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Enhancing Energy Efficiency and Management in Smart Buildings: A Holistic Approach

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Abstract

Energy Efficiency and Management have advanced significantly owing to the increased global emphasis on sustainability, especially in buildings and infrastructure. The expanding global requirement for energy and the increasing environmental implications of energy consumption are the main drivers of concern regarding smart energy use in the modern world. In this regard, utilizing cleaner energy sources and maximizing energy efficiency are crucial. This study investigates the efficiency and management of energy in smart and intelligent buildings. Data were obtained by administering 100 structured questionnaires online to researchers specializing in building energy, architects and engineers, energy managers, building and property owners, property managers, and technicians, as online questionnaires can be easily distributed to many respondents, regardless of geographical location. Among these, only 92 responded to the questionnaire. Descriptive statistical analyses were performed using Microsoft Excel application software. The results revealed significant knowledge of various Energy Management Systems (BEMS), including solar Photovoltaic and HVAC systems. Key barriers to the implementation of these systems include high initial costs and limited public awareness. It was indicated that the significant contribution of supportive government policies, such as mandating intelligent sensors and automation systems and software, access to financial incentives, and establishing clear energy management goals, are the key strategies to overcome these challenges. Implementing an EEMS in smart buildings requires a multifaceted approach that combines financial support, technological integration, stakeholder engagement, and practical policy frameworks. When considered, identifying barriers and leveraging proposed strategies can significantly aid organisations and individuals in enhancing their energy efficiency efforts, ultimately leading to more sustainable building practices and reduced environmental impact.

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I. INTRODUCTION

The growing global emphasis on sustainability has driven significant advancements in energy conservation and reduction strategies, particularly for buildings and infrastructure [1]. The notion of energy optimisation and sustainability on an urban scale in smart buildings is a key aspect gaining importance in advancing and developing countries because of the rising demand for sustainable development [2]. As posited by [2], the context of sustainability in smart buildings hinges on building design, construction, and operation to minimise the environmental impact, conserve resources, and ensure long-term energy efficiency. [3] expressed that energy is at the centre of human life but has its costs. Therefore, excessive or unnecessary energy use can have economic impacts on society and significant global environmental consequences. Exploring the energy landscape by [4] reveals a substantial contribution of the construction and building sector, accounting for approximately 57% of the total energy consumption between 2011 and 2019, dwarfing the industrial sector's share by a mere 10%. The growing mandate for energy and escalating environmental impacts of energy consumption drive modern-day global concerns about wise energy use. The effective utilisation of energy and the use of cleaner energy resources have become highly significant [1].

For this reason, the ecosystem consists of intelligent buildings and structures, also known as smart buildings, and represents a system characterised by various advantages, mostly in terms of energy [3]. [3] defined smart or intelligent buildings as structures with advanced technologies, systems, and sensors that enable automated control, monitoring, and optimisation of various building operations, including energy usage, lighting, HVAC, ventilation, and access. Smart residential buildings, in contrast to traditional residences, are furnished with an array of intelligent systems that facilitate energy-efficient functioning while using technologies such as home automation, advanced data analytics, and Internet of Things (IoT) sensors to optimise

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energy use, reduce their influence on the environment, and boost the building's overall efficiency [5]. A pivotal development in achieving these objectives to further optimise energy usage and streamline building operations is the concept of Building Energy Management Systems (BEMS), which is now being used. A BEMS can be described as a combination of strategies and methods needed to improve the performance, efficiency, and energy utilisation [6]. This technology permits the implementation of key energy management tasks, such as automating demand response approaches, overseeing energy costs, detecting energy-use anomalies, and arranging energy-use information [7]. The primary goal is to advance sustainable energy practices by optimising resources and maximising efficiency in the smart infrastructure [8]. To move from fossil fuels to cleaner, renewable energy sources, sustainable energy development involves various technologies that advance infrastructure, innovative grid systems, energy storage, and power generation [8].

Despite the proliferation of energy management and its adoption in buildings, a significant gap remains in the comprehensive analyses of diverse energy management system types in smart buildings. Therefore, this study aims to investigate the efficiency and management of energy in smart and intelligent buildings by identifying and categorising different kinds of energy management systems based on their functionality and target applications, identifying the key factors influencing the successful implementation and adoption of energy efficiency and management systems, and determining the key drivers of successful energy efficiency and management systems and technology implementation.

II. Concept Of Smart-Building Energy Efficiency And Management

According to [3], technological development linked to energy efficiency and the reduction of energy consumption and its management has set the conditions for the emergence of a new building model: smart buildings. This is a class of buildings in which control systems can manage and monitor the operation of other devices in real time, and the latest generation technologies are exploited to connect a variety of subsystems that were initially operated independently and decentralised [3]. Alternatively, [9] posited that an efficient and well-managed energy-wise smart building creates comfortable living conditions inside the dwelling with the least possible energy consumption, maximising efficiency in the use of resources. As the cost of energy increases and the energy crisis becomes an imminent reality, the need to provide energy-efficient building designs has become more critical [9]. Managing smart building energy and other needs efficiently and intelligently can provide considerable benefits [10]. A building energy management system (BEMS) is a sophisticated method that monitors and controls a building's energy needs [10] and other aspects of the building, regardless of whether it is residential or commercial. A building energy management system is a broad concept of building control with a variety of characteristics. BEMS are limited to sophisticated and advanced control systems [11]. However, although all buildings require control systems, building energy management systems differ substantially [11].

A. Building Automation System (BAS)

According to [12], Building Automation Systems (BAS) are at the heart of energy management in smart buildings, playing a crucial role in integrating and automating key building operations. By connecting various subsystems such as HVAC, lighting, security, and fire safety, the BAS ensures that these systems work together seamlessly to optimise energy use. HVAC systems are one of the most energy-intensive components of buildings and are often responsible for a substantial portion of their total energy consumption [13]. Modern HVAC systems are designed with energy efficiency in mind, incorporating technologies such as smart thermostats, variable-speed drives, and zone-based control. Lighting is another significant energy consumer in buildings, and efficient lighting control systems are essential for reducing energy use. Using a network of sensors, controllers, and software, BAS monitors the building environment in real time, adjusting to minimise energy consumption while maintaining comfort levels [14]. For example, a BAS might automatically lower the heating in an unoccupied building section or dim lights when sufficient daylight is detected [13].

B. Renewable Energy Integration Systems

As buildings strive to reduce their carbon footprint, integrating renewable energy sources has become increasingly important [15]. Renewable energy integration systems manage energy generation, storage, and distribution from on-site sources, such as solar panels, wind turbines, and geothermal systems. The ability to generate and manage renewable energy on-site reduces a building's reliance on fossil fuels and provides resilience to grid outages. Moreover, as energy prices fluctuate, having a renewable energy system can significantly lower operational costs, making it a wise long-term investment for building owners [16].

C. Smart Metering and submetering Systems

According to [17], smart metering and submetering technologies provide detailed data for effective energy management. Smart meters offer real-time insights into a building's overall energy use, allowing for close monitoring and rapid identification of inefficiencies [18]. However, submetering breaks down energy consumption into specific areas or systems within the building, such as different floors, departments, or equipment. These granular data enable targeted energy-saving measures, such as optimising the operation of a specific system or retrofitting a particular area. Additionally, smart metering supports dynamic pricing models, in which energy costs vary based on real-time demand. By enabling more precise control over energy use, smart metering and submetering are essential tools for improving the efficiency and reducing costs in modern buildings [19].

D. Power Quality Management Systems

Power quality management systems are crucial for ensuring that the electrical power supplied to a building is stable and free from disturbances, such as voltage sags, swells, or harmonic distortions [17]. These issues can damage the sensitive equipment, reduce operational efficiency, and increase energy costs. Power quality management systems monitor these parameters in real time, allowing for rapid identification and correction of issues [20]. For example, if a voltage sag is detected, the system can automatically adjust the operation of the critical equipment to prevent damage. In addition, the integration of power quality management systems improves system performance by maintaining optimal voltage and frequency levels, ensuring that electrical systems operate at their highest efficiency, minimising unnecessary energy draws, and extending the lifespan of equipment. By maintaining high power quality, these systems help ensure that a building's energy-consuming devices operate optimally, thereby reducing the overall energy consumption and costs. In modern buildings, where reliance on sensitive electronic equipment is high, the role of power quality management in energy efficiency cannot be understood [20].

III. Implementation Challenges And Barriers

The initial cost is one of the most significant barriers to adopting energy management systems in smart buildings [21]. This includes expenses for advanced hardware, software, installation, and the integration of various HVAC, lighting, and security systems under a centralised platform. Upfront investment is substantial for many building owners and operators, making it a crucial factor in decision making [21]. Studies have shown that the return on investment for energy management systems can range from a few years to over a decade, depending on factors such as building size and government subsidies. This implies that subsidies lower upfront capital expenses, make projects more affordable, and reduce payback periods. Energy usage patterns suggest that facilities with high energy usage benefit more from energy-efficient technologies because savings accumulate faster and local energy costs are higher, implying that higher local energy costs amplify the savings from energy efficiency measures, leading to a shorter payback period [17]. According to the U.S. Upgrading a traditional HVAC system to an energy-efficient model for a commercial building can cost between $10,000 and $50,000, depending on the size of the building and the system complexity. Similarly, replacing incandescent or fluorescent lighting with LED lights costs approximately $100 to $150 per fixture and installation [17].

System integration and interoperability are critical for the success of energy management systems in smart buildings [22]. Buildings often have a mix of legacy systems and modern technologies, and ensuring that these diverse systems can communicate and work together is a complex challenge. Effective integration allows different subsystems of lighting, HVAC, and security to operate harmoniously and optimise energy use across the entire building. Interoperability is critical in the context of smart buildings, where various technologies from different vendors need to work together. The lack of standardised protocols and communication methods can lead to significant integration cost challenges [17].

Furthermore, [23] theorised that the growing emphasis on environmental and social responsibility is a powerful driver for adopting energy management systems in buildings. Organisations are increasingly aware of their environmental impact and are under pressure from stakeholders, including investors, customers, and regulatory bodies, to reduce their carbon footprint and contribute to sustainable goals. Some identifiable roles of these stakeholders include establishing and enforcing energy efficiency standards and building codes, and educating the public and businesses on the benefits of energy efficiency and its management practices [23].

[16] stated that the successful implementation of energy management systems hinges not only on the availability of advanced technology but also on the availability of skilled technicians who can instal, maintain, and optimise these systems. Unfortunately, there is a notable shortage of technicians with expertise required to handle the complexity of modern energy management technologies [16]. This shortage poses a significant challenge, as energy management systems are often highly technical and require specialised knowledge. These systems may not be correctly installed without adequate technical expertise, leading to suboptimal performance or system failure.

IV. Strategies For Successful Energy Efficiency And Management Systems Implementation

Achieving energy efficiency and effective management in smart buildings are increasingly recognised as essential for reducing operational costs, enhancing sustainability, and meeting environmental goals. As the complexity of building systems increases, the implementation of these energy strategies requires a thoughtful, coordinated approach. Succeeding in energy management and efficiency depends on several factors. These optimise energy usage and utilisation, and contribute to the long-term capability and resilience of smart buildings.

A. Smart Building Technologies and IoT Integration

Integrating the Internet of Things (IoT) as an innovative building technology is essential to achieve successful energy management and efficiency [24]. IoT devices, such as smart sensors, meters, and connected HVAC systems, enable the real-time monitoring and control of various building functions, including lighting, temperature, and energy consumption. The data are integrated into an energy management system (EMS) that automatically analyses and adjusts heating, cooling, and lighting, ensuring that the energy is used efficiently. Building management systems can optimise energy usage, reduce waste, and respond dynamically to occupancy patterns and environmental conditions via data from IoT devices and systems [24]. According to [25], IoT integration allows for predictive maintenance, ensuring that building systems operate at peak efficiency, extend their lifespan, and minimise energy use. The unified link and synchronisation between these devices and systems provided by the IoT are essential for overall energy management in smart buildings.

B. Access to Financial Options and Incentives

The initial cost of implementing energy-efficient technologies can be high, thereby posing a barrier to building owners and developers. Consequently, access to financial options and incentives is a critical driver for adopting energy management systems in smart buildings [26]. However, financial options such as green loans, energy performance contracts, and rebates can offset these costs and make investments in energy efficiency more attractive [26]. Furthermore, government incentives, such as tax credits and subsidies for renewable energy installations or energy-efficient upgrades, can significantly reduce the payback period and enhance the return on investment (ROI) of these projects [26]. The provision of access to financial tools and incentives, according to [27], can aid stakeholders such as financial institutions in justifying and prioritising investments in smart building technologies to drive energy efficiency via the development of guarantees or insurance products to reduce financial risks and offer loans of financing for energy-efficient products and projects [27].

C. *Government Policies and Regulations Supporting Energy Efficiency and Management Systems*

Government policies and regulations are instrumental in promoting energy efficiency and the widespread implementation of energy management systems in smart buildings [28]. Regulatory frameworks, such as energy efficiency standards, building codes, and mandates for renewable energy, create a structured environment that encourages compliance and drives innovation in energy management [28]. For instance, implementing stringent energy codes in new construction and retrofitting projects ensures that buildings meet the minimum efficiency requirements and reduce the overall energy consumption [29]. Another recommended governmental policy is establishing and enforcing standards, building codes, and regulations regarding energy utilisation and its management in intelligent buildings [29]. Governments often support these regulations through incentive programs and public awareness campaigns, further accelerating the adoption of energy-efficient technologies. For example, some governmental organisations have initiated training partnerships with technical institutions to bridge the skill gap. Effective policies not only mandate energy efficiency but also provide the necessary support mechanisms for their successful implementation in smart buildings [29].

V. METHODOLOGY

This study adopts a mixed research methodology. Mixed-method research, which integrates quantitative and qualitative methods, is gaining recognition for its strength and comprehensiveness in the investigation of intricate phenomena. This approach comprehensively explains the factors at play and more subjective elements. An extensive literature review was conducted to identify the key energy efficiency, management systems, and technologies, as well as the key factors affecting or influencing implementation. This review includes academic journals, industry reports from websites, and conference papers. A structured questionnaire was designed to collect quantitative data from respondents. The questionnaire was the main instrument consisting of close-ended questions and was administered online. The online questionnaire was chosen because of its ease of distribution to many respondents, regardless of their geographical location [30]. This method was adopted because it can quantify various elements and factors, including management systems and technologies.

The population of this study consisted of researchers specialising in building energy, architects and engineers, energy managers, building and property owners, property managers, and technicians with experience in energy management and efficiency in smart buildings. The purposive sampling technique was used to select respondents because it aids in choosing participants who are most likely to provide relevant and rich information for the study. The data obtained from the survey were analysed descriptively and tables were used to present the results.

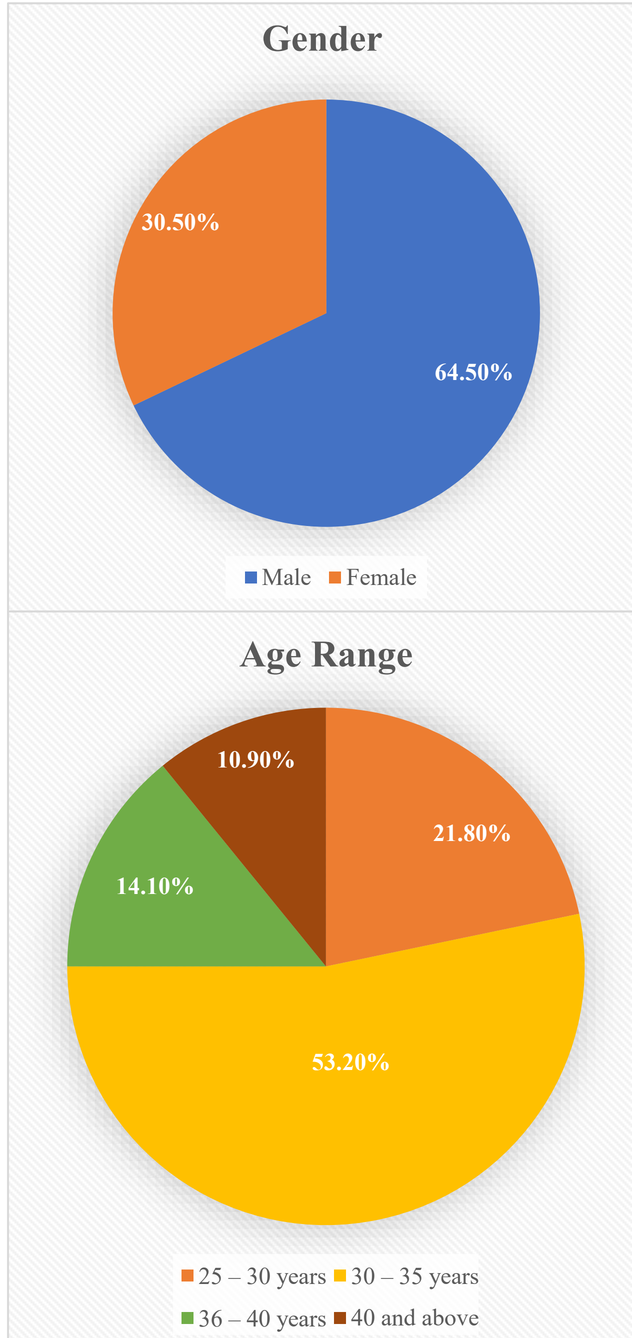

Fig.1. Demographic of the respondents

VI. RESULTS AND FINDINGS

Figures 1 and 2 below show the demographic and present a detailed overview of the respondents involved in the Energy Efficiency and Management Systems (EEMS) survey. Among the 92 respondents, most were male (69.5%), while 30.5% were female. The age distribution revealed that the largest group fell within the 30-35 age range (53.2%), followed by younger respondents aged 25-30 (21.8%). In terms of educational qualifications, most respondents held a bachelor's degree (41.4%), while others had Higher National Diplomas (29.3%), master's degrees (20.6%), and doctorates (8.7%). Professionally, the respondents were diverse, with notable representations from engineers (21.7%), property managers (19.6%), and researchers (20.6%). The sectors they represent include commercial and real estate (37.0%), residential buildings (21.7%), and government (21.7%), indicating broad engagement across various industries related to energy management.

The predominance of male respondents (69.5%) alongside the majority in the 30-35 age range (53.2%) suggests that the field of energy management may attract younger professionals, predominantly males. The educational background of the respondents shows that a significant portion holds at least a bachelor's degree (41.4%), with many also having higher qualifications. This level is likely to correlate with their professional roles, as those in positions such as Engineers (21.7%) and Researchers (20.6%) typically require advanced knowledge and skills. The younger demographic, with a significant portion under 35, may correlate with greater openness to adopting new technologies and practices in energy management and efficiency. Conversely, older professionals may bring valuable experiences and insights into traditional practices, which will benefit from integrating new systems with existing frameworks.

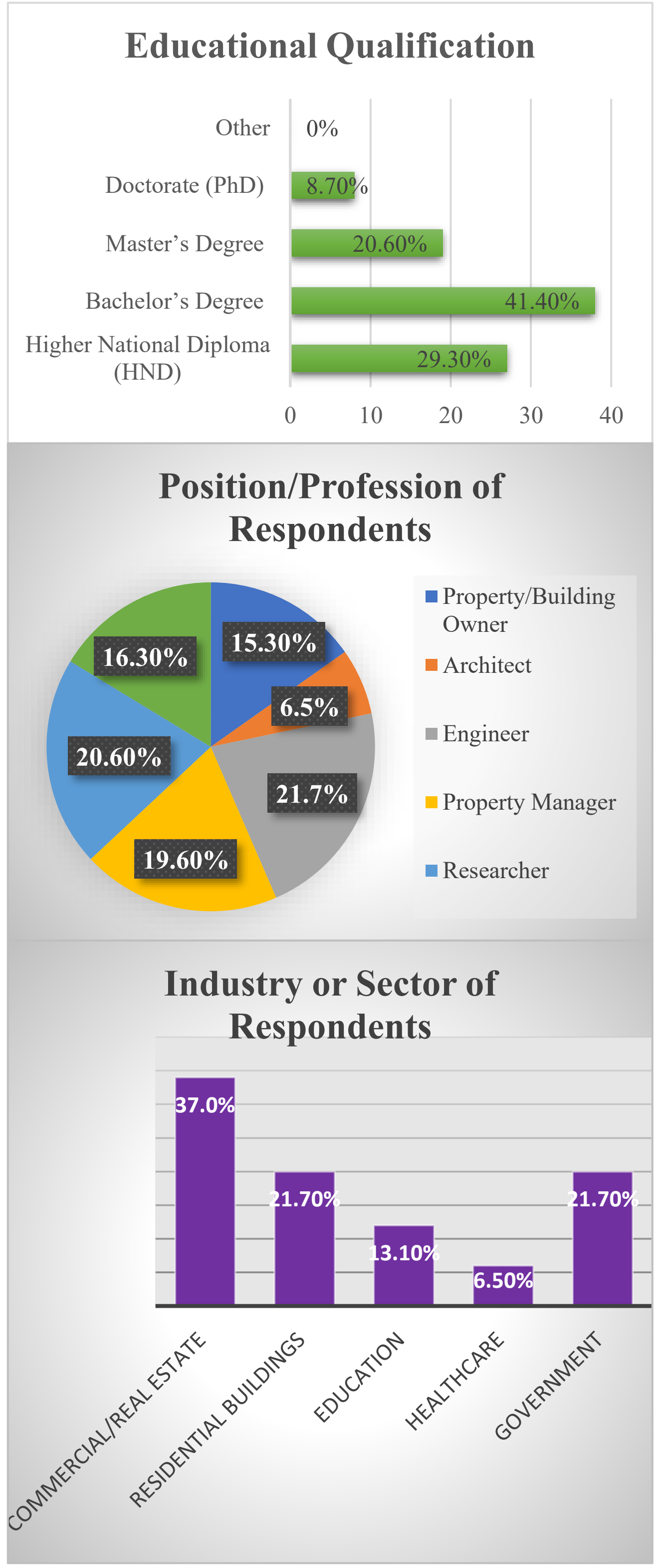

Fig.2. Demographic of the respondents

A. Energy Efficiency and Management Systems and Technologies

This section of the analysis provides an overview of the respondents' degree of knowledge and usage of various Energy Efficiency and Management Systems (EEMS). Table I categorises the different EEMS technologies and indicates the respondents' familiarity with each, using a scale from 1 to 5, where 1 represents low knowledge or usage and 5 represents high knowledge or usage.

TABLE I. DEGREE OF KNOWLEDGE/USAGE OF EEMS

Energy Efficiency and Management Systems (EEMS)	Level of knowledge/usage					Mean	SD	Rank
	1	2	3	4	5			
Solar Photovoltaic (PV) systems	-	6	9	37	40	**4.207**	3.773	1st
Energy-efficient HVAC systems	-	9	14	30	39	**4.076**	3.674	2nd
Smart Thermostats	-	10	19	25	38	**3.989**	3.603	3rd
Geothermal Systems	-	10	18	28	36	**3.978**	3.587	4th
Occupancy Sensors	2	3	34	25	28	**3.804**	3.410	5th
Smart Metering and Submetering Systems	3	9	25	28	27	**3.728**	3.369	6th
Smart Lighting Controls with Daylight Harvesting	2	10	26	32	22	**3.674**	3.297	7th
Plug Load Management Systems	5	10	28	19	30	**3.641**	3.323	8th
Renewable Energy Integration Systems	4	11	27	29	21	**3.565**	3.217	9th
Energy Storage Systems (ESS)	5	13	29	27	18	**3.435**	3.100	10th
Power Quality Management Systems	6	12	29	27	18	**3.424**	3.096	11th
Predictive Maintenance and Fault Detection Systems	6	16	34	20	16	**3.261**	2.941	12th
Building Automation Systems (BAS)	3	20	35	22	12	**3.217**	2.863	13th
Energy Recovery Ventilation (ERV) Systems	7	18	31	20	16	**3.217**	2.915	14th
Grey Water Recycling Systems	12	16	36	16	12	**3.000**	2.719	15th

Source: Field Survey (2024). Note: SD=Standard Deviation

The results in Table I show that the most recognised technology is solar Photovoltaic (PV) systems, with a mean score of 4.207, indicating a high level of knowledge among respondents. This was followed by energy-efficient HVAC systems (mean score of 4.076) and smart thermostats (mean score of 3.989), reflecting significant familiarity. Other technologies, such as Building Automation Systems (BAS) and Energy Storage Systems (ESS), had mean scores of 3.217 and 3.435, respectively, suggesting moderate knowledge levels.

The table also highlights areas where knowledge is comparatively low, such as Grey Water Recycling Systems (mean score of 3.000) and Energy Recovery Ventilation (ERV) systems (mean score of 3.217). Overall, the data indicated a varied degree of knowledge among respondents regarding EEMS, with a tendency towards higher familiarity with more commonly implemented technologies.

B. Factors hindering successful Energy Efficiency and Management Systems Implementation

This section of the analysis entails various factors considered to be some of the main hindering factors to the successful adoption and implementation of Energy Efficiency and Management Systems (EEMS) in smart buildings. Table II identifies several factors along with their corresponding mean values and indicates the level of influence of each factor using a scale of 1 to 5, where 1 indicates no influence and 5 represents high influence.

TABLE II. FACTORS HINDERING THE SUCCESSFUL IMPLEMENTATION OF EEMS IN SMART BUILDINGS

Hindering Factors to EEMS Implementation	Frequencies					Mean	SD	Rank
	1	2	3	4	5			
High initial costs for energy-efficient systems and technologies	-	8	20	26	38	**4.022**	3.624	1st
Limited public awareness of smart-building energy management systems	4	5	16	30	37	**3.989**	3.621	2nd
Lack of technical expertise for the system integration	2	8	19	33	30	**3.880**	3.498	3rd
Insufficient data analytics capabilities	1	4	29	32	26	**3.848**	3.436	4th
Incompatible existing infrastructure	1	6	28	30	27	**3.826**	3.426	5th
Inadequate policies and regulations governing systems	-	5	33	29	25	**3.804**	3.388	6th
Resistance to change from some occupants	3	2	28	37	22	**3.793**	3.388	7th
Limited budget for energy efficiency and management initiatives	5	4	24	31	28	**3.793**	3.433	8th
Inadequate training and sensitisation for building occupants	3	10	21	28	30	**3.783**	3.429	9th
Limited access to financial options for energy management projects	3	5	28	30	26	**3.772**	3.391	10th
High maintenance cost for the systems	3	2	31	34	22	**3.761**	3.359	11th
Difficulty in integrating multiple systems	1	8	26	34	23	**3.761**	3.362	12th
Complexity of energy efficiency and management certification processes	3	8	35	20	26	**3.630**	3.274	13th

Limited availability of labour	2	6	36	29	19	**3.620**	3.224	14th
Lack of standardisation for the systems	7	10	29	26	20	**3.457**	3.138	15th

Source: Field Survey (2024). *Note: SD=Standard Deviation*

As shown in Table II, the most significant barrier is the high initial costs for energy-efficient systems and technologies, which have a mean value of 4.0, indicating a strong perception of financial constraints. Following closely is the Limited public awareness of smart building energy management systems (mean = 3.989). This highlights the need for better education and outreach programmes. The lack of technical expertise for system integration (mean = 3.880) further complicates implementation, as does the insufficient data analytics capabilities (mean = 3.848), which restrict effective optimisation.

In addition, incompatible existing infrastructure (mean = 3.826) poses integration challenges, whereas inadequate policies and regulations (mean = 3.804) can impede progress. Resistance to change from some occupants (mean = 3.793) and limited budgets for energy efficiency initiatives (mean = 3.793) also contributed to the difficulties faced. Other notable factors included inadequate training for building occupants (mean = 3.783), limited access to financial options (mean = 3.772), and high maintenance costs (mean = 3.761), all of which further complicate the implementation landscape. Challenges such as difficulty in integrating multiple systems (mean = 3.761) and the complexity of certification processes (mean= 3.630) add to the hurdles, while limited availability of labour (mean = 3.620) and a lack of standardisation (mean = 3.457) underscore systemic issues that need to be addressed.

These factors collectively illustrate stakeholders' multifaceted challenges in advancing EEMS in smart buildings, emphasising the need for targeted strategies to overcome these barriers.

C. *Strategies for Successful Systems and Technologies Implementation*

Table III outlines strategies for implementing Energy Efficiency and Management Systems (EEMS) in smart buildings.

TABLE III. STRATEGIES FOR SUCCESSFUL IMPLEMENTATION OF EEMS IN SMART BUILDINGS

Driving factors to successful EEMS Implementation	Frequencies					Mean	SD	Rank
	1	2	3	4	5			
Government policies and regulations supporting energy optimisation and conservation systems	-	2	20	31	39	**4.163**	3.724	1st
Access to financial options and incentives	-	3	22	30	37	**4.098**	3.668	2nd
Clear energy management goals and objectives	-	5	21	31	35	**4.043**	3.624	3rd
Smart building technologies and IoT integration	2	1	26	29	34	**4.000**	3.590	4th
Energy management and tracking software	-	5	25	29	33	**3.978**	3.563	5th
Building Design and Architecture optimised for smart-building energy reduction and optimisation	4	2	22	29	35	**3.967**	3.587	6th
Open communication and collaboration among stakeholders	1	4	23	34	30	**3.957**	3.542	7th
Robust data analytics and performance monitoring	2	5	26	28	31	**3.880**	3.492	8th
Employee engagement and training programs	3	-	30	32	27	**3.870**	3.464	9th
Strong leadership and commitment to these systems	2	4	28	30	28	**3.848**	3.452	10th
Collaboration with energy-efficient and management experts and consultants	3	8	22	30	29	**3.804**	3.439	11th
Integration with existing building management systems	7	4	27	29	25	**3.663**	3.326	12th
Building occupant engagement and feedback mechanisms	5	10	27	31	19	**3.533**	3.186	13th
Continuous commissioning and maintenance practices	3	18	29	22	20	**3.413**	3.082	14th
Incentives for energy-efficient behaviours and practices	2	24	33	13	20	**3.272**	2.953	15th

Source: Field Survey (2024). *Note: SD=Standard Deviation*

Table III indicates that the most critical driving factors identified are government policies and regulations supporting energy optimisation and conservation systems, with a mean value of 4.0. This shows a strong consensus on the importance of supportive governmental frameworks in facilitating the adoption of EEMS. Following this, access to financial options and incentives (mean = 4.098) is highlighted as crucial, emphasising the need for financial support to encourage investment in energy-efficient technologies. Another significant factor is the establishment of clear energy management goals and objectives (mean = 4.043), which underscores organisations' need to define specific targets to guide their energy efficiency efforts. Integrating smart building technologies and the IoT (mean = 4.000) is also deemed essential, reflecting the growing importance of advanced technologies in enhancing energy management.

In addition, the energy management and tracking software (mean = 3.978) is recognised as a vital tool for monitoring and optimising energy usage. Other notable strategies include building design and architecture optimised for smart building energy reduction optimisation (mean = 3.967), highlighting the role of design in achieving energy efficiency. The importance of open communication and collaboration among stakeholders (mean = 3.957) was also emphasised because effective collaboration can lead to more successful implementation outcomes. Furthermore, robust data analytics and performance monitoring (mean = 3.880) were essential for informed decision-making, whereas employee engagement and training programs (mean= 3.870) were critical for ensuring that all personnel were equipped to contribute to energy management efforts. Lastly, strong leadership and commitment to these systems (mean = 3.848) are vital for driving initiatives forward and collaborating with energy-efficient management experts (mean = 3.804) to leverage specialised knowledge. Integrating EEMS with existing building management systems (mean = 3.663) and establishing building occupant engagement and feedback mechanisms (mean = 3.533) are essential strategies. This can be achieved by simple methods, such as displaying personalised tips on reducing energy consumption and using competitions or reward systems to encourage energy-saving behaviours in the building. These factors collectively illustrate the multifaceted approaches necessary for the successful implementation of EEMS in smart buildings, highlighting the need for comprehensive strategies that encompass policy, technology, and stakeholder engagement.

VII. Conclusion

Unarguably, the growing need for sustainable development in both developed and developing nations has led to the concept of energy efficiency, management, and optimisation on an urban scale in smart buildings. As posited by [6], Building Energy Management Systems (BEMS) are an idea that is now being employed, taking into account the utilisation of the building and a collection of tactics and procedures required to enhance its effectiveness, efficiency, and energy use.

This study provides a comprehensive understanding of the current landscape of Energy Efficiency and Management Systems (EEMS) in smart buildings. The findings indicate that, while respondents have a significant degree of knowledge and usage of various EEMS technologies, challenges hinder their successful implementation. Key barriers include high initial costs, limited public awareness, and a lack of technical expertise, which underscore the financial and educational gaps that must be addressed. The practical implications of this study highlight the need for enhanced financial options, such as government-subsidised programs for energy-efficient systems, which have been successful in countries such as Germany and Sweden. For instance, the German Federal Government's KfW Bank Group provides loans and grants to property owners for energy-efficient renovations, substantially reducing upfront costs. Similarly, technical expertise challenges can be mitigated by implementing training programs akin to those in the United States, where technical colleges offer specialised courses on energy management systems tailored for smart buildings. Strategies for overcoming these challenges emphasise the essential responsibility of supportive government policies, access to economic incentives, and the establishment of clear energy management goals. Integrating advanced technologies and robust data analytics is necessary to optimise energy management practices. The theoretical implications suggest that EEMS adoption requires a multidisciplinary framework that integrates knowledge from engineering, behavioural sciences, and policy studies to understand and influence system uptake. Socially, this study underscores the critical role of raising public awareness and fostering community engagement, as seen in Japan's "Eco-Town" initiative, which combines public campaigns and practical workshops to promote energy efficiency at the local level. Additionally, fostering collaboration among stakeholders and engaging building occupants are vital for creating a culture of energy efficiency. Insights from this research provide directions for future studies, including exploring the integration of AI-driven predictive analytics to enhance decision-making in EEMS, as demonstrated in pilot programs in Singapore's smart-building ecosystem. In summary, while challenges such as costs and technical expertise persist, technological innovations and growing environmental awareness provide a strong foundation for overcoming these barriers, paving the way for broader adoption of energy management systems.

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