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Establishing Critical Elements of Energy Management for Sustainable Campus Development

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ABSTRACT

A comprehensive energy management guideline tailored to higher education institutions in Malaysia is essential for advancing sustainable campus development. This study identifies 11 critical energy elements consisting of six management and five technical components, based on a review of 23 international sustainability frameworks including Sustainability Tracking, Assessment and Rating System (STARS), GreenMark Green Building Index (GBI), and University of Indonesia (UI) GreenMetric. The review found that most major frameworks incorporate multiple energy-related elements, indicating that energy management is widely acknowledged as a key component in evaluating campus sustainability. A case study was conducted at Universiti Malaysia Sabah, focusing on the Electrical and Mechanical Engineering Unit under the Development and Maintenance Department. Descriptive statistical analysis using a three-point Likert scale was applied, with a mean score of 2.40 established as the threshold for identifying essential elements. All six management elements, namely organizational structure, energy policy, planning, auditing, reporting, and awareness, achieved a mean score of 3.00, reflecting unanimous recognition of their importance. Technical elements including efficient equipment and mechanical systems also recorded a mean score of 3.00, while renewable energy scored 2.90. Retrofitting and building envelope improvements both received a mean score of 2.40, meeting the threshold for essential inclusion. These results confirm that all 11 elements are relevant and necessary for guiding sustainable energy practices. The proposed integrated framework combines technical enhancements with strategic management actions, offering a practical and holistic approach to strengthening energy governance in Malaysian university campuses in alignment with national and global sustainability goals.

Keywords

Sustainable Campus;
Sustainable Campus Assessment Framework;
Sustainable Energy Management;
Guidelines;
Energy Management

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1. Introduction

Sustainable energy can be defined as the consumption of energy efficiently to serve the needs of the present without compromising future generations' energy needs [1]. Energy is a key component that leads to environmental problems, either directly or indirectly, caused by high energy consumption in university buildings [2], due to building size, population, and the various activities taking place in universities.

Given the pivotal role of energy in achieving a sustainable campus, developing a structured guideline or assessment tool is crucial for optimizing energy consumption in higher education institutions. A well-defined framework enables universities to evaluate their sustainability performance, identify key areas for improvement, and develop targeted strategies. This approach fosters a culture of sustainability, enhances the evaluation process, and clarifies what to measure, the expected outcomes, and the appropriate indicators to be used. Sustainable campuses have become a global priority for universities, with each institution striving to achieve environmental, economic, and social sustainability. As complex ecosystems, universities function like small cities, accommodating large populations and

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List of Abbreviations

UMS	*Universiti Malaysia Sabah*
ESE	*Energy Sustainability Elements*
GBI	*Green Building Index*
BREEAM	*British Research Establishment Environmental Assessment Method*
STARS	*Sustainability Tracking, Assessment and Rating System*

hosting diverse activities. These activities, in turn, generate significant environmental, economic, and social impacts, underscoring the importance of implementing effective sustainability practices. Among these practices, energy management emerges as a particularly critical component [3].

However, implementing sustainability in campus settings presents increasing challenges [4]. The rising number of student enrollments each year has led to higher electricity consumption, a situation further exacerbated by the continuous development of new buildings [5]. Despite these pressures, awareness of energy conservation among students and university staff remains insufficient to drive meaningful change [4]. Without effective energy management strategies, universities risk excessive energy consumption, leading to higher operational costs and a greater environmental footprint. In response, a comprehensive energy management guideline tailored to university operations must be developed. Although several energy management frameworks exist for industrial and commercial buildings, university buildings are often categorized within the commercial sector without specific consideration for their unique needs. Moreover, most current guidelines lack technical components such as retrofitting strategies and mechanical system optimization, further highlighting the need for a holistic framework tailored to the higher education sector.

To support this need, robust assessment tools are essential for providing a comprehensive understanding of an institution's sustainability performance. In a key study, [7] emphasized that an ideal sustainability assessment for universities should highlight key issues, be measurable and comparable, go beyond eco-efficiency, evaluate underlying motivations, and maintain clarity.

2. Literature Review

In line with these principles, this study employs a structured approach to selecting appropriate sustainable assessment tools. Table 1 lists 23 sustainability guidelines, categorized by year, country of origin, and the organization or individual responsible for their development. These frameworks, grounded in the principles of

Table 1. List of Previous Sustainability Assessment/Frameworks/Guidelines.

No.	Sustainability Assessment Tool	Year	Organization/ Individual for Development	Country/ States Origin	Reference
1	British Research Establishment Environmental Assessment Method (BREEAM)	1990	BRE Global Ltd	United Kingdom	[7]
2	Campus Ecology Student Environmental Action Coalition (SEAC)	1993	Student Environmental Action Coalition	California, United States	[8]
3	Higher Education Funding Council for England's environmental report and workbook (Environmental Workbook)	1998	Higher Education Funding Council for England	England	[6]
4	University Leaders for a Sustainable Future's Sustainability Assessment Questionnaire for Colleges and Universities (SAQ)	1999	University Leaders for a Sustainable Future (ULSF) Campus	Washington D.C, United States	[6]
5	Environmental Management System Self-Assessment Checklist	2000	Campus Consortium for Environmental Excellence	Washington D.C, United States	[9]

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6	Penn State Indicator Report	2000	Penn State Green Destiny Council	Pennsylvania, United States	[8]
7	Auditing Instrument for Sustainability in Higher Education (AISHE)	2001	Dutch Committee on Sustainable Higher Education (CDHO)	United Kingdom	[10]
8	Campus Sustainability Selected Indicators Snapshot	2001	New Jersey Higher Education Partnership for Sustainability	New Jersey, United States	[11]
9	Campus Sustainability Assessment Review Project (CSARP)	2002	Western Michigan University	Michigan, United States	[10]
10	Campus Sustainability Assessment Framework (CSAF)	2003	Lindsay Cole	Canada	[12]
11	Higher Education Partnership for Sustainability (HEPS)	2003	Forum for the Future	United Kingdom	[8]
12	Good Company's Sustainable Pathways Toolkit	2004	Good Company	Oregon, United States	[11]
13	GreenMark	2005	Building and Construction Authority (BCA)	Singapore	[13]
14	Global Reporting Initiative Modified for Universities	2006	Global Reporting Initiative	Amsterdam, The Netherlands	[14]
15	STARS for Colleges and Universities	2006	Association for the Advancement of Sustainability in Higher Education (AASHE)	Pennsylvania, United States	[15]
16	GREENSHIP	2008	Building Council of Indonesia (GBCI)	Indonesia	[16]
17	LEED for neighborhood Development	2008	U.S. Green Building Council	United States	[16]
18	SURPAM - Sustainable Urban Renewal Project Assessment Model	2008	Sustainable Urban Renewal Project Assessment Model	Hong Kong	[17]
19	Campus Sustainability Assessment Framework Core (CSAF Core)	2009	Sierra Youth Coalition	Canada	[18]
20	FGBC-Green Development	2009	Florida Green Building Coalition	Florida	[19]
21	UI GreenMetric	2010	Universitas Indonesia (UI)	Indonesia	[20]
22	GBI for New Residential Development and Township	2011	Malaysian Institute of Architects	Malaysia	[21]
23	Comprehensive Assesment System for Build Environment Efficiency (CASBEE) for Urban Development	2014	Japan GreenBuild Council (JaGBC)	Japan	[13]

sustainability in higher education, have been widely applied across university campuses globally, serving as valuable references for institutions aiming to strengthen their sustainability initiatives.

Table 1 presents a chronological overview of various sustainability assessment frameworks and guidelines developed globally, highlighting their origins, organizations responsible for their creation, and key contributions. The evolution of these frameworks reflects the growing recognition of sustainability as a crucial element in higher education and urban development. The selection of guidelines from 1990 to 2014 captures key milestones in the development of structured sustainability assessment tools, illustrating how methodologies have evolved over time to address the increasing complexity of sustainability challenges in universities and the built environment.

The early development of sustainability guidelines began in the United Kingdom with the establishment of the BREEAM in 1990, followed by initiatives in the

United States such as the Campus Ecology Student Environmental Action Coalition in 1993. By the late 1990s and early 2000s, numerous frameworks emerged, particularly in North America and Europe, addressing various aspects of sustainability assessment in higher education. Notable examples include the Sustainability Assessment Questionnaire developed by the University Leaders for a Sustainable Future and the Campus Sustainability Assessment Framework from Canada. These guidelines laid the foundation for sustainability assessments by establishing standardized evaluation criteria, influencing the development of future frameworks.

In the ASEAN region, sustainability assessment guidelines gained prominence in the mid-2000s, beginning with the introduction of Green Mark in Singapore in 2005 by the Building and Construction Authority. This was followed by the Greenship framework by the Green Building Council Indonesia in 2008 and the UI GreenMetric initiative by Universitas Indonesia in 2010, which has since expanded and is widely used as a benchmark among ASEAN universities. Malaysia also introduced its own framework, the GBI in 2011, focusing on sustainable building practices. The inclusion of these regional guidelines reflects the growing commitment of ASEAN universities to integrating sustainability into their operations.

Each of these guidelines includes specific energy management elements in their assessment criteria. In a previous study by [5], four prominent guidelines were analyzed for their energy management components within the context of sustainable campus and building frameworks. These include the Sustainability Tracking, Assessment, and STARS from the United States, along with three ASEAN-based frameworks: Green Mark (Singapore), UI GreenMetric (Indonesia), and the Green Building Index (Malaysia). These internationally recognized guidelines play a pivotal role in shaping sustainability policies across universities and in broader urban development initiatives. By focusing on guidelines introduced between 1990 and 2014, this study offers a comprehensive overview of the historical evolution of sustainability assessments and their impact on contemporary practices.

Table 2 demonstrates that STARS, GreenMark, and UI GreenMetric integrate both management and technical aspects of sustainability, while GBI solely focuses on technical elements. This highlights the need for a more balanced framework that effectively combines both policy-driven management strategies and technical improvements to optimize energy sustainability in Malaysian universities. The STARS Framework, developed by the Association for the Advancement of Sustainability in Higher Education (AASHE), is widely recognized, and

Table 2. Comparation of energy management elements for four (4) sustainable guidelines.

Guidelines & Elements	**STARS**	**GREEN MARK**	**UI GREENMETRIC**	**GBI**
a) Management				
Organizational Structure/Energy Team	✓	✓	✓	-
Energy Policy	✓	✓	✓	-
Planning	✓	-	-	-
Audit	✓	✓	✓	-
Reporting	-	-	-	-
Awareness	✓	-	✓	-
b) Technical				
Retrofitting	-	✓	✓	-
Building Envelope	-	-	✓	✓
Efficiency Equipment	✓	✓	✓	✓
Mechanical Systems	-	✓	-	✓
Renewable Energy	✓	✓	✓	✓

Note: ✓ indicates the element is addressed in the framework and - indicates the element not addressed.
Source: [5] Ali et al (2023)

adopted in higher education sustainability [22]. Its holistic approach, incorporating social responsibility and economic viability alongside energy sustainability. This makes it suitable for universities aiming to balance sustainability efforts with institutional and community engagement. However, its broad focus may result in less emphasis on technical energy efficiency improvements, which are crucial for tropical climates like Malaysia's. Similarly, according to [21] and [23], GreenMark and GBI are well-known certification schemes for sustainable buildings that are recognized in the construction sector and by government programs.

GreenMark and GBI focus on building performance and energy conservation makes it highly relevant for the construction of new facilities and the retrofitting of existing ones. They provide clear criteria for assessing and certifying buildings based on sustainable features such as energy-efficient design and operation. These frameworks prioritize technical solutions such as efficiency equipment, mechanical systems, and building envelope enhancements. However, they lack a comprehensive focus on sustainability management strategies, which are essential for long-term energy governance in universities.

The UI GreenMetric framework, developed by Universitas Indonesia, offers a sustainability assessment approach tailored specifically for academic institutions [UI GreenMetric citation]. Unlike other frameworks, it places strong emphasis on energy components and operational aspects relevant to universities, covering both management and technical dimensions. This makes it particularly suitable for Malaysian universities, where education, research, and energy efficiency are central to sustainability priorities. Its focus on climate change adaptation and energy management is especially significant in Malaysia's tropical climate, where cooling loads account for a major share of energy demand.

In contrast, the Green Building Index (GBI) adopts a primarily technical orientation, emphasizing efficiency equipment, mechanical systems, and building envelope measures, but lacking management focused aspects such as energy policy, reporting, and awareness initiatives. As a result, it is less effective as a comprehensive tool for campus wide governance. Similarly, while international standards such as ISO 50001 provide robust organizational protocols for energy management, they do not extend to building level interventions or the operational realities of university campuses [24]. These limitations highlight the need for an integrated framework that can bridge both managerial and technical domains.

The novelty of this study lies in addressing these deficiencies. The proposed framework integrates six management elements: organizational structure, policy, planning, auditing, reporting, and awareness with five technical elements: retrofitting, building envelope, efficient equipment, mechanical systems, and renewable energy. Unlike existing tools that emphasize either governance or technical design, this balanced integration provides a holistic and context sensitive model. It directly responds to the operational realities of Malaysian higher education institutions, offering a practical pathway to strengthen energy governance in line with national sustainability agendas and global climate targets.

According to [25], energy management consists of six elements: organizational structure, energy policy, planning, auditing, reporting, and awareness. In this study, these are grouped as management elements, which play a crucial role in effectively managing and optimizing energy consumption. By establishing a clear organizational structure, implementing energy policies [26], conducting regular audits, and promoting awareness, institutions can significantly improve energy performance. Additionally, retrofitting has been identified as a key strategy for reducing energy use [27], while the building envelope plays a major role in moderating thermal loads [28]. Efficient equipment, mechanical systems, and renewable energy are also widely recognized as critical measures for sustainable performance [29]. Together, these five aspects form the technical elements of this study.

3. Methodology

This study followed a structured process to identify and validate eleven ESE relevant to Malaysian university campuses. The methodology was structured to ensure clarity in defining the population, determining the sampling strategy, developing the research instrument, conducting expert validation, and outlining the analytical approach.

3.1 Population, Target Population, and Sampling Frame

Judgmental (purposive) sampling was employed to ensure that responses were obtained from individuals with direct and specialised knowledge of campus energy management. The population of interest comprised all technical personnel engaged in energy management activities within

Malaysian higher education institutions. For this case study, the target population was defined as the staff of the Electrical and Mechanical Engineering Unit under the Development and Maintenance Department at Universiti Malaysia Sabah (UMS), the organisational unit directly responsible for operational energy management on campus.

The sampling frame consisted of the complete list of technical staff in this unit, which, at the time of the study, comprised only ten individuals: three engineers, four assistant engineers, and three technicians. This small number reflects the actual organisational structure of the department rather than a subsample. Following the approach recommended by [30] when the target population is small and well defined, a census method was adopted instead of random sampling, eliminating sampling error and ensuring complete representation of the group's perspectives. Accordingly, all members of the sampling frame were surveyed (n = 10). While this provides full coverage of the target unit, it is acknowledged that the results cannot be statistically generalised beyond the case institution.

3.2 Questionnaire Development

Following an extensive literature review, 11 energy sustainability elements were identified as potentially relevant to university contexts. A structured questionnaire was then developed to assess the perceived relevance and practical importance of each element from the perspective of the target population identified in Section 3.1. The instrument was designed to capture both demographic data and respondents' awareness and perceptions of the ESE. The survey aimed to gauge the respondents' level of understanding and awareness of the identified energy management elements. The questionnaire consisted of two sections:

- Part A: Collected demographic information.
- Part B: Evaluated awareness and perceptions of the energy sustainability elements using a three-point Likert scale ranging from "Agree", "Neutral" and "Strongly Agree."

The breakdown of respondents by job position is presented in Table 3.

3.3 Expert Review and Refinement for Questionnaire Reliability

To ensure the clarity, reliability, and content validity of the instrument, the questionnaire underwent an expert validation process involving three domain experts, each with over ten years of professional experience in sustainable energy and the AECO (Architecture, Engineering, Construction, and Operations) industry. Their feedback was as follows:

- Expert 1 focused on the overall structure and logical flow of the questionnaire. He recommended refining the title to more accurately reflect the study scope and target audience, for instance, "Questionnaire on Awareness of Sustainable Energy Management Among Technical Staff at UMS." He also suggested revising the introductory statements to improve clarity and respondent engagement.
- Expert 2 concentrated on grammar, spelling, and formatting consistency. He identified and corrected typographical issues (for example, "sustaianable" was corrected to "sustainable") and recommended rephrasing ambiguous phrases for clarity, particularly in Section B where awareness of energy practices was being assessed.
- Expert 3 evaluated the clarity and relevance of the questionnaire items. She noted that several statements were too brief or general (for example, "Efficiency Equipment") and advised rewording them into specific and actionable items such as "I am aware that energy efficient equipment is used in UMS buildings.

Based on the consolidated expert feedback, the questionnaire was thoroughly refined. The title and objective statement were clarified, vague items were rephrased for specificity, the demographic section was expanded for

Table 3. Composition of respondents based on their position.

Position	Number of respondents	Percentage
Engineer	3	30
Assistant Engineer	4	40
Technician	3	30
Total	10	100

richer respondent profiling, and the response scale was upgraded to enhance data depth. These revisions ensured that the final instrument was well structured, contextually relevant, and aligned with the research objectives of identifying critical elements for sustainable energy management on campus.

3.4 Data Collection and Analysis

Data were collected via self-administered questionnaires distributed in person to all members of the target population. The completed responses were analysed using SPSS software, where descriptive statistics (mean, minimum, maximum, and standard deviation) were computed for each ESE. In addition, frequency distribution analysis was conducted to examine the percentage of responses for each level of agreement. This combined approach provided a comprehensive interpretation of overall awareness trends and highlighted specific elements that were either highly prioritized or under-recognized by the technical staff at UMS.

4. Result and Discussion

The data collected from the survey were input into SPSS for analysis, and descriptive statistics were employed to examine and interpret the findings. This section presents the results of the survey, which explore the level of awareness among technical staff members regarding various energy management elements.

Table 4 provides the mean scores and standard deviations for the responses concerning the energy management elements. It presents the descriptive statistics (mean, minimum, maximum, and standard deviation) for each element. Notably, elements such as Organizational/Energy Team, Energy Policy, Planning, Audit, Reporting, Awareness, Efficiency Equipment, and Mechanical Systems all received a mean score of 3.00, indicating unanimous agreement among the respondents. Conversely, elements like Retrofitting and Building Envelope scored a mean of 2.40, reflecting more varied perceptions among the technical staff. The Renewable Energy element, with a mean score of 2.90, demonstrated strong agreement among most respondents.

Table 5 presents the frequency distribution of responses for each energy element. These results offer a deeper understanding of the level of agreement expressed by the respondents regarding key components of energy management practices by UMS. The majority of respondents (100%) strongly agreed with elements such as Organizational/Energy Team, Energy Policy, Planning, Audit, Reporting, Efficiency Equipment, and Mechanical Systems, indicating that these areas are well-recognized and prioritized within the department. shows the frequency distribution for each element. These results reflect the degree of agreement among staff members regarding key components of energy management practices at UMS. It provides the frequency distribution for each energy management element, offering a deeper look into the level of agreement expressed by respondents. The majority (100%) strongly agreed with elements such as Organizational/Energy Team, Energy Policy, Planning, Audit, Reporting, Efficiency Equipment, and Mechanical System. This strongly

Table 4. Mean Scores and Standard Deviations of Energy Elements.

	N	Minimum	Maximum	Mean	Std. Deviation
Organizational/Energy Team	10	3	3	3.00	.000
Energy Policy	10	3	3	3.00	.000
Planning	10	3	3	3.00	.000
Audit	10	3	3	3.00	.000
Reporting	10	3	3	3.00	.000
Awareness	10	3	3	3.00	.000
Retrofitting	10	1	3	2.40	.699
Building Envelope	10	1	3	2.40	.843
Efficiency Equipment	10	3	3	3.00	.000
Mechanical System	10	3	3	3.00	.000
Renewable Energy	10	2	3	2.90	.316
Valid N (listwise)	10				

suggests these areas are well acknowledged and prioritized within the department.

4.1 Elements of Energy Management

This section discusses the findings of the survey conducted to evaluate the awareness and perceived importance of eleven key energy management elements identified through a comprehensive literature review and analysis of sustainability frameworks. These elements are categorized into two main groups: management elements, which include Organizational/Energy Team, Energy Policy, Planning, Energy Audit, Reporting, and Awareness; and technical elements, comprising Retrofitting, Building Envelope, Efficient Equipment, Mechanical Systems, and Renewable Energy. The purpose of this evaluation is to determine the extent to which these elements are recognized and prioritized by technical personnel at UMS, who are directly involved in campus energy operations. The results, presented through descriptive statistics and frequency distributions, provide insights into current energy management practices and potential areas for improvement. These findings support the argument that a tailored framework that encompasses both strategic management practices and technical improvements is essential for Malaysian universities. Existing schemes like ISO 50001 or GBI may serve as broad references but do not reflect the ground level realities and operational challenges faced by technical departments in campus environments. The following subsections detail the analysis for each element.

4.1.1 Organizational/Energy Team, Policy, Planning, Audit, Reporting, Awareness, Efficiency Equipment, and Mechanical System

For elements such as Organizational Structure/Energy Team, Energy Policy, Audit, Planning, Reporting, Awareness, Efficiency Equipment, and Mechanical System, the mean scores were 3.00, with standard deviations of 0.000 (Table 4), indicating full agreement across all 10 respondents. The corresponding frequency data in Table 5 confirmed that 100% of respondents strongly agreed with the importance of these elements. This reflects a high level of understanding and support for structured energy management practices among UMS technical staff.

4.1.2 Retrofitting

The mean score for the Retrofitting element was 2.40, with a wider standard deviation of 0.699 (Table 4).

Table 5. Frequency Distribution of Energy Elements.

Energy Elements	Response	Frequency	Percent	Valid Percent	Cumulative Percent
Organisational/Energy Team	Strongly Agree	10	100.0	100.0	100.0
Energy Policy	Strongly Agree	10	100.0	100.0	100.0
Planning	Strongly Agree	10	100.0	100.0	100.0
Audit	Strongly Agree	10	100.0	100.0	100.0
Reporting	Strongly Agree	10	100.0	100.0	100.0
Retrofitting	Agree	1	10.0	10.0	10.0
	Neutral	4	40.0	40.0	50.0
	Strongly Agree	5	50.0	50.0	100.0
	Total	10	100.0	100.0	
Building Envelope	Agree	2	20.0	20.0	20.0
	Neutral	2	20.0	20.0	40.0
	Strongly Agree	6	60.0	60.0	100.0
	Total	10	100.0	100.0	
Efficiency Equipment	Strongly Agree	10	100.0	100.0	100.0
Mechanical System	Strongly Agree	10	100.0	100.0	100.0
Renewable Energy	Neutral	1	10.0	10.0	10.0
	Strongly Agree	9	90.0	90.0	100.0
	Total	10	100.0	100.0	

Frequency data (Table 5) revealed that 50% of respondents strongly agreed, 10% agreed, and 40% were neutral. This indicates a positive but somewhat mixed perception regarding the importance of retrofitting existing systems with modern technology to improve energy efficiency. The variance in responses may reflect both technical and financial considerations. From a technical standpoint, retrofitting often involves integrating new equipment into older building systems, which can present compatibility and performance challenges. Financially, retrofitting projects require substantial upfront investment, and budgetary constraints within public universities can limit their feasibility despite long-term energy savings potential. Additionally, decision-makers may prioritize measures with more immediate and visible benefits over large-scale retrofits that require phased implementation.

4.1.3 Building Envelope

Similarly, Building Envelope scored a mean of 2.40 (Table 4), with 60% of respondents strongly agreeing, 20% agreeing, and 20% being neutral (Table 5). This suggests that while the element is generally viewed positively, there may still be a need for enhanced awareness or further clarification on its significance in energy conservation. The mixed responses are likely shaped by both climatic and cost-related factors. In Malaysia's tropical climate, where cooling loads are high year-round, building envelope improvements such as enhanced insulation or double glazing may deliver less noticeable energy savings compared to mechanical system upgrades [31]. Furthermore, such measures can be expensive to implement in existing buildings, especially when façade or structural modifications are required. These realities may explain why technical staff, while recognizing the theoretical value of envelope improvements, perceive them as less immediately practical in the campus context without dedicated funding or long-term planning.

4.1.4 Renewable Energy

For Renewable Energy, the analysis yielded a mean score of 2.90 with a standard deviation of 0.316 (Table 4). As shown in Table 5, 90% of respondents strongly agreed on its importance, while 10% remained neutral. These results reflect a strong consensus on the relevance of incorporating renewable energy sources into campus energy management strategies. This finding aligns with the study by [32], which highlights the critical role of renewable energy in supporting sustainable development goals. The study emphasizes the current state of renewable technologies, their contribution to sustainability, ongoing research on their long-term viability, and their integration into low-carbon energy systems.

5. Conclusion

This study addresses the urgent need to strengthen energy management practices in Malaysian higher education institutions, where rapid campus growth has led to increased energy consumption and environmental impacts. Existing sustainability assessment tools often fail to comprehensively integrate both technical and management energy aspects. To overcome this limitation, the study reviewed 23 international sustainability frameworks and identified 11 critical energy management elements, which were organized into a structured framework tailored for university campuses.

A case study was conducted at Universiti Malaysia Sabah, focusing on technical personnel from the Electrical and Mechanical Engineering Unit under the Development and Maintenance Department. A structured questionnaire using a three-point Likert scale was used, with 2.40 set as the threshold to determine whether each element was essential. The main results and their implications are summarized below:

- Eleven essential energy management elements were established, comprising:
  a. Management components: organizational structure, energy policy, planning, auditing, reporting, and awareness
  b. Technical components: retrofitting, building envelope, efficient equipment, mechanical systems, and renewable energy
- Frameworks such as STARS and UI GreenMetric incorporate several of these elements, reflecting a global consensus on the importance of energy strategies in sustainability.
  a. However, none of the reviewed frameworks cover all eleven elements, highlighting gaps in current global tools.
  b. For example, UI GreenMetric omits planning and reporting, while STARS excludes retrofitting and building envelope considerations.
  c. Compared to ISO 50001 and GBI, the proposed framework demonstrates conceptual novelty by bridging strategic energy

governance with technical implementation. These two domains are often treated separately by existing standards. By aligning the framework with campus-specific operations, the study provides a more actionable and adaptable model for Malaysian higher education institutions seeking to improve their energy sustainability practices.

- Validation through campus survey showed full agreement on all six management elements and strong support for most technical elements.
    a. Mean scores for management and several technical components reached 3.00 (maximum rating).
    b. Retrofitting and building envelope elements scored 2.40, meeting the essential threshold but indicating areas for improvement in implementation and awareness.
- The framework provides a practical and adaptable tool for institutional decision-makers, supporting:
    a. More systematic measurement and management of campus energy performance
    b. Strategic alignment with national sustainability goals and global climate targets
    c. A scalable model to guide other universities in transitioning toward low carbon and energy-resilient campus environments.

5.1 Limitations and Future Research Directions

This study has several limitations that should be acknowledged. Firstly, the research was conducted at a single institution, Universiti Malaysia Sabah (UMS), and involved only one department, the Electrical and Mechanical Engineering Unit. The sample consisted of all ten technical personnel, and while this ensured full participation from the target group, the findings remain institution specific and may not reflect practices or perspectives at other universities. Additionally, the study employed descriptive statistical analysis without the use of inferential techniques, as the objective was to explore and validate key energy management elements within a focused campus setting.

Furthermore, while the findings reflect strong consensus among technical staff on the relevance of the identified elements, these perceptions were not cross validated against actual campus energy performance metrics, such as measured consumption data or post retrofit savings. Without this empirical linkage, the practical impact of the identified priorities on real world energy outcomes remains unverified. Incorporating operational energy data in future studies, ideally through pre and post intervention comparisons, would allow for a more robust evaluation of the framework's effectiveness, strengthen causal inferences, and enhance the persuasiveness of results for institutional decision makers.

These limitations restrict the generalisability of the results but provide a valuable foundation for future investigations involving broader and more diverse institutional contexts. Future research should aim to test and refine the eleven element energy management framework across a wider range of Malaysian higher education institutions, encompassing diverse geographic, climatic, operational, and institutional contexts. Comparative analyses involving universities of varying sizes, building typologies, and energy consumption patterns would yield deeper insights into implementation challenges and context specific adaptation strategies. Additionally, longitudinal studies could evaluate the long term effectiveness of the framework in reducing energy use and enhancing sustainability performance.

Moreover, the current study applied equal weighting to all eleven energy management elements (ESEs). Future studies are encouraged to employ multi criteria decision making methods such as the Analytic Hierarchy Process (AHP) to systematically determine the relative importance of each element. This approach would provide a more nuanced prioritization of ESE based on expert judgment and contextual factors, enhancing the framework's applicability and effectiveness.

Parallel efforts should focus on integrating the framework with emerging smart campus technologies, such as real time energy monitoring systems, IoT enabled building controls, predictive analytics, and AI based diagnostics, to improve operational efficiency and support data driven decision making. Institutionalisation of the framework through campus policies, standard operating procedures, and performance metrics will be crucial for ensuring consistent and sustainable adoption. Furthermore, promoting inclusive stakeholder engagement, including students, technical staff, academics, and campus leadership, can foster behavioural change and institutional commitment. Embedding sustainability principles into curricula, research activities, and cross sectoral collaborations will further strengthen the knowledge ecosystem and accelerate Malaysia's progress toward low carbon, energy resilient, and climate responsive campuses in line with national and global sustainability goals.

References

[1] Jie H, Khan I, Alharthi M, Zafar MW, Saeed A. Sustainable energy policy, socio-economic development, and ecological footprint: the economic significance of natural resources, population growth, and industrial development. *Utilities Policy* 2023; 81:101490. https://doi.org/10.1016/j.jup.2023.101490.

[2] Iqbal A, Zhang W, Jahangir S. Building a sustainable future: the nexus between artificial intelligence, renewable energy, green human capital, geopolitical risk, and carbon emissions through the moderating role of institutional quality. *Sustainability* 2025;17(3):990. https://doi.org/10.3390/su17030990.

[3] Østergaard, P. A., & Sperling, K. (2014). Towards sustainable energy planning and management. *Research Portal Denmark*, *1*, 1–6. https://doi.org/10.5278/ijsepm.2014.1.1.

[4] Herth, A., Verburg, R., & Blok, K. (2024). The innovation Power of living Labs to Enable Sustainability Transitions: Challenges and Opportunities of On-Campus Initiatives. *Creativity and Innovation Management*. https://doi.org/10.1111/caim.12649.

[5] Ali-Ashgar SK, Gungat L, Asmawan Mohd Sarman, Nurmin Bolong. The impact of building information modelling (BIM) strategies in energy sustainability elements to sustainable campus using PLS-SEM Approach. *International Journal of Integrated Engineering* 2023;15(2). https://doi.org/10.30880/ijie.2023.15.02.011.

[6] Shriberg M. Institutional assessment tools for sustainability in higher education. *International Journal of Sustainability in Higher Education* 2002;3(3):254–270. https://doi.org/10.1108/14676370210434714.

[7] Braulio-Gonzalo M, Bovea MD. Relationship between green public procurement criteria and sustainability assessment tools applied to office buildings. *Environmental Impact Assessment Review* 2020;81:106310. https://doi.org/10.1016/j.eiar.2019.106310.

[8] Yarime M, Tanaka Y. The issues and methodologies in sustainability assessment tools for higher education institutions: a review of recent trends and future challenges. *Journal of Education for Sustainable Development* 2012;6(1):63–77. https://doi.org/10.1177/097340821100600113.

[9] Clarke A, Kouri R. Choosing an appropriate university or college environmental management system. *Journal of Cleaner Production* 2009;17(11):971–984. https://doi.org/10.1016/j.jclepro.2009.02.019.

[10] Bolaji R. An investigation of the relationship between organisational culture and sustainability performance in higher education institutions in Ilorin, Nigeria. Master's thesis. Cardiff: Cardiff Metropolitan University; 2020.

[11] Saadatian O, Sopian KB, Salleh E. Adaptation of sustainability community indicators for Malaysian campuses as small cities. *Sustainable Cities and Society* 2013; 6:40–50. https://doi.org/10.1016/j.scs.2012.08.002.

[12] Du Y, Arkesteijn MH, den Heijer AC, Song K. Sustainable assessment tools for higher education institutions: guidelines for developing a tool for China. *Sustainability* 2020;12(16):6501. https://doi.org/10.3390/su12166501.

[13] Al-Sakkaf A, Zayed T, Bagchi A. A sustainability-based framework for evaluating the heritage buildings. *International Journal of Energy Optimization and Engineering* 2020;9(2):49–73. https://doi.org/10.4018/IJEOE.2020040104.

[14] Lozano R. The state of sustainability reporting in universities. *International Journal of Sustainability in Higher Education* 2011;12(1):67–78. https://doi.org/10.1108/14676371111098311.

[15] AASHE. History of AASHE. 2024. Available at: https://www.aashe.org/about-us/aashe-history/. [Accessed 25 Jan 2025].

[16] Lucianto AE, Hasibuan HS, Herdiansyah H. Comparative assessment the subsidized housing using LEED, BREEAM and GREESHIP Neighbourhood (Case study: Parung Panjang, West Java, Indonesia). *E3S Web of Conferences* 2020;211:01031. https://doi.org/10.1051/e3sconf/202021101031.

[17] Hashim H-Y, Hakim A, Mohamed HZ, Shah Redza. Developing conceptual waste minimization awareness model through community-based movement: a case study of Green Team, International Islamic University Malaysia. *Geografia: Malaysian Journal of Society and Space* 2011;8(5):112–123.

[18] Arroyo P. A new taxonomy for examining the multi-role of campus sustainability assessments in organizational change. *Journal of Cleaner Production* 2017; 140:1763–1774. https://doi.org/10.1016/j.jclepro.2015.08.100.

[19] Chan TC. Marketing the green school: form, function, and the future. Hershey, PA: IGI Global; 2014.

[20] Universitas Indonesia. Guideline UI GreenMetric World University Rankings 2023: Innovation, impacts and future direction of sustainable universities. Jakarta: Universitas Indonesia; 2023. p. 1–50.

[21] Ali SBM, Mehdipoor A, Samsina Johari N, Hasanuzzaman M, Rahim NA. Modeling and performance analysis for high-rise building using ArchiCAD: initiatives towards energy-efficient building. *Sustainability* 2022;14(15):9780. https://doi.org/10.3390/su14159780.

[22] Konbr U, Elsayed M, Elboshy B. A framework for assessing the sustainability of Egyptian university campuses. *Civil Engineering and Architecture* 2023;11(4):1909–1939. https://doi.org/10.13189/cea.2023.110419.

[23] Satola D, Wiberg AH, Singh M, Babu S, James B, Dixit M, Sharston R, Grynberg Y, Gustavsen A. Comparative review of international approaches to net-zero buildings: knowledge-sharing initiative to develop design strategies for greenhouse gas emissions reduction. *Energy for Sustainable Development* 2022; 71:291–306. https://doi.org/10.1016/j.esd.2022.10.005.

[24] Quispe, E. C., Viveros Mira, M., Chamorro Díaz, M., Castrillón Mendoza, R., & Vidal Medina, J. R. (2025). Energy Management Systems in Higher Education Institutions' Buildings. *Energies, 18*(7), Article 1810. https://doi.org/10.3390/en18071810

[25] Turner WC, Roosa SA, Doty S. Energy management handbook. 9th ed. Denmark: River Publishers; 2020.

[26] Gupta, K, & Ahlgren EO. Analysis of city energy systems modeling case studies: A systematic review. *International Journal of Sustainable Energy Planning and Management* 2025; 43:123–139. https://doi.org/10.54337/ijsepm.9335.

[27] Taufan A, Zaki SA, Tuck NW, Singh MK, Rijal HB. Energy-efficient retrofitting strategies in mosque buildings: a review. *Renewable and Sustainable Energy Reviews* 2023; 183:113479. https://doi.org/10.1016/j.rser.2023.113479.

[28] Nasrollahzadeh N. Comprehensive building envelope optimization: improving energy, daylight, and thermal comfort performance of the dwelling unit. *Journal of Building Engineering* 2021; 44:103418. https://doi.org/10.1016/j.jobe.2021.103418.

[29] Hossain J, Kadir AFA, Hanafi AN, Shareef H, Khatib T, Baharin KA, Sulaima MF. A review on optimal energy management in commercial buildings. *Energies* 2023;16(4):1609. https://doi.org/10.3390/en16041609.

[30] Hossan, D., Mansor, Z. D., & Jaharuddin, N. S. (2023). Research population and sampling in quantitative study. *International Journal of Business and Technopreneurship (IJBT)*, *13*(3), 209–222. https://doi.org/10.58915/ijbt.v13i3.263.

[31] Kadraoui, H., Chikhaoui, A., & Bekkouche, S. M. E. A. (2019). Analysis of energy consumption for Algerian building in extreme North-African climates. *International Journal of Sustainable Energy Planning and Management, 19*, 45–58. https://doi.org/10.5278/ijsepm.2019.19.5.

[32] Paul B, Niu D, Nath TKB, Chau KW, Goswami S. A comprehensive review of renewable energy sources: Status, challenges and future directions. *Renewable Energy* 2023; 202:150–181. https://doi.org/10.1016/j.renene.2022.09.065