-saving strategies that can be implemented at KKTF College. This paper's findings indicate that energy usage in KKTF is higher than in the KKTDI college even though it has the same building structure. However, this paper focuses solely on suggesting energy-saving strategies applicable to the residential college based on the energy consumption analysis conducted.

Other studies at KKTF College focus on the Building Energy Index (BEI) and Energy Efficiency Measures. This study focuses on measuring the gross floor area of the KKTF college and gathering data for the annual power bill to determine the building energy index. The results indicate that the BEI calculation is significantly lower than the MS1525:2017 standard [27]. The study's research gap is the insufficient depth of the energy audit approach and the identification of energy-saving methods based on no-cost measure categories. Universiti Teknologi Mara (UITM Perak) conducted an energy audit for its university accommodation. The audit focused on the process in selected UITM accommodation buildings and identified practices to improve energy consumption. The paper highlights the key criteria in an energy audit, comparing the energy management processes of the selected buildings through energy consumption analysis. The number of electrical appliances, equipment, machinery, and building operations affects energy consumption and efficiency. The study utilized HOMER software to analyze and

Int. Journal of Integrated Engineering Vol. 17 No. 8 (2025) p. 78-88

generate energy profiles and usage patterns, a tool typically used in preliminary audits. However, the research primarily addresses key audit procedures in Malaysian institutions from the perspectives of recognized energy audit professionals [28].

3. Methodology

Energy profiling conducted in the UTHM residential college required a few stages: choosing a suitable building to be audited, collecting desktop and field data, analyzing energy consumption patterns, identifying the breakdown of energy usage in buildings, and calculating BEI for KKTDI college. The outcomes from this study will assist to shape plan for improving energy efficiency and reducing overall energy consumption. By implementing targeted actions based on the data, UTHM may advance towards a more sustainable future.

3.1 Building Information

Tun Dr. Ismail Residential College (KKTDI), located at the main campus of UTHM, Parit Raja, has been selected as the suitable building for these studies. This residential college consists of four dormitory blocks and is always occupied by students and staff. It has various facilities such as a management office, discussion room, laundry room, cafeteria, and mini market. Fig. 1 and Table 1 illustrate the KKTDI building layout and provide additional building information.

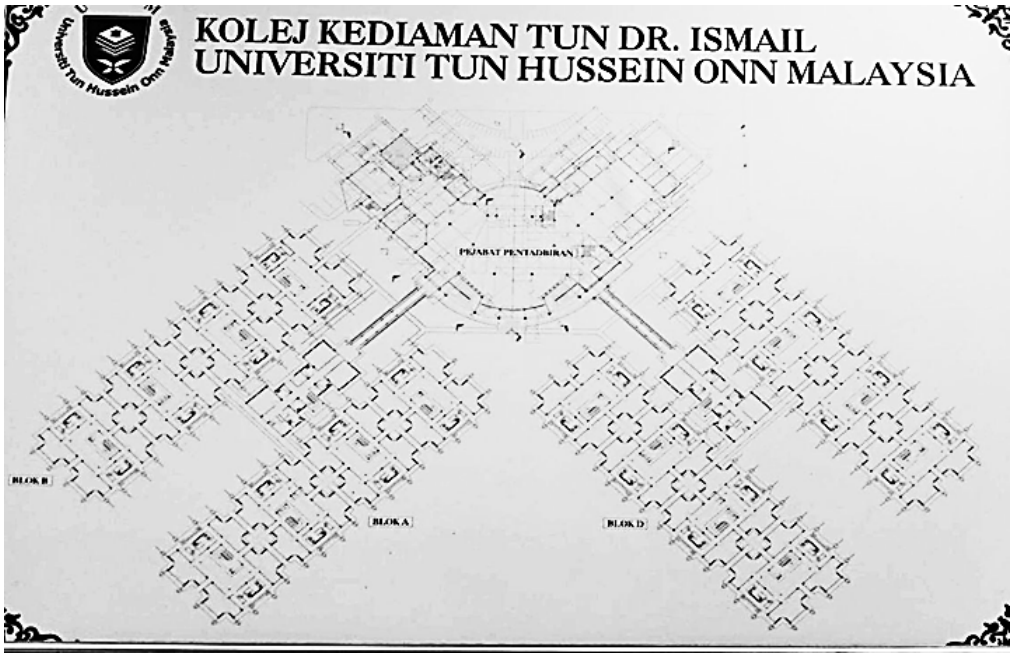

Fig. 1 *KKTDI building layout*

Table 1 *Building information details*

Type of building information	Details
Building	Kolej Kediaman Tun Dr. Ismail
Parcel	Universiti Tun Hussein Onn Malaysia (UTHM)
Address	Persiaran Tun Dr. Ismail, 86400 Parit Raja, Johor
General office hours	8.00 am to 6.00 pm (Sunday – Thursday)
Electricity tariff	Tariff C1
Gross floor area	28,599.52 m^2
Number of occupancies	468 students (male)
Number of rooms occupied	94 room

3.2 Data Collection

Desktop and field data collection are two different methods of gathering the KKTDI energy consumption data. Desktop data collection involves collecting data from existing documents, such as utility bills, historical energy

consumption data, technical drawings, building information, and equipment specifications. This approach helps reduce the time and manpower required for subsequent processes. However, field data collection involves on-site inspections and physical measurement of systems and equipment, such as general walk-throughs in the building and power logging activity. This approach assists in determining the building's present state of operation and maintenance to gather the necessary data.

3.3 Analysis of Building Energy Consumption Pattern and Breakdown of Energy Usage

The energy consumption pattern in KKTDI Residential College can be analyzed using desktop and field data collection. This method helps identify the breakdown of energy usage within the building, enabling the determination of the building's energy profile and the KKTDI Building Energy Index (BEI). Below, indicates the process used to obtain the annual, weekly, and daily energy consumption patterns for KKTDI Residential College.

3.3.1 Annual Energy Profiling

Historical monthly energy consumption data for all buildings at UTHM was gathered using the SCADA system installed in each building's utility room. This system collects energy consumption data at 10-minute intervals, which allows for the creation of detailed consumption profiles for each building over the course of a month. This data serves as utility information for UTHM to monitor and track energy usage within the buildings. KKTDI College also uses SCADA systems in its utility room to keep track of and record how much energy the building uses each month. An analysis of the recorded energy consumption data can help identify patterns in energy usage at the KKTDI residential college over the years. This information is instrumental in understanding how energy is utilized at KKTDI College for the year 2023.

3.3.2 Weekly Energy Profiling

The process involved identifying the energy consumption pattern for the week by installing a power logger to track and record energy use at KKTDI College. Power data logging was conducted in the KKTDI main distribution board room, where the power logger was clamped onto the distribution board. This setup monitored all electrical systems in the building to measure running current, power, and voltage, enabling the estimation of energy usage patterns. The installation of the power logger adhered to the manufacturer's manual and guidance from a qualified chargeman. Power logging measurements were taken over the course of a week, as recommended by the Energy Commission (ST) [29]. After the logging period, the collected data were downloaded and analyzed to create the energy profile for the building. These data were then presented in charts and tables to examine energy consumption patterns over the week.

3.3.3 Daily Energy Profiling

The daily energy consumption pattern in KKTDI College can be determined using the power logger activity and the energy consumption estimation equation. The power logger activity involves capturing energy data at 30-minute intervals over 24 hours, from 8:00 AM to 8:00 AM the next day, to monitor and establish the daily energy usage pattern in the building. In addition, the Energy Consumption Estimation equation predicts daily energy consumption by calculating the total quantity of all equipment in the building with the rated power and multiplying it by the operational hours [30]. This estimation focuses on three major systems: lighting, ACMV, and general equipment. The equation can also assess breakdown energy usage in the KKTDI buildings. Both methods can be compared to evaluate the accuracy of daily energy usage in the KKTDI buildings. The equation used is shown in Eq. (1).

$$\begin{aligned} &Energy\ Consumption\ (kWh) \\ &= Total\ Quantity\ of\ Equipment \times Rated\ Power\ (W) \times Usage\ Hours\ (h) \end{aligned} \tag{1}$$

3.4 Building Energy Index

The energy performance of the KKTDI residential college building is evaluated using the Building Energy Index (BEI) equation, which is presented in Eq. (2).

$$BEI = \frac{Annually\ Total\ Energy\ Consumption\ \left(kWh/Year\right)}{Total\ Gross\ Floor\ Area\ (m^2)} \tag{2}$$

Int. Journal of Integrated Engineering Vol. 17 No. 8 (2025) p. 78-88

4. Results and Discussion

This section presents the annual, weekly, and daily energy consumption patterns in the KKTDI Residential College, along with a detailed breakdown of energy usage within the college. Additionally, this section includes the calculation of the Building Energy Index (BEI) for the KKTDI Residential College.

4.1 KKTDI Energy Profiling

This subsection presents the annual, weekly, and daily energy consumption patterns that occur in the KKTDI Residential College to analyze the building's energy performance. By understanding these patterns, it is crucial to identify the KKTDI maximum and minimum energy usage, as well as the potential areas for energy efficiency improvement in the future.

4.1.1 Annual Energy Profiling

Table 2 provides the energy consumption data for KKTDI Residential College for the 12-month period of 2023. Based on information gathered from the SCADA system, the total energy consumption for KKTDI Residential College in 2023 is 940,444 kWh, which results in an average monthly energy consumption of 78,730 kWh. These figures serve as indicators for assessing the energy performance of KKTDI Residential College and reflect the energy consumption patterns over the course of the year.

Table 2 *Energy consumption data for KKTDI over 12-month period in 2023*

Month	Energy consumption (kWh)
January	63,641
February	79,680
March	36,601
April	29,503
May	84,737
June	111,247
July	111,773
August	46,941
September	34,373
October	96,134
November	122,644
December	123,170
Total energy consumption (kWh)	940,444
Average energy consumption (kWh)	78,370

Fig. 2 illustrates the monthly variation in energy consumption within KKTDI Residential College throughout 2023. The graph reveals clear seasonal and behavioural energy trends tied to the university's academic calendar and student occupancy patterns. Energy consumption varies significantly across the year, ranging from the lowest consumption (29,503 kWh) in April to the highest consumption (123,170 kWh) in December. These differences demonstrate a strong dependence on student presence and campus activity levels. The trends of increasing and decreasing energy consumption align with the UTHM academic semester and the dynamic rhythm of campus life.

The academic schedule at UTHM closely influences the energy consumption pattern at KKTDI Residential College. Semester 1 which runs from October to February, shows a gradual increase in energy usage, peaking in December as academic activities and lectures become more intense. This rise likely coincides with students returning after a long break and fully engaging in academic and student life. Similarly, Semester 2 from March to July, also exhibits a positive trend as it marks the beginning of the second semester and a resumption of academic activities. In contrast, energy consumption significantly decreases during the semester breaks in August and September, reflecting reduced occupancy as students vacate the dormitories. A notable anomaly occurs in April, when energy consumption hits its lowest point for the year. This decline can be attributed to a natural disaster that temporarily disrupted on-campus activities, leading to a shift to online teaching and prompting students to return to their hometowns. This event underscores the sensitivity of KKTDI Residential College's energy demand to unexpected disruptions and occupancy levels, which are key factors influencing overall consumption.

Besides that, student behaviors significantly influence energy consumption in KKTDI Residential College. During lecture periods, students tend to spend more time indoors working on assignments, research, and projects, which increases their use of laptops, lights, and cooling devices. Energy consumption also spikes during exam periods as students study late into the night, relying heavily on lighting, laptops, and other electronic devices. Moreover, the social dynamics among roommate impact energy consumption behaviors in dormitories. As students share living spaces, their social interactions and group norms influence their energy-use habits. For instance, habits such as not unplugging devices and having multiple fans or shared lighting contribute to higher energy usage in the dorms.

Over time, these dynamics tend to stabilize, creating consistent energy consumption patterns that recur each semester. While academic and behavioral factors primarily drive these trends, seasonal changes also play a role in the rising energy consumption at KKTDI Residential College. For example, the increased ambient temperatures from May to July lead to a higher demand for cooling, resulting in more frequent fan usage. Consequently, the observed peaks in energy consumption are influenced not only by academic activities but also by climatic factors.

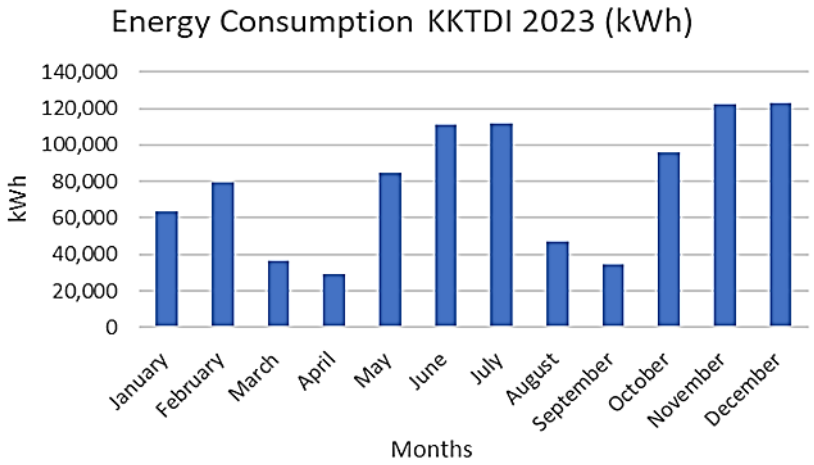

Fig. 2 *Monthly energy consumption in 2023 for KKTDI Residential College*

4.1.2 Weekly and Daily Energy Profiling

Power-logged data was recorded from 26 June 2024 until 2 July 2024 for 7 days at the KKTDI main distribution board to obtain the weekly energy profile. This analysis is crucial for evaluating the energy performance of KKTDI Residential College, as it helps to understand the dynamic and fluctuating nature of energy consumption that daily and annual analyses may overlook. These weekly energy profiles show short-term variations in energy usage that are significantly influenced by various factors. Table 3 present the weekly energy consumption of KKTDI Residential College, indicating an overall energy consumption of 29969.05 kWh. The daily consumption values range from 4,087.31 kWh to 4,445.94 kWh, indicating a consistent pattern of energy usage throughout the week with minor fluctuations between days. The peak energy consumption occurred on 27 June 2024 (Thu) at 4,445.94 kWh, while the lowest energy consumption was recorded on 30 June 2024 (Sunday) at 4,087.31 kWh. This results in a variance of 358.63 kWh indicating consistent building activity and occupancy throughout the period.

Table 3 *Weekly energy consumption in KKTDI Residential College*

Date	Energy consumption (kWh)
26/6/2024 (Wed)	4375.86
27/6/2024 (Thu)	4445.94
28/6/2024 (Fri)	4340.52
29/6/2024 (Sat)	4346.94
30/6/2024 (Sun)	4087.31
1/7/2024 (Mon)	4100.69
2/7/2024 (Tue)	4271.79
Overall total electricity usage (kWh)	29969.05

Fig. 3 illustrates the daily energy consumption in the KKTDI Residential College. The graph indicates that energy consumption during weekdays (Wednesday through Friday) is slightly higher than during weekends

Int. Journal of Integrated Engineering Vol. 17 No. 8 (2025) p. 78-88

(Saturday and Sunday). This trend reflects the typical behavior of student residents, who tend to engage in more activities on weekdays due to lectures, laboratory work, and other campus-related commitments. On weekends, there is a noticeable decrease in energy consumption compared to weekdays. This suggests that while students continue to reside at the college, their participation in activities within the buildings diminishes. In contrast, non-residential buildings experience a significant drop in energy usage on weekends. The weekend energy consumption highlights the ongoing operational nature of student residential facilities, where electricity is essential for lighting, ventilation, and personal electronic devices, even outside of regular office hours.

The variation in daily energy consumption depends on several factors, including academic activity levels. The highest energy consumption typically occurs midweek, especially on Thursdays, due to intensive academic activities that necessitate extended use of lighting, fans, and personal electronic devices. Additionally, student lifestyle and behavior play a significant role in the fluctuations of KKTDI energy consumption, as students tend to remain indoors more often than outdoors, leading to increased use of electrical appliances for their activities.

Overall, the daily energy consumption pattern of KKTDI Residential College from June 26, 2024, to July 2, 2024, demonstrates stable energy usage on weekdays, contrasted with minimal consumption on weekends. These findings reflect the continuous operation of residential colleges, where daily energy demand is shaped by student behavior, constant occupancy, and varying environmental conditions. The insights gained from daily energy profiling inform targeted energy management strategies that promote sustainable energy use and help reduce the university's operational expenses.

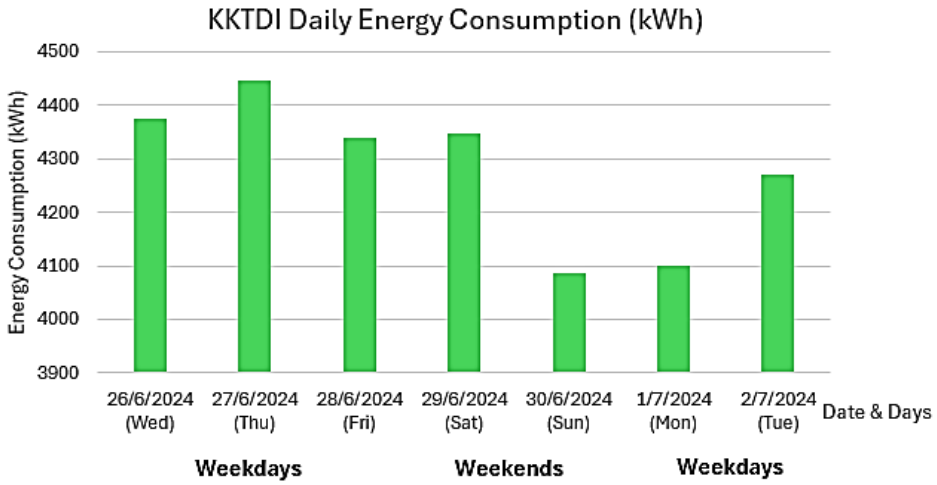

Fig. 3 *Daily energy consumption in KKTDI Residential College*

4.2 Breakdown of Energy Usage in KKTDI Building

This subsection presents the findings and analysis of energy usage in the KKTDI residential college building focusing on how energy is distributed among the major KKTDI building systems. This analysis used to provide a detailed picture of the overall energy consumption pattern and to determine the system that contribute most significantly to the building's electrical load. The system evaluated include general equipment, lighting and air conditioning and mechanical ventilation (ACMV) systems due to this system are the major electrical system used for daily operation in the KKTDI building. The calculation of energy consumption per system was estimate using eq. (1). The approach accurately approximates total daily energy usage and enables the comparison of different systems.

Table 4 shows the estimated total daily energy consumption at KKTDI Residential College is 2900.06 kWh. This values than verify with the actual daily energy consumption on 27 June 2024 refer to Table 3 where this data representing the highest energy consumption within a weekly period. This data selected as the benchmark in calculating the daily KKTDI energy performance under peak operation. The entire estimated energy consumption was then apportioned to the three major building systems, as illustrated in Table 4. The findings show that the general equipment had the highest estimated energy consumption of 1,521.02 kWh, then lighting system has 924.24 kWh and lastly, ACMV system has 454.80 kWh.

Fig. 4 shows that the general equipment category is the largest energy consumer in the building, responsible for approximately 52% of total energy consumption. Plug-in electrical appliances like computers, printers, and various home or office devices, used continuously throughout the day, fall into this category. The lighting system accounts for about 32% of total daily energy consumption, highlighting its significant impact on the building's energy performance. This considerable percentage illustrates the value of lighting for the building's functionality, especially given the extended operational hours and the many shared and common areas that require illumination.

In contrast, the ACMV system has the lowest energy consumption at 16% compared to other systems. Most areas of the building rely on fans instead of air conditioning, which helps reduce energy usage. Specific areas, however, do utilize air conditioning, including the administration office, mini-market, control room, activity hall, prayer hall, and technician room. The air conditioning operates according to office hours, from 8 a.m. to 5 p.m. In areas using fans, energy consumption remains lower, even with continuous operation throughout the day.

Table 4 *Estimation of daily energy consumption for the major building system in KKTDI Residential College*

Building system	Total estimation energy consumption (kWh)
General equipment	1521.02
Lighting system	924.24
ACMV system	454.80
Overall energy consumption (kWh)	2900.06

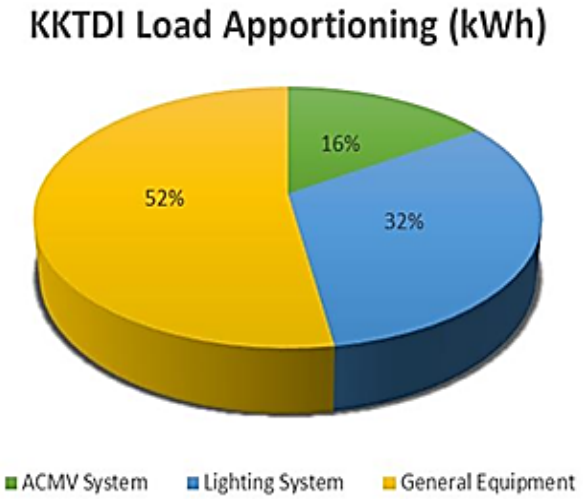

Fig. 4 *KKTDI Residential college building load apportioning*

4.3 Building Energy Index

The Building Energy Index (BEI) is a parameter that represents the energy performance of KKTDI residential college buildings. It is the ratio of the total energy use to the gross floor area of the building per year, which gives a standard measure of energy performance between one building and another, or between the energy use in one year and the energy use in another year. The BEI for KKTDI Residential College calculated using eq. (2).

$$BEI = \frac{Annually\ Total\ Energy\ Consumption\ \left(kWh/Year\right)}{Total\ Gross\ Floor\ Area\ (m^2)}$$

$$BEI = \frac{940{,}444\ \left(kWh/Year\right)}{28{,}599.52\ m^2}$$

$$BEI = 32.88\ kWh/m^2/year$$

The BEI of KKTDI was calculated to be 940,444 kWh/m^2 per year of total yearly energy consumption, with 28,599.52 m^2 of gross floor area producing a BEI of 32.88 kWh/m^2/year. This is a relatively low value that indicates that the building consumes a minimal amount of energy depending on its size and use, indicating that it is energy efficient. Compared to the Malaysian Standard MS1525:2019, which provides acceptable BEI norms for non-residential buildings, the KKTDI Residential College has a much lower BEI. This is a deviation, indicating that the building performs better than conventional benchmark values, consuming less energy per unit area. One of the key factors contributing to the lower BEI is the varying pattern of energy usage each month, which influences the overall annual average. Energy usage in the building is expected to vary significantly between lecture periods and non-lecture periods. Occupancy levels are elevated during lecture hours since students are present and utilize

more lighting, air conditioning, and electrical gadgets, leading to higher energy consumption. Conversely, energy usage is markedly reduced during non-lecture hours due to the majority of spaces being unoccupied and equipment remaining inactive. This anomaly leads to a decreased total yearly consumption averaged across the year.

The low BEI value indicates that the building is operating efficiently. The KKTDI Residential College is effectively utilizing energy to meet its operational requirements without unnecessary consumption. This leads to lower operational expenditures since less energy is required to maintain everyday operations, as well as a reduction in carbon footprint, which promotes sustainability and environmental goals. However, while a low BEI normally indicates a high level of energy efficiency, it is important to ensure that the low energy consumption does not compromise occupant comfort, indoor air quality, or functioning. Consistent monitoring of energy performance, occupancy, and external factors is recommended to achieve an optimal equilibrium between energy efficiency and user comfort.

Overall, the Building Energy Index (BEI) of 32.88 kWh/m^2/year for the KKTDI Residential College is commendable in terms of energy performance, significantly lower than the benchmarks established by MS1525:2019. This indicates that the building is efficient, yielding economic and environmental advantages. Energy management is a continuous process that requires persistent application, and adaptability to variations in occupancy rates can enhance the overall energy performance and sustainability profile of the building.

5. Conclusions

In conclusion, conducting energy profiling and assessing building efficiency at the KKTDI Residential College is crucial. The constant occupancy of university buildings by students can result in increased energy consumption and operational costs. This study aims to analyze the energy consumption patterns, break down energy usage within the residential building system, and calculate the Building Energy Index (BEI) to evaluate building efficiency.

Based on the findings, KKTDI Residential College exhibits significant energy consumption throughout 2023, suggesting that seasonal and behavioral energy trends are closely linked to the university's academic calendar and student occupancy patterns. Furthermore, energy consumption on weekdays is slightly higher than on weekends, which is attributed to students engaging in academic activities. The daily energy consumption pattern during weekdays shows stable energy usage, in contrast to minimal consumption observed on weekends. This pattern reflects student activity, consistent occupancy, and varying environmental factors.

The breakdown of energy usage within the KKTDI residential college indicates that general equipment is the largest contributor to energy consumption, followed by lighting and the Air Conditioning and Mechanical Ventilation (ACMV) system. Annual energy profiling at UTHM shows that the BEI for KKTDI Residential College is 32.88 kWh/m^2/year for 2023. This is below the MS1525:2019 BEI standard, which means that KKTDI uses less energy to meet its needs. However, achieving lower BEI values must be balanced with occupant comfort to reach an optimal equilibrium between energy efficiency and user satisfaction. These findings underscore the importance of analyzing energy usage in buildings to identify consumption patterns and determine building efficiency.

In the future, the identified energy consumption patterns can be leveraged to pinpoint inefficiencies and potential energy savings within the student residential building. This study provides a foundation for reducing operational costs and enhancing sustainability in university residential facilities.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** Nur Syafiqah Adha Narrudin, Mohd Azahari Razali*;* ***data collection:*** Nur Syafiqah Adha Narrudin*;* ***analysis and interpretation of results:*** Nur Syafiqah Adha Narrudin*;* ***draft manuscript preparation:*** Nur Syafiqah Adha Narrudin*, Winardi Sani, Juntakan Taweekun, Mohd Azni MD Kasim. All authors reviewed the results and approved the final version of the manuscript.*

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