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Barriers to the Adoption of Building Energy Management Systems in Residential Buildings: A Property Manager's Perspective

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Abstract

Purpose: Building Energy Management Systems (BEMS) are increasingly recognized as essential tools for improving energy efficiency and sustainability in residential buildings; however, their adoption remains limited, particularly in developing contexts such as South Africa. This paper aims to investigate the barriers to the adoption of BEMS from the perspective of property managers to inform strategies that can enhance their implementation and uptake. Research Methodology: The study adopted a quantitative research methodology and utilized a questionnaire to gather data from the property managers in Bloemfontein, Free State, South Africa. The data gathered was analyzed descriptively. Findings: The study found that key barriers to the adoption of energy management systems in residential buildings consist of Lack of Awareness, Lack of commitment from top management, and Lack of Knowledge. The study further found that Lack of Funds, Resistance To change, and Lack of trust also play a significant role in preventing holistic implementation of BEMS in residential buildings. Practical Implications: The study provides policymakers, property managers, and industry stakeholders with practical guidance to develop targeted strategies and interventions that address key barriers and promote the effective adoption of Building Energy Management Systems in residential buildings. Value/Originality: The originality of this study lies in its focus on property managers' perspectives within the South African residential context, offering context-specific insights into BEMS adoption barriers that are often overlooked in existing literature.

Keywords
Building Energy Management Systems (BEMS), Adoption Barriers, Residential Buildings, Property Managers, Energy Efficiency.

1. Introduction

There is a rise in global energy demand, which has posed a significant challenge to climate change, since most energy is generated by burning coal, which releases greenhouse gases that are not environmentally friendly (Khafiso et al. 2025). Therefore, this necessitates a drive for energy efficiency in the built environment to address this challenge and a relook at renewable energy generation alternatives that can mitigate global energy issues. Khafiso et al. (2024) state that residential buildings globally account for a significant proportion of total energy consumption through cooking, heating, and cooling, etc., which presents a critical opportunity to reduce energy consumption and associated carbon emissions. As a response, digital innovations such as BEMS have emerged as effective systems for monitoring, controlling, and reducing energy consumption in real time (Hwang et al. 2025). Khafiso (2024) states that these innovative systems have advanced technologies embedded in them, which consist of sensors, automation, and data analytics, which holistically enhance structures' operational efficiency and assist in sustainable building practices. Despite the evident benefits of BEMS in residential buildings, in developed countries, the adoption of BEMS in residential buildings is uneven in developing countries.

In developing countries, adoption of BEMS is very low and is mainly contributed to by a multifaceted array of challenges. Zarate-Perez et al. (2023) allude that the state of Building Energy Management Systems (BEMS) in developing countries reflects a growing but still evolving landscape shaped by increasing urbanization, rising energy demand, and the global push toward sustainability. In many emerging economies, residential buildings are gradually transitioning from conventional energy practices to more digitally enabled systems that allow for real-time monitoring, control, and optimization of energy use (Khafiso et al. 2025). Governments and industry stakeholders are increasingly recognizing the role of BEMS in improving energy efficiency, reducing operational costs, and supporting national energy security goals. As a result, there has been a steady increase in pilot projects, smart housing developments, and the integration of basic automation systems within residential buildings. In the South African country, as part of the developing countries, BEMS adoption is very low thus, the objective of the study is to: Assess barriers to the adoption of BEMS in residential buildings in Bloemfontein, Free State, South Africa

1. Overview of Building Energy Management Systems (BEMS)

BEMS are considered advanced digital systems that are mainly designed to monitor, control, and reduce energy consumption within buildings, thereby enhancing sustainability and efficiency in buildings, whether commercial or residential (Akbulut et al. 2025). In residential settings, the adoption of BEMS enhances operational efficiency and overall productivity of the end users since it also taps into the thermal comfort of the building (Ramantswana et al. 2026). Khafiso (2024) states that BEMS are mostly regarded as integrated systems that integrate hardware and software to manage building services, which consist of heating, ventilation, air conditioning, lighting, and electrical systems. These advanced systems play a very critical role in reducing energy consumption, which in turn lowers operational costs and supports environmental goals such as carbon emission reduction. With the emerging trend of smart buildings and sustainable development, BEMS have been seen as the fundamental component of modern building management strategies, especially from the perspective of energy efficiency and climate change mitigation through the components embedded in the BEMS systems (Borah 2025).

Fundamental components of BEMS consist of sensors, automation systems, and control mechanisms, which make the whole system work efficiently (Sayed and Gabbar 2017). Sensors, a part of the system, are mainly responsible for collecting real-time data on environmental and operational parameters, which consist of temperature, humidity, occupancy, and energy utilization (Chaudhari et al. 2024). The data collected from the sensors is then processed by the automation systems that now analyse the data to illustrate patterns and thus trigger appropriate remedial actions. Control systems, on the other hand, act as a decision-making interface which the regulation of building services through predefined algorithms and user inputs (Plasson-Simoni et al. 2026). Holistically, these main components make a closed-loop system that ensures optimal performance by continuously adjusting building operations to match ever-changing climatic conditions. Therefore, the inclusion of these technologies, especially in energy management, enables enhanced accuracy, responsiveness, and efficiency in energy management in residential buildings.

In residential buildings, the inclusion or integration of BEMS has gained attention due to rising energy costs and growing energy demand that is driven by rapid population growth and demand for sustainable living environments (Vuruşan and Nafa 2026). BEMS in the residential setting are used to manage energy usage in both the standalone and multi-unit levels, enabling end users to monitor and control their energy usage more effectively. Kumar et al. (2026) assert that common applications include automated lighting systems, smart thermostats, and energy-efficient

HVAC control, which contribute to reduced energy wastage and improved comfort levels. Additionally, BEMS can facilitate demand-side management by allowing users to adjust their energy consumption based on real-time pricing signals or grid demands, thereby enhancing overall energy system efficiency (el Abed et al. 2026). Furthermore, the integration of BEMS in residential buildings supports the transition towards smart homes and smart grids. These systems enable interoperability with other digital technologies such as the Internet of Things (IoT), renewable energy systems, and energy storage solutions, thereby creating a more resilient and adaptive energy ecosystem. As highlighted in the literature, the successful implementation of BEMS depends on factors such as user awareness, technological infrastructure, and supportive policy frameworks, which collectively influence their effectiveness and scalability in residential settings.

2. Theoretical Framework

The theoretical framework of this study is grounded in behavioral and technology adoption theories to explain the factors influencing the uptake of BEMS in residential buildings. Central to this framework is the Theory of Planned Behaviour, which posits that an individual's intention to adopt a technology is determined by three key constructs: attitude toward the behavior, subjective norms, and perceived behavioural control (Sen et al. 2026). In the context of BEMS, attitude reflects residents' perceptions of the usefulness and benefits of the system, subjective norms capture the influence of peers, industry stakeholders, and societal expectations, while perceived behavioral control relates to ease of use, affordability, and access to the necessary infrastructure. These constructs collectively shape behavioral intentions, which ultimately influence actual adoption and usage of BEMS in residential settings.

To strengthen the explanatory power of the framework, TPB is integrated with complementary perspectives from technology adoption theories such as the Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT). These models introduce additional constructs such as perceived usefulness, ease of use, facilitating conditions, and social influence, which are critical in understanding digital technology adoption in the built environment. The integration of these theories provides a comprehensive lens for analysing both behavioural and technological determinants of BEMS adoption, particularly in developing country contexts like South Africa. This combined framework enables the study to examine how individual perceptions, social pressures, and enabling conditions interact to influence decision-making, thereby offering a robust foundation for assessing the adoption and implementation of BEMS in residential buildings.

3. Research Methodology

The study adopted a quantitative research methodology. According to Cresswell and Cresswell (2017), quantitative research methodology is a systematic approach used to collect and analyze numerical data, allowing researchers to quantify variables and identify patterns, relationships, or trends. This methodology is grounded in the scientific method and involves the use of structured instruments, such as surveys, experiments, or existing statistical data, to gather data that can be subjected to statistical analysis(Gawali, 2023.). It emphasizes objectivity and reliability, often seeking to establish cause-and-effect relationships by controlling variables and using large, representative samples to ensure the validity of the results (Luzano, 2024). A three-stage multi-phase research approach, as shown in Figure 1, is used in this study. The questionnaire used a five-point Likert scale, where answers ranging from 1 to 5 indicated either strongly disagree, disagree, neutral, agree, or strongly agree. The questionnaire consisted of 26 questions, 1 to 3 measuring the demographic background of the respondents. 4 to 26 examined the respondent's level of agreement with various drivers to the adoption of energy management systems in residential buildings. The closed-ended questionnaire was dispatched via email to all the property managers who were managing residential buildings in Bloemfontein, Free State, South Africa. A total of 80 property managers were sent the questionnaire, but only 43 of them responded to it. This type of sampling is referred to as total population sampling under purposive sampling. In total, 43 responses were received, which is deemed appropriate because most studies require a sample size of at least 30 (Memon et al. 2020; Ajayi et al. 2022). Pereira (2024) state that for all practical purposes, if the sample size is relatively large, 30 or more is the standard rule of thumb. The reason for the 43 responses is also that most of the managers manage multiple buildings in Bloemfontein; for instance, they manage 4 properties with more than 60 residences in each.

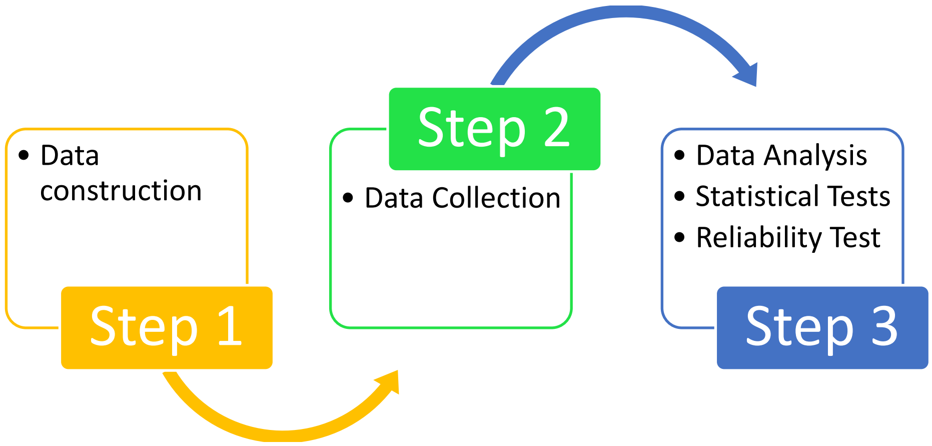

Figure 1. A three-stage multi-phase research approach (Source: Authors)

4. Findings and Discussions

5.1. Demographic Data of the respondents

Figure 2 illustrates that the majority of respondents have relatively limited experience in property management, with 58.1% having between 1–5 years of experience. This suggests that the sample is largely composed of early-career property managers, which may influence perspectives on emerging systems such as BEMS. A moderate proportion of respondents (18.6% each) fall within the 6–10 years and 11–15 years categories, indicating a reasonable level of mid-career experience contributing to the study. However, only 4.7% of respondents have more than 16 years of experience, reflecting a limited representation of highly experienced professionals. Thus, the figure indicates a youthful and developing professional cohort, which may be more adaptable to technological adoption but potentially less informed by long-term industry experience.

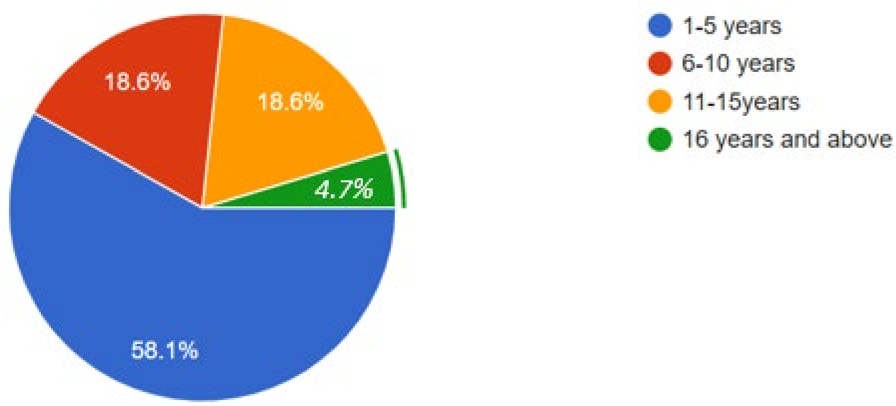

Figure 2. Number of Years of Managing Property.

The Figure 3 indicates that a majority of respondents rely on limited backup solutions during energy cuts, with 58.1% reporting short-term or basic backup capacity. A further 18.6% of respondents have moderate backup systems capable of sustaining operations for slightly longer periods, while another 18.6% indicate more developed backup arrangements. However, only 4.7% of respondents have advanced or long-duration backup systems in place. This distribution suggests that while some level of backup exists across most properties, the predominance of short-term solutions highlights insufficient preparedness for prolonged energy disruptions.

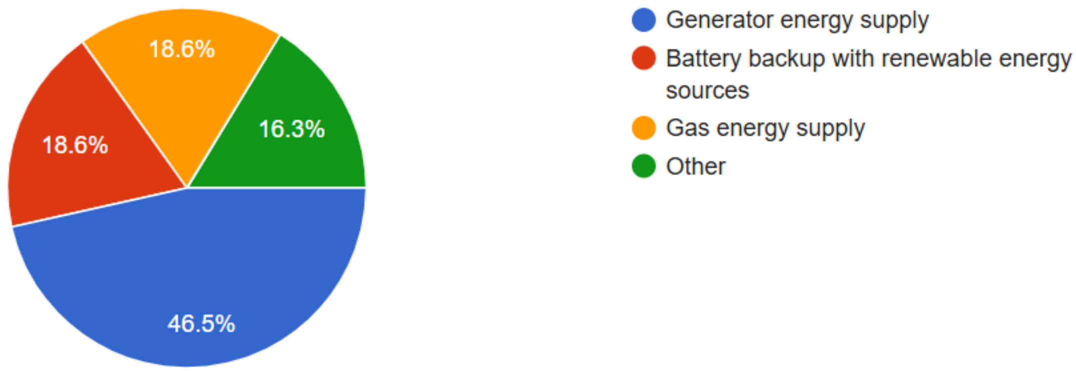

Figure 3, Backup Energy Sources During Power Cuts

The figure suggests that occupancy size varies across the sampled buildings, with the majority falling within the lower to medium occupancy categories. Approximately 58.1% of the buildings can be associated with smaller occupancy sizes, indicating fewer residents and relatively lower demand on building services. A further 18.6% represent medium-sized occupancy levels, where demand for energy and services begins to increase. Another 18.6% fall within larger occupancy categories, reflecting higher usage intensity and greater pressure on infrastructure. Only 4.7% of buildings can be considered as having very large occupancy sizes (Figure 4).

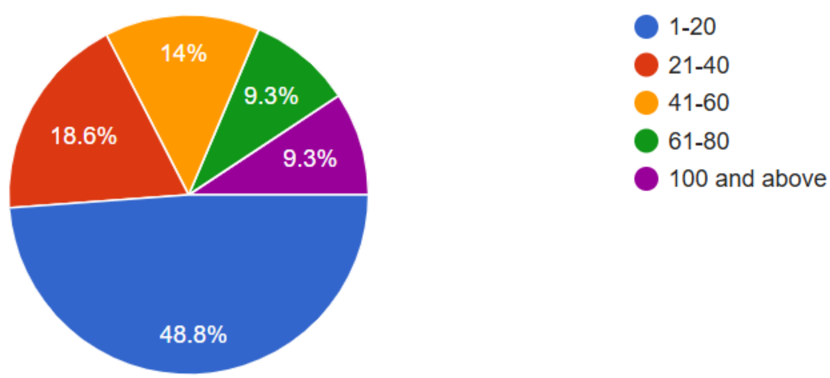

Figure 4. Occupancy Size of the Building Being Managed

5.2. Barriers to the adoption of Energy Management Systems in residential buildings

The results in Table 1 indicate that property managers perceive multiple barriers to the adoption of BEMS as significant, with all mean scores above 3.9, suggesting overall agreement that these factors hinder adoption. The highest-ranked barrier is lack of awareness (Mean = 4.21), followed closely by lack of commitment from top management (Mean = 4.19) and lack of knowledge (Mean = 4.16). This pattern highlights that informational and organisational barriers are more critical than purely technical issues. Property managers appear to struggle with insufficient understanding of BEMS benefits and limited strategic support from leadership, which aligns with the broader challenge of digital adoption in developing contexts like South Africa. These results align with studies such as Building Energy Management Systems adoption literature, which emphasise awareness and managerial support as key drivers of technology uptake, particularly in developing contexts (Khafiso et al. 2025; Amasyali and El-Gohary, 2018; Zhou et al., 2016).

Financial constraints also emerge as a major concern. Lack of funds (Mean = 4.07), high initial costs (Mean = 4.00), and high repair costs (Mean = 3.91) indicate that cost-related issues significantly deter implementation. The relatively high standard deviations (around 1.1–1.2) suggest some variability in responses, meaning that while many managers strongly agree on these barriers, others may have differing financial capacities or exposure to funding mechanisms. This reinforces the need for financial support mechanisms and incentives to improve adoption. This is consistent with findings by Darko et al., (2017), who argue that high capital investment and uncertain returns discourage adoption in emerging economies

Behavioural and trust-related barriers are also evident, with resistance to change (Mean = 4.00) and lack of trust (Mean = 4.00) indicating a high level of agreement among respondents that human factors significantly slow BEMS adoption. This strong agreement is consistent with technology adoption literature, which emphasises that user perceptions, uncertainty, and risk aversion often hinder the uptake of new systems, particularly in the built environment (Venkatesh et al., 2012; Davis, 1989). These barriers typically arise from concerns about system reliability, disruption to established workflows, and limited familiarity with digital technologies, reinforcing findings by Amasyali and El-Gohary (2018) that behavioural resistance remains a critical challenge in energy management system implementation. Furthermore, lack of technicians (Mean = 4.00) and unavailability of local BEMS suppliers (Mean = 3.98) also show strong agreement, highlighting capacity and market constraints. This aligns with studies in developing countries, which report that limited technical expertise and underdeveloped supply chains restrict the scalability of smart building technologies (Darko et al., 2017; Olanrewaju et al., 2022).

From a policy perspective, lack of governmental incentives (Mean = 3.93) indicates moderate to high agreement, suggesting that institutional support mechanisms are perceived as insufficient to drive adoption. This finding corroborates previous research which identifies weak policy frameworks and limited financial incentives as major barriers to energy efficiency technologies in emerging economies (IEA, 2021; UNEP, 2020). The statistical distribution further reinforces the strength of these perceptions, as the negative skewness values across all variables indicate that responses are clustered towards agreement, meaning most property managers consistently recognise these barriers as significant. Meanwhile, the kurtosis values, with some positive (e.g., awareness and management commitment) and others near zero, suggest a combination of strong consensus and moderate variability in responses. This pattern reflects that while certain barriers are universally acknowledged, others may vary depending on organisational context, supporting broader literature that highlights the contextual and multi-dimensional nature of BEMS adoption challenges (Zhou et al., 2016; Allouhi et al., 2015).

Table 1. Barriers to the adoption of BEMS in Residential Buildings

	No of property managers	**Mean**	**Std. Deviation**	**Skewness**		**Kurtosis**	
	Statistic	**Statistic**	**Statistic**	**Statistic**	**Std. Error**	**Statistic**	**Std. Error**
Lack of Awareness	43	4.21	1.103	-1.553	.361	1.917	.709
Lack of commitment from top management	43	4.19	1.052	-1.291	.361	1.054	.709
Lack of Knowledge	43	4.16	.998	-.944	.361	-.218	.709
Lack of Funds	43	4.07	1.203	-1.172	.361	.366	.709
Resistance To change	43	4.00	1.215	-1.002	.361	-.025	.709
Lack of trust	43	4.00	1.234	-.956	.361	-.198	.709
High initial costs	43	4.00	1.134	-.719	.361	-.934	.709
Lack of Technicians	43	4.00	1.069	-.736	.361	-.198	.709
Unavailability of local BEMS suppliers nationally	43	3.98	1.102	-1.073	.361	.754	.709

Lack of governmental incentives	43	3.93	1.183	-.855	.361	-.122	.709
High repair costs	43	3.91	1.171	-.837	.361	-.091	.709

The results in Table 2 of the Friedman Test indicate that there is no statistically significant difference in how property managers ranked the barriers to BEMS adoption ($\chi^2 = 13.186$, df = 10, p = 0.213). Since the p-value is greater than 0.05, this suggests that the identified barriers are perceived as relatively equally important, meaning no single barrier overwhelmingly dominates the others. This reinforces the earlier descriptive findings that barriers are collectively influential rather than isolated issues. The Kendall's Coefficient of Concordance (W = 0.031) indicates very weak agreement among the 43 property managers in ranking these barriers. This implies that while managers generally agree that barriers exist, they differ in how they prioritise them, likely due to variations in organisational context, experience, or resource availability. However, the reliability analysis using Cronbach's Alpha ($\alpha = 0.965$) indicates excellent internal consistency among the 11 barrier variables. This means the instrument used to measure barriers is highly reliable and the items consistently capture the concept of BEMS adoption barriers from property managers' perspectives.

Table 2. Test statistics and Reliability Statistics (Source: Authors)

Test Statistics				**Reliability Statistics**	
No. of Property Managers	43	No. of Property Managers	43	Test result	No. of barriers
Chi-Square	13.186	Kendall's W[a]	.031	0.965	11
Df	10	Chi-Square	13.186		
Asymp. Sig.	.213	df	10		
a. Friedman Test		Asymp. Sig.	.213		
		a. Kendall's Coefficient of Concordance		Cronbach's Alpha	

6. Conclusion

In conclusion, the study demonstrates that the adoption of Building Energy Management Systems (BEMS) in residential buildings is constrained by a complex interplay of behavioural, financial, technical, and institutional barriers. The findings reveal a high level of agreement among property managers that lack of awareness, limited top management commitment, and insufficient knowledge are the most critical challenges, indicating that organisational readiness and information dissemination remain key gaps. Financial constraints, including high initial and maintenance costs, further limit adoption, particularly within resource-constrained environments typical of developing countries such as South Africa. Additionally, behavioural factors such as resistance to change and lack of trust highlight the importance of user perceptions in influencing technology uptake, while the shortage of skilled technicians and limited availability of local suppliers point to an underdeveloped support ecosystem. Policy-related challenges, including inadequate governmental incentives, further compound these barriers by failing to create an enabling environment for widespread implementation. Overall, the statistical trends, including consistent agreement reflected in negative skewness values, reinforce the significance of these barriers across the sample. The study, therefore, concludes that successful BEMS adoption requires a holistic approach that integrates awareness campaigns, capacity-building, financial support mechanisms, and strong policy interventions. Enhancing technical skills, strengthening local supply chains, and promoting leadership commitment within organizations are essential steps toward improving adoption rates. Ultimately, addressing these barriers will not only facilitate the integration of BEMS but also improve energy efficiency, sustainability, and resilience in residential buildings. The study was limited to Bloemfontein, Free State; therefore, the generalisability of the findings is limited. Further studies could focus on the other provinces.

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