

Energy Profile and Building Energy Index (BEI) for Malaysian Public University: A Case Study of Universiti Tun Hussein Onn Malaysia (UTHM)

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Abstract

Energy consumption is steadily increasing in emerging nations like Malaysia, driven by economic growth and the expansion of both commercial and residential sectors. The government has implemented various measures to ensure optimal and efficient building energy use. One such measure is the MS1525 standard, which evaluates a building's energy efficiency as a benchmark for compliance with existing regulations. This study examines the Building Energy Index (BEI) of Universiti Tun Hussein Onn Malaysia (UTHM) at the Parit Raja, Batu Pahat campus to determine whether the buildings meet standard BEI requirements. The study's objectives were achieved by collecting data on monthly energy consumption and selected buildings' gross floor area, and then calculating the BEI to ensure accurate results. A preliminary audit involved a quick assessment of building and utility operations, site observations, and facility tours. Additionally, general audits provided more detailed insights into building operations, helping to identify the primary sources of energy consumption. According to the findings, the BEI for UTHM buildings ranges from 57 to 65 kWh/m²/year—significantly lower than the recommended BEI benchmark of 200 kWh/m²/year, as specified by Malaysian Standards and the guidelines for Malaysian green government buildings. However, fluctuations in the university's energy consumption, influenced by factors such as semester breaks and the presence of multipurpose buildings, suggest the need for an adjusted method of BEI computation. A refined approach would provide more accurate BEI benchmarks tailored to public universities.

1. Introduction

Universiti Tun Hussein Onn Malaysia (UTHM) is a public university located in Batu Pahat. Its main campus features several key buildings, including the Tunku Mahkota Ismail Hall, the Sports Complex, the Sultan Ibrahim Mosque, the Sultan Ibrahim Hall, and the Tunku Tun Aminah Library. Energy plays a vital role in UTHM's daily operations, particularly due to the high electricity demand for campus facilities. One significant energy consumer is the ventilating and air-conditioning (VAC) system, which ensures adequate thermal comfort and indoor air quality. In Malaysia, most office buildings rely on electricity to power lifts, office equipment, and air conditioning essential components of mechanical and electrical (M&E) systems that contribute significantly to overall energy consumption during operation [1].

UTHM is located in Johor Darul Takzim, a state with a tropical climate characterized by high temperatures and humidity throughout the year. These climatic conditions contribute to significant energy consumption in UTHM's office buildings, highlighting the need for a system to assess and monitor energy usage. Studies show that the commercial and residential sectors consume nearly half of the electricity generated, and the UTHM campus is no exception to Malaysia's high energy demand [2]. Given the objectives of this study, it is essential to evaluate energy efficiency in buildings.

Measuring the Building Energy Index (BEI) in universities is essential for assessing energy performance and identifying efficiency opportunities. Various studies have analyzed the energy consumption of university buildings to enhance sustainability efforts. For instance, an Energy Efficiency Index (EEI) was developed to evaluate lecturer rooms in a university building, incorporating the number of occupants as a key factor influencing energy usage [3]. Another study conducted an energy audit on a university building, assessing energy performance at different levels, including organizational, system, and equipment levels [4]. Thomas Wu et al. introduced a benchmarking model for campus building energy consumption using random forest and K-means clustering to classify buildings based on energy usage patterns [5]. Additionally, an energy audit of a Research and Development building at Universiti Malaya in Malaysia focused on identifying energy conservation opportunities. The audit revealed that air-conditioning, lighting, and computers were the primary contributors to energy consumption. Implementing LED lighting resulted in substantial energy savings and cost reductions [6]. Furthermore, research by S.N.N. Syed Yahya et al. examined the correlation between electricity consumption and students' perceived academic performance, finding that higher energy consumption was linked to improved perceived performance in academic buildings [7]. These studies highlight the importance of energy audits and efficiency measures in university buildings, offering insights into strategies for reducing energy consumption while maintaining optimal performance.

Monitoring and measuring the Building Energy Index (BEI) is essential for identifying areas of energy inefficiency within buildings. By analyzing energy usage patterns, UTHM can implement targeted energy-saving measures and technologies to reduce consumption, ultimately leading to long-term cost savings. Regular BEI assessment ensures compliance with relevant energy and environmental regulations. Tracking BEI trends over time provides valuable insights into the performance of building systems and equipment. A rising BEI may indicate a decline in energy efficiency, signalling the need for maintenance, upgrades, or optimization efforts. Furthermore, understanding energy consumption across different buildings and facilities enables UTHM to allocate resources more effectively. This data-driven approach helps prioritize energy-saving initiatives where they are most needed, maximizing efficiency and sustainability.

2. Malaysia Climate

Malaysia's weather remains relatively stable throughout the year. The Malaysian Meteorological Department describes the country's climate as consistently hot, humid, and rainy, with minimal wind. Even during severe droughts, an entirely cloudless day is rare. Conversely, outside the northeast monsoon season, it is uncommon to experience several consecutive days without sunshine. Rainfall distribution across the country is influenced by seasonal wind patterns and regional topography. Exposed areas, such as the northeast coast of Sabah, western Sarawak, and the east coast of Peninsular Malaysia, receive heavy downpours during the northeast monsoon. In contrast, inland areas and regions shielded by mountain ranges are largely unaffected. The most effective way to understand Malaysia's rainfall patterns is by examining them by season.

2.1 Rainfall

Peninsular Malaysia experiences three distinct seasonal variations in rainfall. Firstly, the East Coast states receive the most rainfall from November to January, while June and July are typically the driest months across most districts. Secondly, most of the Peninsula excluding the southwest coastal region follows a bimodal rainfall pattern, characterized by two peaks and two dry periods. The primary maximum rainfall occurs in October or November, while the secondary maximum typically happens in April or May. The primary minimum usually falls between June and July, with a secondary minimum in February. However, in the northwest region, the primary minimum

occurs in January–February, and the secondary minimum in June–July. Lastly, the southwest coastal region exhibits a different pattern, with continuous rainfall from May to August, making distinguishing between distinct maximum and minimum periods difficult. Overall, the wettest months are October and November, while February is the driest. Rainfall patterns for March, April, May, June, and July are inconsistent or unclear.

2.2 Sunshine and Solar Radiation

Southeast Asia's Malaysia receives abundant natural sunlight and solar radiation. However, based on previous data from the Meteorological Department, completely clear skies are rare, even during severe droughts. On average, Malaysia experiences six hours of sunshine per day, though cloud cover significantly reduces the total solar energy received. Sunshine duration also varies by season and location. For instance, Universiti Tun Hussein Onn Malaysia (UTHM) records an average of seven hours of sunshine per day, whereas Kuching, Sarawak (in East Malaysia) receives only about five hours daily.

3. Energy Efficiency

Energy efficiency is generally recognized as a key strategy for managing and reducing energy consumption [8]. A building is considered energy efficient if it delivers the same level of services with less energy input or increases energy input while maintaining efficiency [9]. It is defined as the ratio of required energy services such as heating, lighting, and motion to the energy consumed [10]. In Malaysia, many buildings have the potential to implement energy-saving programs through various techniques. While modern technology can enhance energy efficiency, it often comes with high costs. However, cost-effective strategies, such as raising awareness and educating people about energy conservation, can also yield significant savings. Although some energy-saving techniques involve substantial installation and administrative expenses, adopting the right strategies can facilitate effective energy management [11,12]. Many of these practices can be implemented immediately at minimal cost while still achieving meaningful energy savings and improved efficiency [13].

In Malaysia's hot and humid climate, conventional office buildings typically consume more than half of their total energy mainly in the form of electricity on air conditioning. As a result, improving energy efficiency in buildings is a top priority for identifying key factors that hinder energy savings [14]. To address the causes of high energy consumption, numerous previous studies have implemented various strategies aimed at optimizing energy use in buildings while reducing operational costs [15,16].

4. Building Energy Index (BEI)

According to Suruhanjaya Tenaga's (Energy Commission's) published guidelines, energy auditing commonly employs three methods: benchmarking, preliminary audit, and general audit. Benchmarking primarily involves comparing a building's measured energy consumption with that of similar buildings, such as office buildings. This process is essential for identifying potential energy savings. In this study, the researcher used the Building Energy Index (BEI) as a performance indicator to assess energy consumption. The BEI, expressed in kilowatt-hours per square meter per year ($\text{kWh}/\text{m}^2/\text{year}$), represents the total annual energy consumption of a building divided by its gross floor area. This metric is widely used to compare energy usage across different building types and to evaluate their efficiency over a given period [17–21].

The index, based on a normalizing factor, is used to compare the annual energy consumption of buildings. Architects typically use gross floor area as the normalizing factor when comparing buildings, depending on the intended use of the index [22]. Preliminary audits, considered the simplest and fastest type of energy audit, generally involve a few interviews, a brief review of utility bills and operational data, and a walkthrough to understand facility operations. This type of audit primarily identifies major problem areas. A general audit expands upon the preliminary audit by collecting more detailed data on building operations [23]. For this study, utility bills from the past four years, covering 12 months each, were collected to assess energy usage characteristics.

5. University Building

The main campus building of Universiti Tun Hussein Onn Malaysia (UTHM) was selected as the case study for this research. It is located at approximately 2°N latitude and 103°E longitude in Parit Raja, Batu Pahat, Johor, Malaysia. Figure 1 illustrates the layout of the UTHM main campus. The main campus is divided into several zones to facilitate management and identification. Within these zones, four Energy Accounting Centres (EACs) were designated for the university's buildings, identified as EAC-01, EAC-02, EAC-03, and EAC-04. Each zone comprises multiple buildings, ranging from two to twenty-five structures, each serving a distinct purpose with varying usage patterns. Table 1 presents the floor area of the buildings categorized by zone.

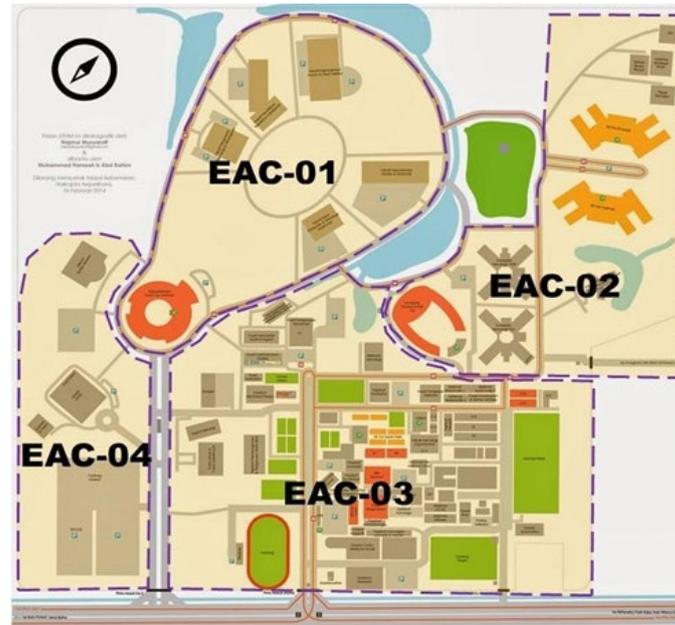


Fig. 1 Layout of the main campus of UTHM in each EAC

Table 1 Building floor area

Energy Accounting Centre (EAC)	Num. of Building	Gross Floor Area (m ²)
EAC-01	8	108 059.11
EAC-02	16	68 036.07
EAC-03	16	124 491.37
EAC-04	17	26 542.58

The Universiti Tun Hussein Onn Malaysia (UTHM) spans a total area of 327,129.13 m². The main campus can accommodate up to 3,000 staff members and 12,000 students, offering a wide range of facilities to support academic and daily activities. Most buildings on campus operate during regular office hours, from 8:00 a.m. to 5:00 p.m. However, the utilization of specialized spaces such as laboratories, workshops, computer labs, and studios varies depending on students' course schedules. UTHM's campus features various buildings, each serving a specific purpose. The teaching and learning buildings are designed for academic activities, and equipped with classrooms, seminar rooms, exam rooms, lecture halls, and other instructional spaces. These facilities are fully air-conditioned and incorporate advanced teaching aids to enhance the learning experience. Additionally, the campus includes several cafeterias and canteens, providing dining options for both students and staff. These establishments are conveniently located across the university, offering a variety of meals throughout the day.

The University provides a wide range of sports facilities, including a stadium equipped for track and field events, as well as dedicated fields for football, rugby, and hockey. Additionally, there are courts for netball, handball, volleyball, basketball, and squash, along with a badminton hall. For medical and health services, the University Medical Centre caters to both students and staff, focusing on urgent care and outpatient treatment. A team of doctors and medical assistants collaborates closely with paramedic staff to ensure quality healthcare. The centre also offers ambulance services for emergencies. To enhance students' knowledge, skills, and potential in engineering and technology, state-of-the-art laboratories have been fully equipped with the latest tools and technology. The University library houses an extensive collection of monographs, journals, magazines, theses, CD-ROMs, and microfilms, along with audiovisual materials. It also provides electronic information retrieval services through CD-ROM databases. On-campus accommodation is available, with hostels capable of housing up to 2,600 students. These hostels feature various amenities, including a mosque, canteen, rest areas, study rooms, magazines, cyber cafés, and copier kiosks. For the convenience of students and staff, the main campus also includes a bank, ATM, and a mini post office. The postal facility offers services such as registered mail, parcel delivery, postal orders, and a one-stop payment centre.

5.1 Monthly Electricity Consumption

The primary sources of electricity consumption on the UTHM campus are office equipment, lighting, and air conditioning systems [24]. The campus's electricity usage over the past three years (2020–2022) was recorded by collecting monthly electricity bills, as summarized in Table 2.

Table 2 Energy consumption in 2020 until 2022 (kWh)

Month	2020	2021	2022
Jan	1 974 833	1 391 499	1 667 661
Feb	1 997 816	1 295 943	1 299 807
Mar	1 841 083	1 614 515	1 687 905
Apr	966 135	1 684 677	1 677 283
May	1 003 087	1 474 757	1 808 828
Jun	1 435 008	785 534	1 898 681
Jul	1 660 131	943 345	1 711 890
Aug	1 597 601	1 259 123	1 702 619
Sep	1 661 984	1 260 797	1 522 069
Oct	1 783 572	1 203 650	1 822 074
Nov	1 645 083	1 615 147	2 001 705
Dec	1 254 102	1 676 101	2 038 119

Figure 2 illustrates the monthly energy consumption from 2020 to 2022. In 2020, electricity usage data shows a significant drop in April due to the COVID-19 pandemic, with consumption falling by 966,135 kWh—874,948 kWh less than the previous month. However, from April to October, energy usage began to recover. Despite semester breaks typically occurring in mid-January, mid-February, a week in April, and two months between late June and early September, there was no noticeable impact on the campus's energy consumption patterns. However, electricity usage declined in November, totaling 1,645,083 kWh, and continued to drop in December to 1,254,102 kWh. The total energy consumption for 2020 is estimated at 18,820,435 kWh.

The building's energy consumption in 2021 was low initially but increased in March and April, reaching 1,684,677 kWh. In May, consumption declined to 1,474,757 kWh. The lowest energy usage of the year occurred in June, likely due to the extended semester break. From that point onward, energy consumption steadily rose, peaking at 1,676,101 kWh in December. The total energy consumption amounted to 16,205,088 kWh.

Energy consumption 2022 exhibited two peaks, with demand surging in November (2,001,705 kWh) and December (2,038,119 kWh). In other months, energy consumption remained lower but consistently exceeded 1,900,000 kWh. The increased demand in November and December can be attributed to the convocation ceremony held during that time, particularly in Sultan Ibrahim Hall. Notably, December also saw high energy consumption in the previous year, reaching 1,676,101 kWh.

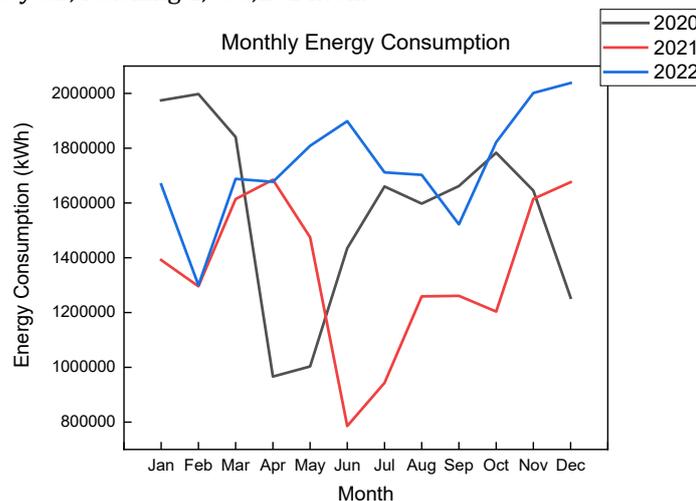


Fig. 2 Monthly energy consumption

5.2 Energy Consumption Comparison

The types of electric density loads varied, primarily depending on operational hours, as well as functional and aesthetic requirements. Additionally, small electrical appliances, such as audio/visual and office equipment, contributed to the overall load.

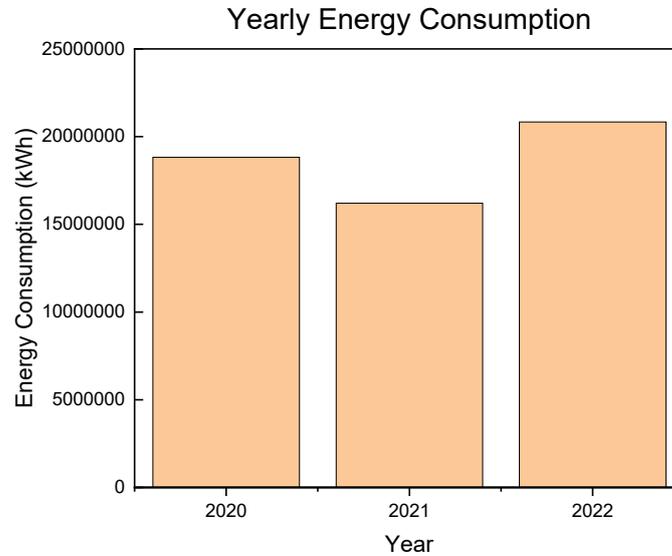


Fig. 3 Yearly energy consumption

UTHM's campus consistently consumed high amounts of energy (kWh) throughout the year, as its buildings remained occupied year-round. This trend is evident in the historical monthly electricity consumption data. Fig. 3 presents a comparison of annual consumption from 2020 to 2022.

Artificial lighting systems are essential for illuminating both interior office spaces and exterior areas, such as hallways and building façades. The building's electrical system distributes power for lighting, plug loads, and other uses. Lighting efficiency is primarily assessed based on two key factors: lighting power density and brightness level.

The electricity consumption on the UTHM campus fluctuates throughout the year. This variation is reflected in the Building Energy Index (BEI) calculation.

$$BEI = \frac{\text{Total energy consumption} \frac{kWh}{year}}{\text{Gross floor area (m}^2\text{)}} \tag{1}$$

Table 3 Building energy index

	UTHM's Campus		
	2020	2021	2022
Annual Energy Consumption (kWh)	18 820 435	16 205 088	20 838 641
Gross Floor Area (m ²)	327 129.13	327 129.13	327 129.13
Building Energy Index (BEI) kWh/m ² /year	57.53	49.54	63.70

According to the MS 1525:2019 Standard, any building can achieve a Building Energy Index (BEI) of 200 kWh/m²/year by implementing energy-efficient measures. Energy audit results indicate that most office buildings in Malaysia have BEIs ranging from 200 to 250 kWh/m²/year [16]. As shown in Table 3, the BEI of the UTHM campus currently falls between 57 and 65 kWh/m²/year. Meanwhile, according to Table 4, the BEI of each EAC in 2022 ranged from 25 to 67 kWh/m²/year. It is important to note that BEI data for each EAC were only considered from 2022 onward, as data collection for individual EACs began that year.

Table 4 Building energy index of each EAC for 2022

	UTHM's Campus			
	EAC-01	EAC-02	EAC-03	EAC-04
Annual Energy Consumption (kWh)	7 170 407	2 764 256	3 186 343	730 878
Gross Floor Area (m ²)	108 059.11	68 036.07	124 491.37	26 542.58
Building Energy Index (BEI) kWh/m ² /year	66.36	40.63	25.59	27.54

6. Comparison of Building Energy Index (BEI) Between UTHM and Green Government Buildings (GGB) in Malaysia

The Green Government Buildings (GGB) Initiative in Malaysia promotes sustainability and environmental consciousness in governmental infrastructure. This initiative focuses on designing and constructing buildings that minimize carbon footprints, reduce energy consumption, and incorporate eco-friendly materials and technologies.

Key features of GGBs include energy-efficient lighting and HVAC systems, integration of renewable energy sources like solar panels, rainwater harvesting systems, and effective waste management practices. These elements help GGBs meet the stringent environmental performance criteria required for certification under green building standards such as the Green Building Index (GBI) or Leadership in Energy and Environmental Design (LEED).

The Malaysian government's adoption of Green Government Buildings (GGBs) demonstrates a strong commitment to mitigating climate change, reducing resource consumption, and promoting sustainable development within the public sector. Beyond lowering long-term operational costs, these buildings enhance occupant well-being by offering a healthier indoor environment with better air quality and increased natural lighting.

The GGB initiative is pivotal in advancing green building practices throughout the construction industry. It fosters innovation and drives economic growth by supporting the development of sustainable technologies and expertise. By prioritizing sustainability in governmental infrastructure, Malaysia aims to lead by example in environmental stewardship, inspiring similar initiatives in the private sector. This commitment contributes to a more resilient and sustainable built environment for future generations.

Table 5 compares five different GGBs, highlighting the various criteria used in each. Despite some modifications, the core objectives of these GGBs remain consistent: facilitating the implementation of energy conservation opportunities, reducing greenhouse gas emissions, ensuring energy efficiency, and integrating green technology where necessary in buildings.

Table 5 Comparison of BEI rating between UTHM and green government buildings in Malaysia

	MKR (25)	Diamond (26)	PAM Centre (27)	LEO (21)	GEO (29)	UTHM Campus
Annual Energy Consumption (kWh)	4 823 000	1 248 225	200 446	1 780 000	126 000	20 838 641
Gross Floor Area (m ²)	53 000	14 685	3 782	17 800	4 200	327 129.13
Building Energy Index (BEI) kWh/m ² /year	91	85	53	100	30	64

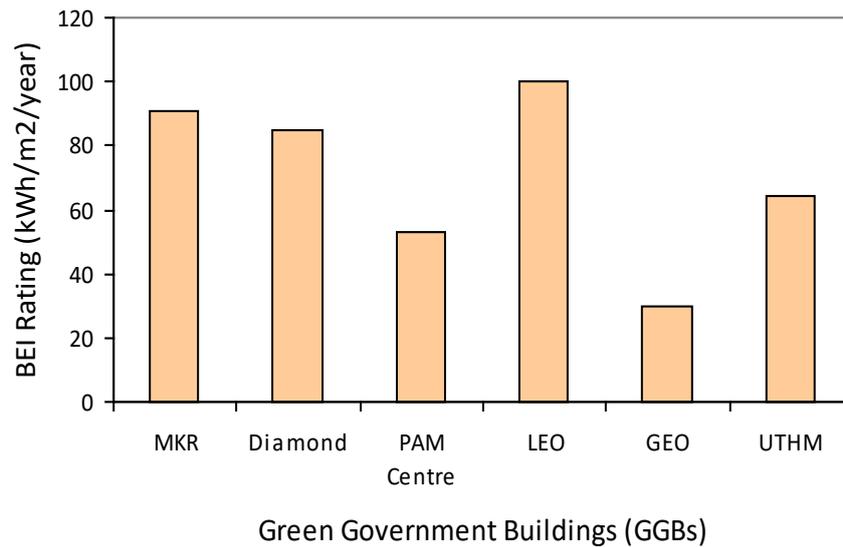


Fig. 4 Comparison of BEI rating of different GGBs

Figure 4 presents the five GGBs assessed based on their annual BEI ratings. In Malaysia, most of these GGBs explore energy conservation strategies, starting with their buildings. Once positive feedback and energy-saving recommendations are obtained, these strategies can be applied to private and residential buildings for greater energy-saving opportunities. A lower BEI indicates higher energy efficiency. Among the assessed buildings, GEO has the lowest BEI at 30, making it the most energy-efficient. The PAM Centre follows with a BEI of 53, indicating relatively high efficiency. Meanwhile, MKR and Diamond have BEI ratings of 91 and 85, respectively, placing them in the mid-range category with moderate energy efficiency. Further investigation into the factors influencing their BEI ratings could help identify areas for improvement.

The Building Energy Index (BEI) for the UTHM building is currently estimated to range between 57 and 65 kWh/m²/year. According to Malaysian Standards, the optimal BEI practice is 200 kWh/m²/year. This indicates that the UTHM building's BEI is significantly lower than both the standard requirement and the BEI of Malaysian green government buildings. However, these results may not accurately reflect the building's true performance, as the university is not fully utilized throughout the entire year. The campus operates at full capacity only during the first and second semesters, suggesting that the actual BEI could potentially double under full-year utilization.

The findings of this study should be refined by considering the number of days the buildings remained vacant. During semester breaks, when students are not on campus, university buildings are not utilized at full capacity. At UTHM, semester breaks typically occur from mid-January to mid-February, with an additional week in April and a two-month break between late June and early September. Despite these extended periods of reduced occupancy, no significant changes were observed in the campus's energy consumption patterns. Although lower energy demand would be expected due to reduced student and staff presence, energy usage remained relatively stable. This suggests that factors beyond occupancy may influence energy consumption during these periods. Further investigation is needed to explore potential underlying causes, such as operational practices, building systems, or external environmental factors [30].

The operational dynamics of a university building differ significantly from those of factories, office buildings, or retail malls, which typically operate year-round with relatively stable energy demands [31]. This distinction directly impacts the Building Energy Index (BEI) rating. Unlike factories that run continuously with consistent energy needs for manufacturing, university buildings experience fluctuating occupancy and activity levels. Additionally, they serve multiple functions such as classrooms, laboratories, administrative offices, and communal spaces each with unique energy requirements and usage patterns. This multifunctionality complicates BEI assessments, as energy consumption varies across different areas and functions. Consequently, accurately evaluating and adjusting BEI ratings for university buildings requires accounting for these complex operational dynamics and seasonal fluctuations in occupancy and energy use.

7. Conclusion

An adjusted BEI calculation methodology was proposed to account for the variability in the university's energy profile due to factors such as semester breaks and multifunctional buildings. First, energy consumption data were normalized for seasonal variations, particularly during semester breaks when occupancy levels fluctuated. This

normalization established baseline consumption patterns for peak and off-peak periods, ensuring energy performance assessments remained accurate regardless of occupancy changes. Additionally, a weighted average approach was applied to multifunctional buildings with diverse energy usage profiles, assigning proportional weights based on energy intensity. These adjustments enhanced the accuracy of BEI calculations, providing a more precise measure of energy efficiency across the campus and enabling effective monitoring and management of energy consumption despite operational fluctuations and varying building functions.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: **study conception and design:** M.A.R, I.F.I; **data collection:** M.A.A.A; **analysis and interpretation of results:** M.A.A.A, M.A.R, I.F.I, W.S, J.T; **draft manuscript preparation:** M.A.A.A. All authors reviewed the results and approved the final version of the manuscript.

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